# Coaches and road safety in Europe

## An indication based on available data 2007-2016

R-2019-11

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**Prevent** crashes
**Reduce** injuries
**Save** lives

# Report documentation


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# Summary

This study has compared the safety of coaches in traffic with the safety of other modes of transport (passenger car, train and airplane) in the European countries Austria, Belgium, Germany, Denmark, France, the Netherlands and the United Kingdom, in the years 2007-2016.

The available road crash data did not allow to distinguish between coaches and public transport buses. Therefore, this study discusses the umbrella category “buses”.

The comparison of the safety of these transport modes was carried out by comparing risk. Vehicle risk is defined as the number of casualties per vehicle distance travelled (vehicle kilometres), and person risk is defined as the number of casualties per distance travelled by the vehicle occupants (person kilometres). In this report the casualties are fatalities: people killed in traffic within the borders of each relevant country. This also includes non-residents. Severely injured casualties were not included in this study.

The following data sets were used[1]:

- Community Road Accident Database (CARE), maintained by the European Commission
- International Traffic Safety Data and Analysis Group (IRTAD), maintained by OECD
- European Statistics (Eurostat), maintained by the European Commission
- World Bank Open Data

These data sets were not always complete. Whereas the number of deaths for the investigated transport modes were available for all relevant countries for all of the years, this was not the case for the distances travelled by vehicles and vehicle occupants. When necessary, missing values were imputed, i.e. copied from the year before or after, or averaged if the data for both the year before and the year after were known.

For a fair comparison of the different transport modes, not only deaths among vehicle occupants – “inside-the-vehicle deaths” – but also “outside-the-vehicle deaths” (with that vehicle as the crash opponent) should be taken into account. This was only possible for cars and buses, and not for trains and airplanes. Therefore, only *occupant deaths* (“inside the vehicle”) could be used to compare the *fatality risks* of the four different transport modes. Especially for trains, this means that a large proportion (more than 85%) of the reported rail deaths was excluded; for these deaths it was not clear whether they were inside or outside the train or whether passenger trains were involved. Therefore, the calculated train fatality risk (the occupant risk) may be lower than the factual train fatality risk.

For airplanes, the crash in France in 2015 with 150 deaths among the airplane occupants was included in the Eurostat data set, even though it has been determined to have been caused deliberately by the co-pilot. This has a negative effect on the result for the safety of passenger airplanes.

1. The authors would like to thank Niels Bos for his help with gathering the necessary data for this study.

To calculate the occupant risk from the vehicle risk, it is necessary to estimate the average number of occupants in each vehicle. For trains and airplanes, this could be calculated from the available data sets. For buses and cars, this was not possible and it was decided to use the values from an earlier study done in the Netherlands over the years 2010-2014 (p. 24, Temürhan & Stipdonk, 2016).

According to this earlier study, cars carry an average of 1.5 persons per trip and buses carry an average of 10.3 passengers per trip. This average includes public transport buses. A study conducted for the Royal Dutch Association of Transport Companies (KNV) reports 40 passengers on average in coaches over the years 2004-2015 (KNV, 2015). We assume that these values are sufficiently accurate for the risk estimate in this report.

Hence we assume 109 passengers per airplane, 127 passengers per train, 40 or 10.3 passengers per coach/bus and 1.5 persons (occupants) per passenger car.

The accuracy of the following results is therefore dependent on the correctness and limitations of the data sets and the assumptions that have been made.

The lowest occupant risk was found for train passengers, keeping in mind the probable underestimation due to the large group of rail deaths excluded. The risk for airplane occupants was similar, keeping in mind the relatively big crash in France in 2015 with 150 casualties affecting the results. The highest risk was found for car occupants. The occupant risk in buses was between that in cars and that in trains and airplanes.

If we take the occupant risk for buses to be 1, assuming an average of 10.3 bus passengers, the risks for occupants of the other modes of transport become:

| | In the bus | In the car | In the train | In the airplane |
|---|---|---|---|---|
| Deaths inside the vehicle per $10^9$ person km | 1 | 2.0 | 0.14 | 0.17 |

Given these risks, it seems safer to travel by bus, train or airplane than by car.

For buses, the Netherlands seems to have a relatively low number of road deaths among bus occupants compared to deaths “outside”, with a bus as the crash opponent (about 1 : 14); France seems to have relatively many road deaths among bus occupants, about 1 : 4.

For cars, the ratio between the fatality risk “inside the car” and the risk “outside the car” (with a car as crash opponent) is similar for all individual countries.

As was expected, buses appear to be more dangerous than cars related to casualties outside the vehicle. The reverse appears to be true for persons inside the vehicle. It is safer for the occupants to travel by bus, train or airplane than by car.

# Contents

# 1 Introduction

**This report presents a comparison study into the safety of coaches in traffic in Europe over the years 2007-2016, commissioned by the Royal Dutch Association of Transport Companies (KNV). The aim is to compare safety of transport by coach to that by car, train and airplane.**

This study uses the following data sets:

- Community Road Accident Database (CARE) maintained by the European Commission
- International Traffic Safety Data and Analysis Group (IRTAD) maintained by OECD
- European Statistics (Eurostat), maintained by the European Commission[2]
- World Bank Open Data

The available data does not distinguish between coaches and public transport buses. Therefore, this study covers the umbrella category “buses” and compares its road safety with that of cars, trains and airplanes.

The comparison involves the following European countries:

- Austria
- Belgium
- Germany
- Denmark
- France
- the Netherlands
- the United Kingdom

This selection is based on the availability of data and on the fact that these countries are within a reasonable travelling distance from the Netherlands by coach.[3]

Italy was originally included in this selection, but had to be removed because no data was available for distance travelled by buses and cars. The only data found was the number of kilometres travelled (vehicle kms) for light and heavy vehicles, which could not be compared to the distances travelled for buses and cars in the other countries.

This report continues with a more detailed description of the framework of this study in *Chapter 2*. *Chapter 3* summarizes the data sets used for this study. *Chapter 4* compares the mobility (distance travelled) by bus, car, train and airplane for the relevant countries. *Chapter 5* presents a similar comparison for the number of deaths. In *Chapter 6*, the *Chapters 4* and *5* will be combined to calculate the risk (number of deaths per distance travelled) for each mode of transport. *Chapter 7* will discuss the results and conclude this report.

2. For rail transport, the newest ERA-based Eurostat database was used. In this report, we will simply refer to this data as well as the other Eurostat data as ‘Eurostat-database’.
3. An interesting study which compares travel by train and airplane in the Netherlands within 800 km radius, is by Savelberg et. al. (2018).

# 2 Framework of the study

**To compare the safety of different kinds of transport modes in different countries, it is important to find a common ground. In road safety research, this is done by comparing "risk".**

Risk is defined as the number of casualties per distance travelled. In this report the casualties are deaths. Severely injured will not be a part of this study for two reasons:

- data is often not available, and
- the definition of severely injured is not equal in many countries included in this study.

An earlier study reported on the safety of coaches in the Netherlands over the years 1993-2014 (Temürhan & Stipdonk, 2016). The study compared the safety of buses (coaches and other types combined) with that of cars, for deaths and for severely injured. An important result was the necessity to look at safety from different points of view. In case of a crash involving a bus, an occupant of the bus is comparatively much safer than the users of other modes of transport involved in such a crash. For a fair comparison, we will try to make the distinction of casualties "inside the vehicle" versus casualties in crashes in which that vehicle was the crash opponent("outside the vehicle").

The used categories will be:

- Deaths inside the bus: the casualty's mode of transport is a bus
- Deaths with the bus as the crash opponent: the casualty's mode of transport is NOT a bus
- Deaths inside the car: the casualty's mode of transport is a car
- Deaths with the car as the crash opponent: the casualty's mode of transport is NOT a car

When a bus-bus or a car-car collision occurs, the number of deaths will be counted in the first and third categories, respectively.

In case of trains, the data sets allow a distinction between:

- Passengers: the casualty's mode of transport is a train
- Level-crossing users: the casualty's mode of transport is NOT a train
- Employees: the casualty's mode of transport is unknown
- Unauthorized persons: the casualty's mode of transport is unknown
- Others: the casualty's mode of transport is unknown

We assume that the passengers (predominantly) must have been inside the train and level-crossing users must have been outside the train. It is not entirely clear from the (meta)data whether the other casualties were inside the train during the crash, or somewhere else. For instance, employed personnel need not have been on the train. In fact, Eurostat (2018) reports that in the EU in general – irrespective of their role as passenger, level-crossing user or other – an average of about 68% of the rail deaths are in crashes of the category "Accidents to persons by rolling stock in motion". This could be an indication that there is a large group of rail deaths outside the train, other than level-crossing users. In conclusion, the data does not allow to implement to trains a distinction similar to the distinction between deaths "inside the bus" and "outside the bus".

Furthermore, the data used in this study is organized in such a way that it is not possible to distinguish all deaths according to their role (i.e. passenger, level-crossing user, employee, etc.). *Table 2.1* shows the distribution of the reported rail deaths between passengers, level-crossing users and other rail deaths for the relevant European countries. The 'Other' group constitutes a substantial proportion of the rail deaths, for UK even the largest part: 79%. To be clear: deaths as a result of suicide are already excluded from this table. Also Eurostat (2018) reports a large group of non-passenger rail deaths: it mentions about 95% of rail deaths occur in crashes at level crossings and crashes involving unauthorized persons. It is possible that the relevant countries may have a different way of counting and/or reporting deaths involving trains.[4] The current report considers the used Eurostat data to be the best data available.

*Table 2.1. The distribution of rail deaths between passengers, level-crossing users and the rest over the years 2007-2016 (source: Eurostat).*

| | AT | BE | DE | DK | FR | NL | UK |
|---|---|---|---|---|---|---|---|
| Passengers | 1% | 15% | 2% | 1% | 6% | 2% | 1% |
| Level-crossing users | 51% | 45% | 27% | 38% | 41% | 82% | 20% |
| Other | 48% | 40% | 71% | 61% | 53% | 16% | 79% |

An additional complication for this study is that, unless the casualty is a passenger, it is not clear whether passenger trains were involved. This information is required to identify the number of deaths – for example among level-crossing users – due to passenger travel (similar to "outside the bus"). We could not estimate this number of "outside deaths" due to passenger trains. For example, even if the number of passenger trains and the number of non-passenger trains in the period considered were known, it is likely that non-passenger trains did not travel during the rush hours or even during day-time. This would have an effect on the results, so that the proportion of passenger trains would even be a questionable measure to determine the proportion of "outside deaths" due to passenger travel.

To be certain, we will consider in this study only passengers as "inside-the-train deaths" and only level-crossing users as "outside-the-train deaths" in the analysis of the *number of deaths* (*Chapter 5*). For the analysis of *fatality risk* (*Chapter 6*) we will only consider passenger deaths ("inside the train"), as mobility data consists of passenger distance travelled and it is unclear whether the other rail deaths – including level-crossing users – are due to passenger trains. As a consequence, also for the other transport modes only deaths among vehicle occupants ("inside the vehicle") could be used for a comparison of the fatality risks. The fact that not all deaths related to passenger travel by the considered transport modes were taken into account in the fatality risk calculation,  will have an effect on the results but it is not possible to estimate the size of this effect.

In the case of airplanes, only the risk of commercial air passenger transport can be calculated, since data about passenger mobility is only available for this type of aviation. The reported deaths are those inside the airplane, crew and passengers combined. Of course, an airplane crash can also cause casualties outside the plane. Some of the best known crashes do not concern passenger flights, like the crash in Amsterdam Bijlmer in 1992 (39 deaths on the ground) or are not considered to be traffic crashes, like the Lockerbie bombing in 1988 (11 deaths on the ground). For passenger flights, there is insufficient data to include deaths outside the plane in this study.

4. Eurostat (2018) mentions that "Accident figures are reliable from 2010 onwards, following the strict application of standard definitions. Belgium, Poland and Slovakia typically reported all railway accidents in the past, instead of significant accidents only. This meant a lower count in several categories of accidents since 2010." Further reasons are also given in this Eurostat document for differences with other sources to occur, even at Eurostat.

# 3 Used data sets

**This chapter gives information about the data sets used in this study.**

In this study the following datasets were used:

**Deaths**:
- Buses and cars: Community Road Accident Database (CARE)
- Trains: European Statistics (Eurostat, ERAIL-ERA data)
- Airplanes: European Statistics (Eurostat)

**Mobility** (distance travelled):
- Buses and cars: International Traffic Safety Data and Analysis Group (IRTAD)
- Trains: World Bank Open Data
- Airplanes: European Statistics (Eurostat)

These data sets cover the countries Austria, Belgium, Germany, Denmark, France, the Netherlands, and the United Kingdom over the years 2007-2016.

The numbers of deaths for buses, cars, trains and airplanes are available for all relevant countries and for all relevant years.

The distance travelled is not available for all the relevant countries and years. When necessary, missing values were copied from the year before or after, or averaged if the data for both the year before and after were known.

## 3.1 Buses and cars

For buses and cars, the distance travelled was available for all the countries, but not for all the years. The missing years have been copied from the previous year, or the following year, or was averaged over the previous and the following year when both were available. *Table 3.1* shows the missing years for buses and cars:

*Table 3.1. Missing years (denoted as x) per country for mobility of buses and cars (source: IRTAD).*

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|
| AT | | | | | | | | | | |
| BE | | | | | | | | | | x |
| DE | | | | | | | | | | |
| DK | x | | | | | | | | | |
| FR | | | | | | | | | | |
| NL | x | | | | | | | | | |
| UK | | x | | | | | x | x | x | x |

The distance travelled is in terms of vehicle kms, which is defined as a measure of traffic flow, determined by multiplying the number of vehicles on a given road or traffic network by the average length of their trips measured in km (source: IRTAD).

The available data sets with the number of deaths (CARE) provide:
- The number of deaths for buses as mode of transport
- The number of deaths involving buses
- The number of deaths for cars as mode of transport
- The number of deaths involving cars

Subtracting the number of deaths for buses as mode of transport from the number of deaths involving buses, gives an indication of the number of deaths "outside the bus". This can also be done for cars.

## 3.2 Passenger trains

For trains, the number of passenger kms is considered. Freight and mail rail transports are excluded.

The Eurostat database contains train passenger kms for the relevant countries, except for NL, which had provided only the year 2007. Statistics Netherlands has data on NL train passenger kms over the years 2010-2016, but this data seemed to conflict with the one year in Eurostat. We decided not to use the Eurostat data set for train passenger mobility.

Another available data set with train passenger kms is from World Bank Open Data; only data from several countries in 2016 and one country in 2015 is missing. The data for missing years has been copied from the preceding year. *Table 3.2* shows the missing years for trains.

*Table 3.2. Missing years (denoted as x) per country for mobility of train passengers (Source: World Bank Open Data).*

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|
| AT | | | | | | | | | | |
| BE | | | | | | | | | | x |
| DE | | | | | | | | | | x |
| DK | | | | | | | | | | |
| FR | | | | | | | | | | x |
| NL | | | | | | | | | | x |
| UK | | | | | | | | | x | x |

As was mentioned in the previous chapter, only deaths "inside the train" (1-15% of all reported rail deaths) from the Eurostat database were used to calculate a train fatality risk: the occupant risk.

## 3.3 Airplanes

For airplanes, the Eurostat data uses 3 categories:
- commercial air passenger transport (passenger kms)
- general aviation (civil aviation operations), maximum take-off mass above 2250 kg
- general aviation (civil aviation operations), maximum take-off mass below 2250 kg

The numbers of crash deaths – including crew - are available for all three categories; the lightweight category has the highest number of deaths. However, only commercial air passenger transport has data available about passenger kms, over national territory for each of the countries and for all the relevant years.

The heavy category of general aviation mainly contains commercial freight and mail air transport; this category does not include passenger flights.

The risk for the lightweight general aviation category is likely to be highest with many casualties and relatively few persons carried or distances flown. With the current data, it is not possible to calculate that risk.

Commercial passenger air transport (by reporting country) may constitute the best choice for the comparison with buses and trains, since their main business is to carry passengers. Also, these trips are comparable in the sense that travelers who need to choose between bus, car, train or airplane, will only consider commercial services.

# 4 Comparing mobility

**Calculating the risk for each mode of transport involves the number of deaths and mobility (distance travelled). This chapter compares the mobility by buses, cars, trains and airplanes in the relevant countries.**

Note that for buses and cars, mobility is defined in terms of vehicle kms, whereas for trains and airplanes it is passenger kms.

## 4.1 Buses

*Figure 4.1* shows the development of distance travelled by buses, in billion vehicle kms in the period 2007-2016. The order of countries in 2016 from the top down is UK, FR, DE, BE, DK, NL and AT.

*Figure 4.1. Distance travelled [$10^9$ vehicle km] by buses in AT, BE, DE, DK, FR, NL and UK during the period 2007-2016. Please note that the vertical axis is logarithmic.*

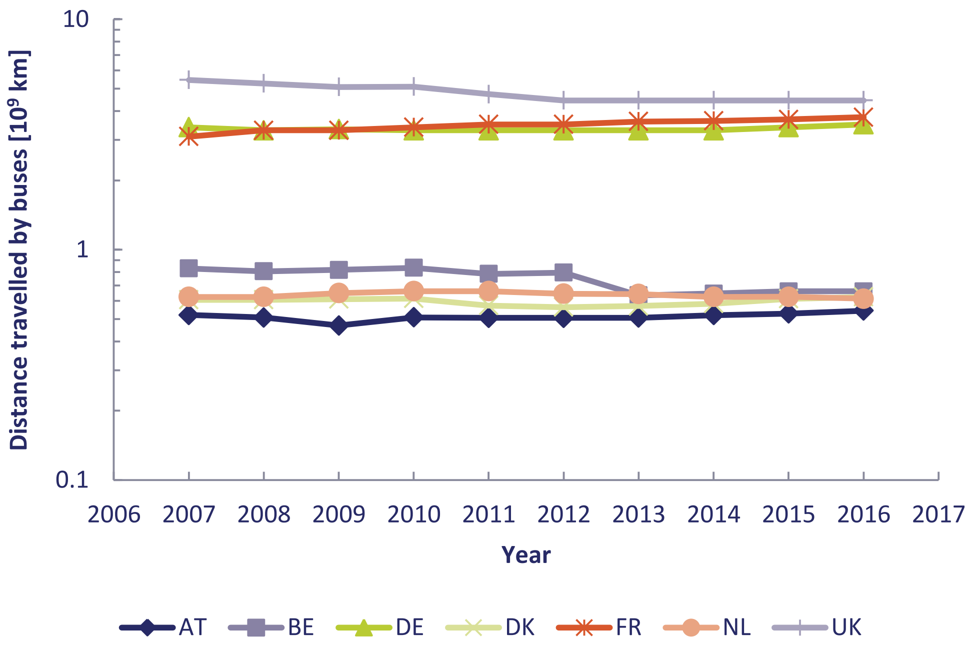


Figure 4.2. Distance travelled [$10^9$ vehicle km] by buses in AT, BE, DE, DK, FR, NL and UK in the periods 2007-2011 and 2012-2016.

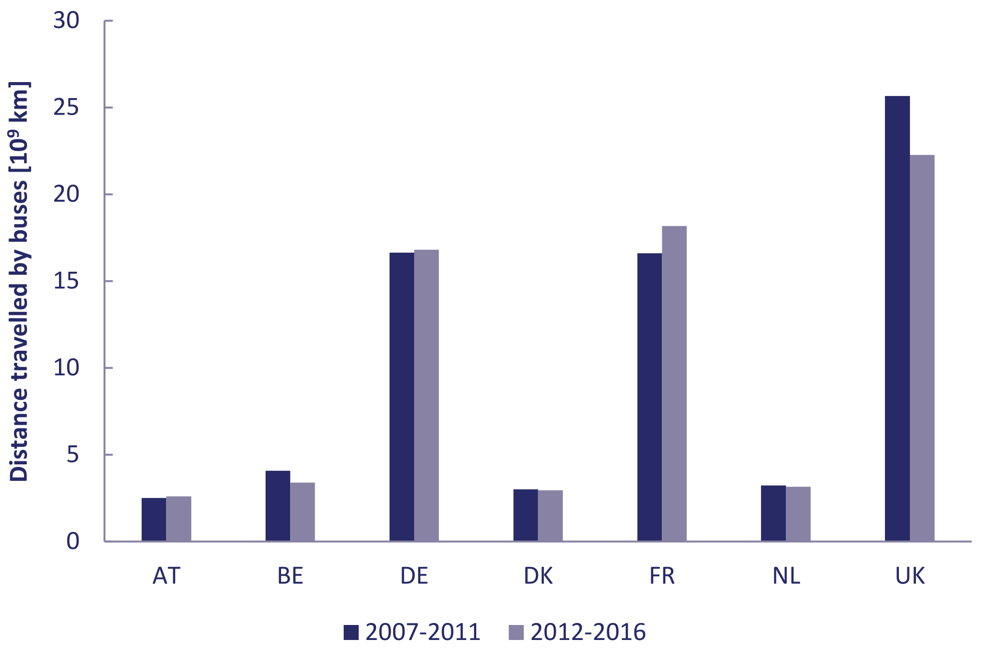



*Figure 4.2* shows the development of bus mobility at 5-year intervals. BE and UK show a large decrease (17% and 13% respectively), FR shows an increase of 9%, while the values for the other countries seem fairly constant. Bear in mind that the UK data does not include the years 2013-2016. Data for these years is set equal to 2012. The development might have been different with actual data.

## 4.2 Cars

*Figure 4.3* shows the development of distance travelled by cars, in billion vehicle kms in the period 2007-2016. The order of countries in 2016 from the top down is DE, FR, UK, NL, BE, AT and DK.

Figure 4.3. Distance travelled [$10^9$ vehicle km] by cars in AT, BE, DE, DK, FR, NL and UK during the period 2007-2016.

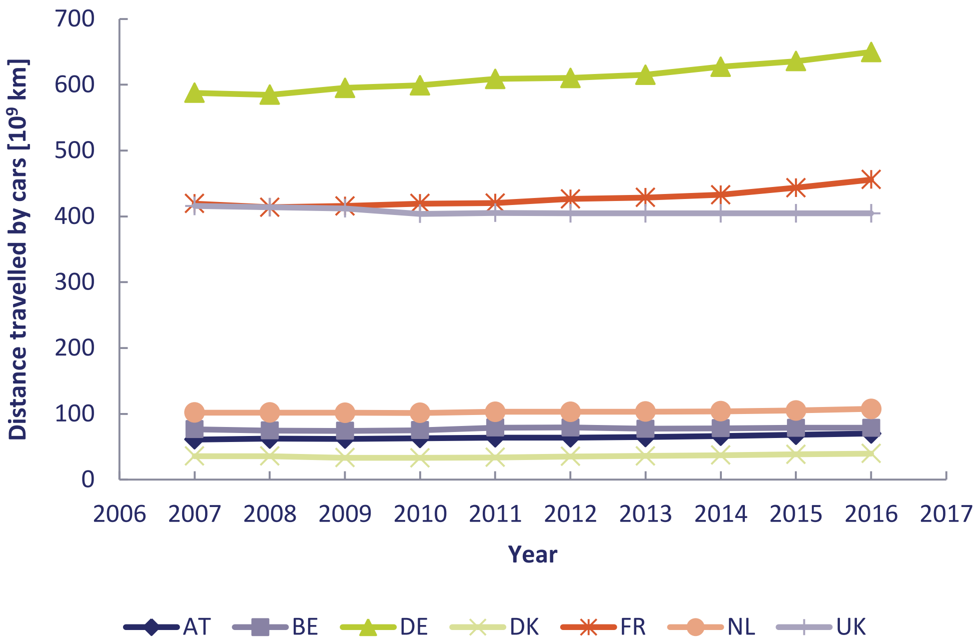


Figure 4.4. Distance travelled [10^9 vehicle km] by cars in AT, BE, DE, DK, FR, NL and UK in the periods 2007-2011 and 2012-2016.


*Figure 4.4* shows the development of car mobility at 5 year intervals. AT and DK show an increase of 7% and 9% respectively, DE and FR both show an increase of 5%, while the values for the other countries seem fairly constant, the UK being the only one showing a decrease. Bear in mind that the UK misses data of the years 2013-2016, these have been set equal to 2012. The small decrease might have been different with actual data.

## 4.3 Trains

*Figure 4.5* shows the development of distance travelled by passengers in trains, in billion passenger kms in the period 2007-2016. The order of countries in 2016 from the top down is FR, DE, UK, NL, AT, BE and DK.

Figure 4.5. Distance travelled [10^9 passenger km] by passengers in trains in AT, BE, DE, DK, FR, NL and UK during the period 2007-2016.

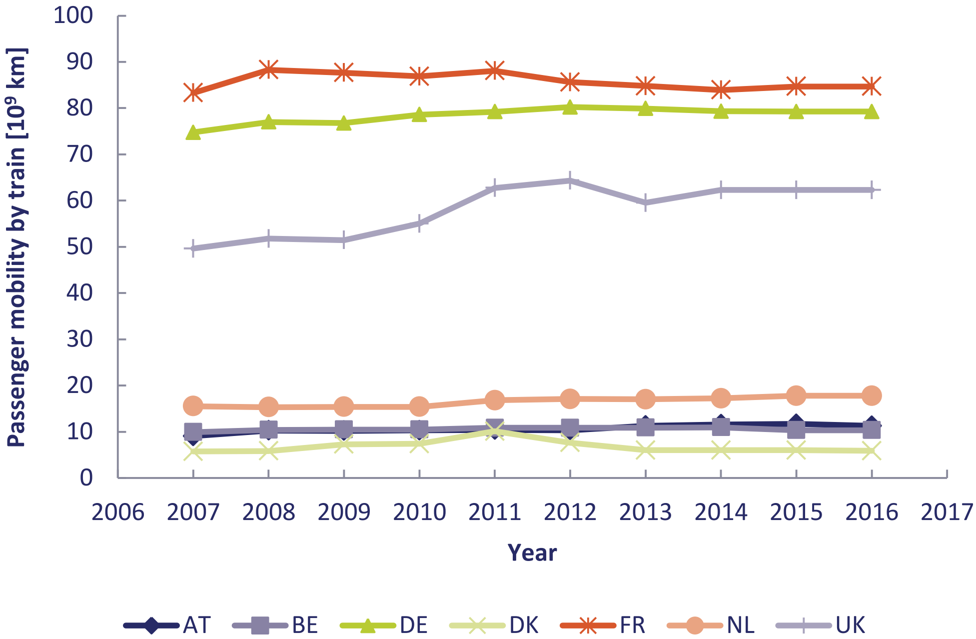


*Figure 4.6. Distance travelled [$10^9$ passenger km] by passengers in trains in AT, BE, DE, DK, FR, NL and UK in the periods 2007-2011 and 2012-2016.*

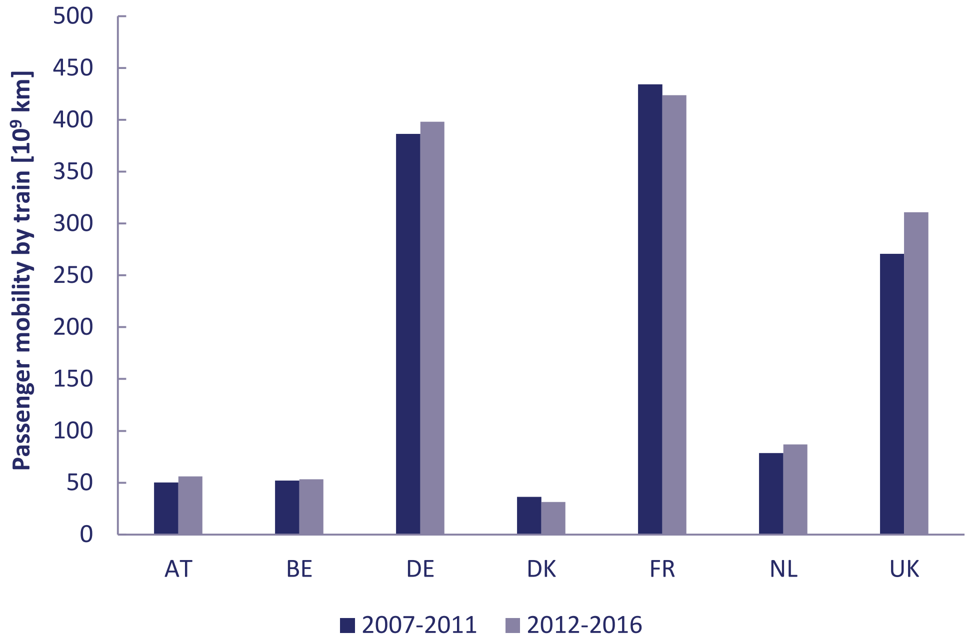



*Figure 4.6* shows the development of train passenger mobility at 5 year intervals. The UK shows the biggest relative increase, while DK shows the biggest relative decrease.

## 4.4 Airplanes

*Figure 4.7* shows the development in the distance travelled by airline passengers, by reporting country over national territory, in billions of passenger kms in the period 2008-2016. No data is available for 2007. To be consistent with the other modes of transport, values of 2008 were used for 2007. The order of countries in 2016 from the top down is FR, DE, UK, AT, NL, BE and DK.

*Figure 4.7. Distance travelled [$10^9$ passenger km] by commercial passenger airplanes in AT, BE, DE, DK, FR, NL and UK during the period 2007-2016.*

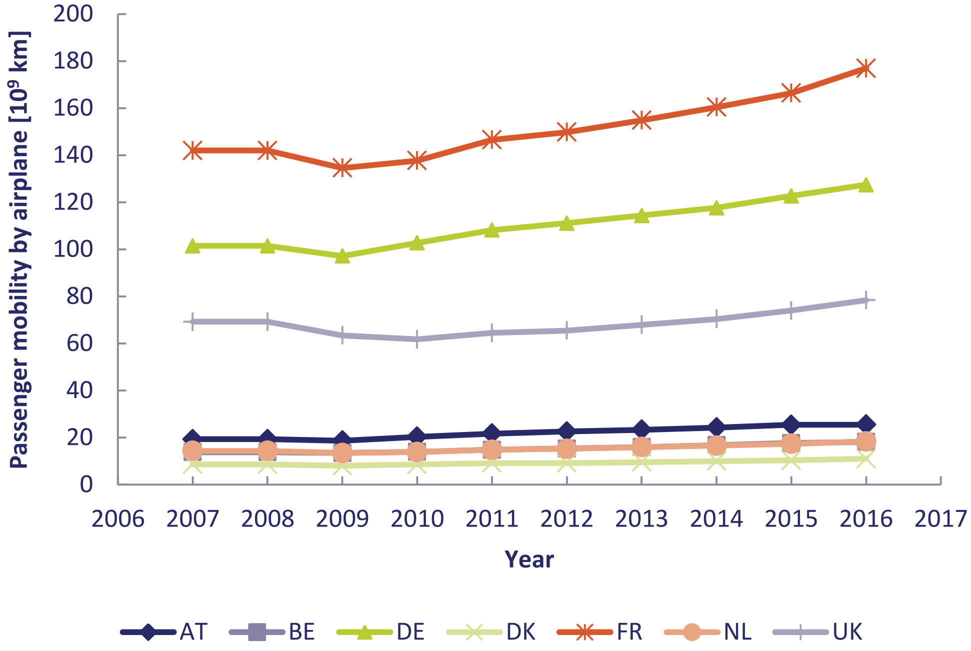
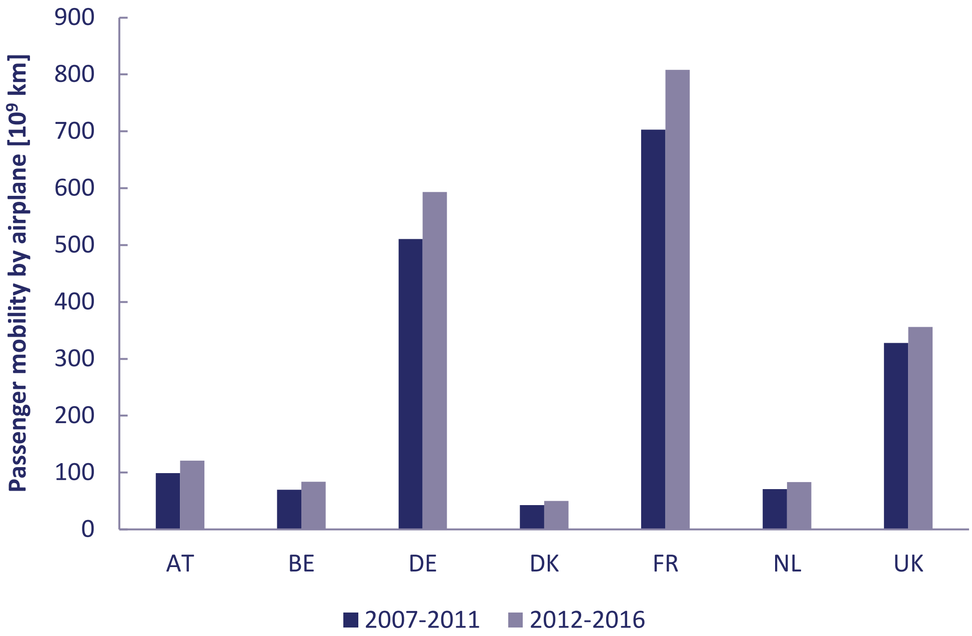


*Figure 4.8* shows the development of airplane passenger kms at 5 year intervals. All countries show a large increase, with AT showing the largest and UK the smallest relative change.

*Figure 4.8. Distance travelled [$10^9$ passenger km] by commercial passenger airplanes in AT, BE, DE, DK, FR, NL and UK in the periods 2007-2011 and 2012-2016.*



# 5 Comparing number of deaths

**Calculating the risk for each mode of transport involves the number of deaths and mobility (distance travelled). This chapter compares the numbers of deaths for buses, cars, trains and airplanes in the relevant countries.**

We try to distinguish the following possibilities:
- vehicle as the mode of transport of the casualty, and
- vehicle as the mode of transport of the casualty's crash opponent.

## 5.1 Buses

*Figure 5.1* shows the development of road deaths inside a bus during two 5-year periods. The years were combined because there are many years with zero deaths in a bus.

*Figure 5.1. Number of road deaths inside a bus in AT, BE, DE, DK, FR, NL and UK in the periods 2007-2011 and 2012-2016.*

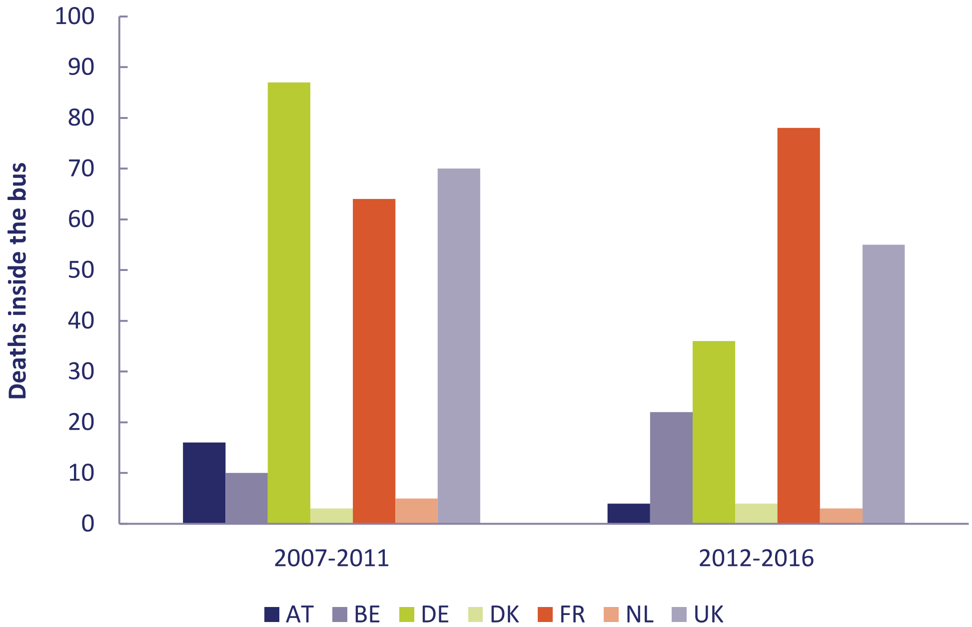


*Figure 5.2. Number of road deaths with a bus as the crash opponent, in AT, BE, DE, DK, FR, NL and UK in the periods 2007-2011 and 2012-2016.*

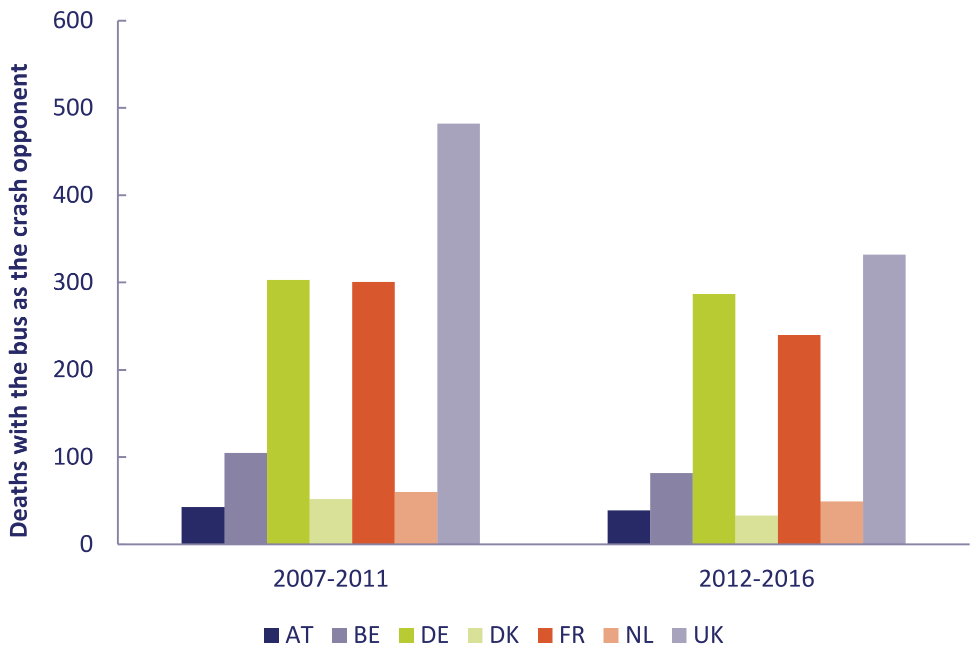
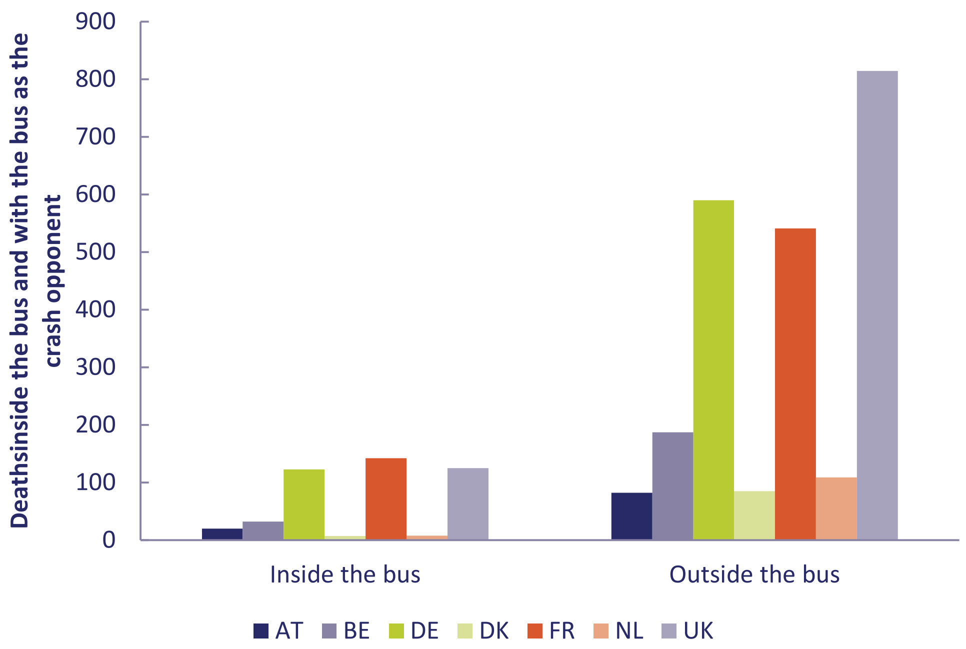



*Figure 5.2* shows the development of road deaths with the bus as the crash opponent during two 5-year periods. The years were combined for a better comparison with road deaths inside the bus. *Figure 5.3* shows the two groups together over the entire period. As expected from the earlier study for the Netherlands (Temürhan & Stipdonk, 2016), there is a substantial difference in the number of "inside-the-bus deaths" and "outside-the-bus deaths", i.e. with a bus as the crash opponent.

*Figure 5.3. Number of road deaths inside the bus and with a bus as the opponent, in AT, BE, DE, DK, FR, NL and UK during the period 2007-2016.*



## 5.2 Cars

*Figure 5.4* shows the development of road deaths in the car in two 5-year periods.

*Figure 5.4. Number of road deaths inside the car in AT, BE, DE, DK, FR, NL and UK in the periods 2007-2011 and 2012-2016.*

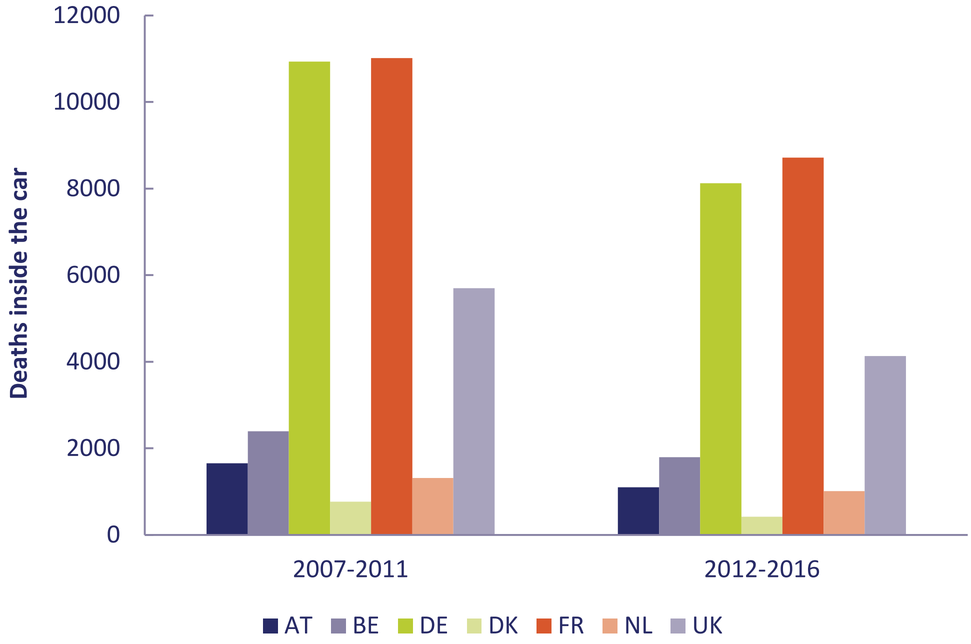



*Figure 5.5* shows the development of road deaths with the car as the crash opponent during two 5-year periods. *Figure 5.6* shows the developments for the two groups together over the entire period. There is again a substantial difference in the death numbers in these two groups, but in the *opposite* direction compared to buses: there are more "inside-the-car deaths" than "outside-the-car deaths", i.e. with a car as the crash opponent.

*Figure 5.5. Number of road deaths with a car as the crash opponent, in AT, BE, DE, DK, FR, NL and UK in the periods 2007-2011 and 2012-2016.*

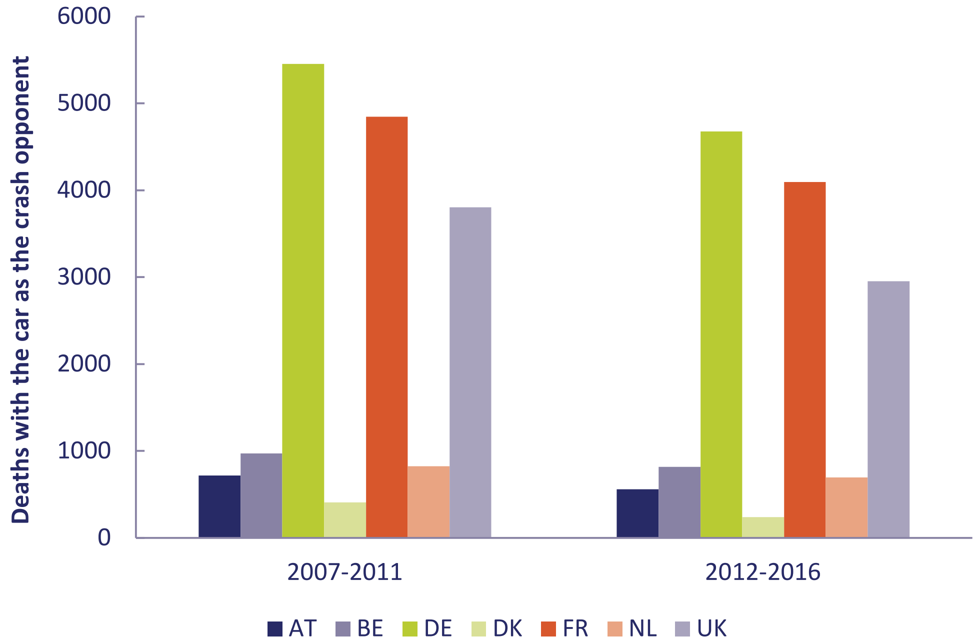
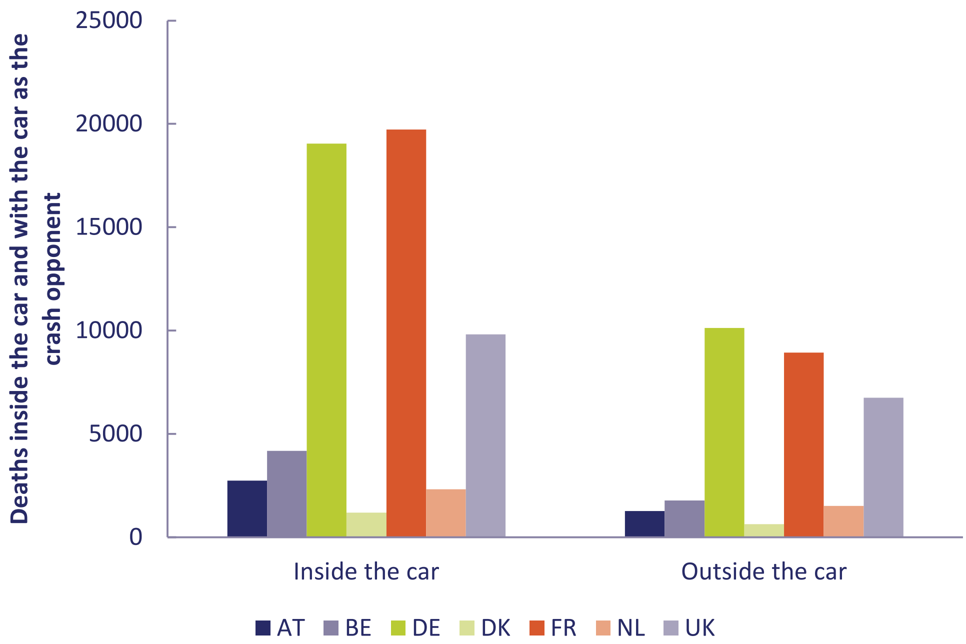


*Figure 5.6. Number of road deaths inside the car and with a car as the crash opponent, in AT, BE, DE, DK, FR, NL and UK during the period 2007-2016.*




## 5.3 Trains

For deaths involving trains, only passengers and 'level-crossing users' are distinguished. For a large group of other rail deaths, it is not clear whether they were killed inside or outside the train and – if outside – whether they were hit by a passenger train or, for instance, by a freight train (see *Chapter 2*). For this reason, the *fatality risks* of the different transport modes (see *Chapter 6*) can only be compared by using the passenger deaths. In this section about the number of deaths in train crashes, we will additionally show the reported number of deaths among level-crossing users.

*Figure 5.7* shows the development in the number of deaths among train passengers during two 5-year periods. There are many years with zero passenger deaths in train crashes. This is probably due to the fact that passengers only die when trains collide with another big object, which does not occur often. *Figure 5.8* shows the number of deaths among level-crossing users. Here, the numbers are much higher, due to the fact that anything hit by a moving train will have to absorb a great impact which causes great damage. Suicides were excluded from this analysis, but not necessarily level-crossing crashes with freight or mail rail transport.

*Figure 5.7. Train passenger deaths in AT, BE, DE, DK, FR, NL and UK in the periods 2007-2011 and 2012-2016.*

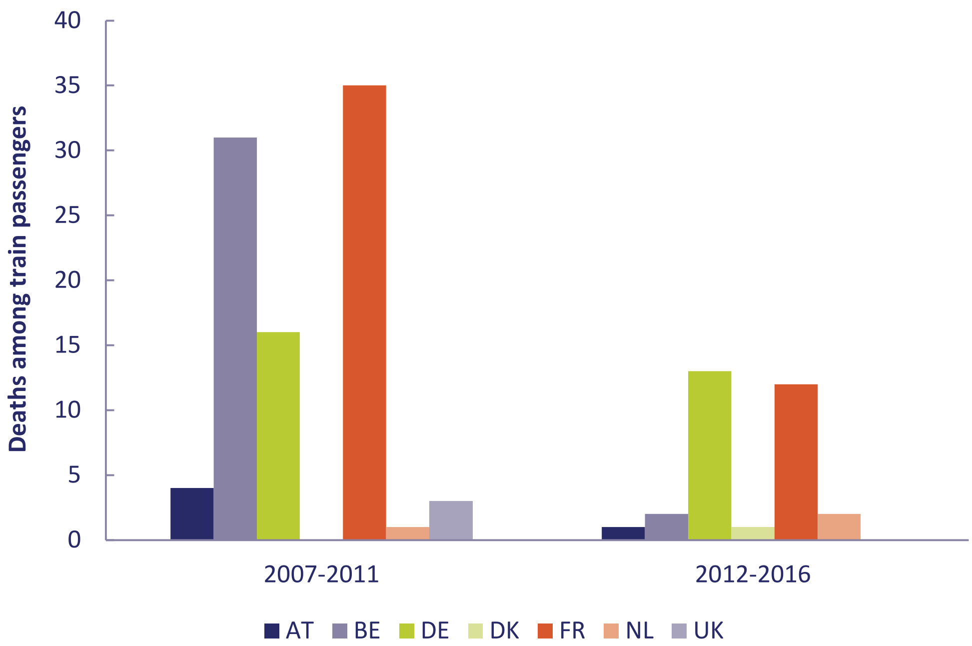
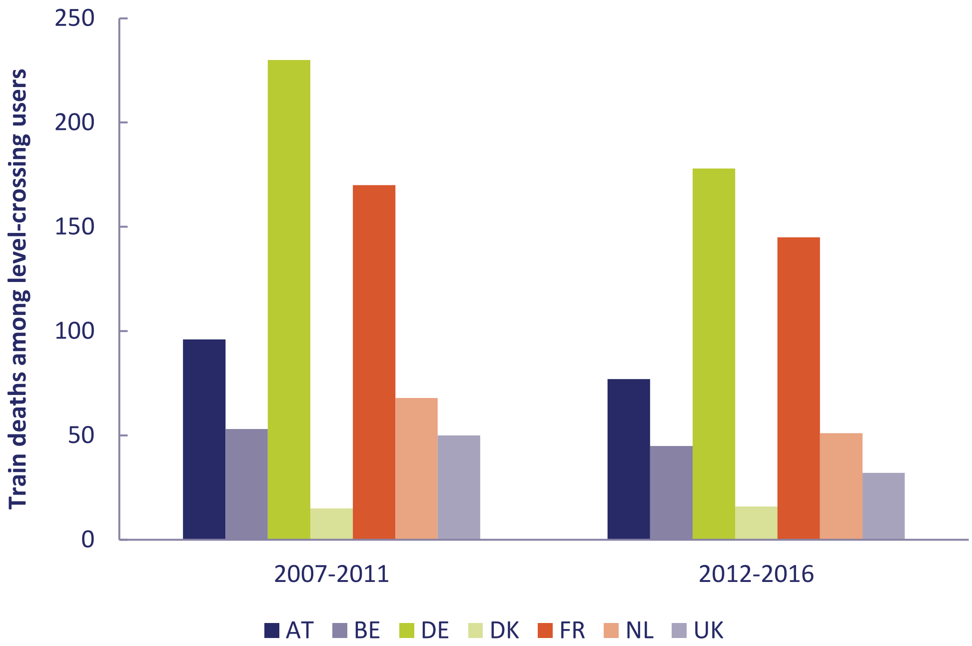



*Figure 5.8. Deaths among level-crossing users, with trains as the crash opponent in AT, BE, DE, DK, FR, NL and UK in the periods 2007-2011 and 2012-2016.*




## 5.4 Airplanes

*Figure 5.9* shows the number of deaths in commercial air passenger transport, by country of occurrence and country of aircraft registry during two 5-year periods. Many years have zero deaths. An exception is FR in 2015 with 150 deaths.[5]

5. This crash involved a German aircraft which crashed in the French Alps. Investigation showed that the crash had been caused deliberately by the co-pilot. Deliberate crashes are not a part of traffic casualty statistics, but since EUROSTAT has included this crash, we will also take it into account.

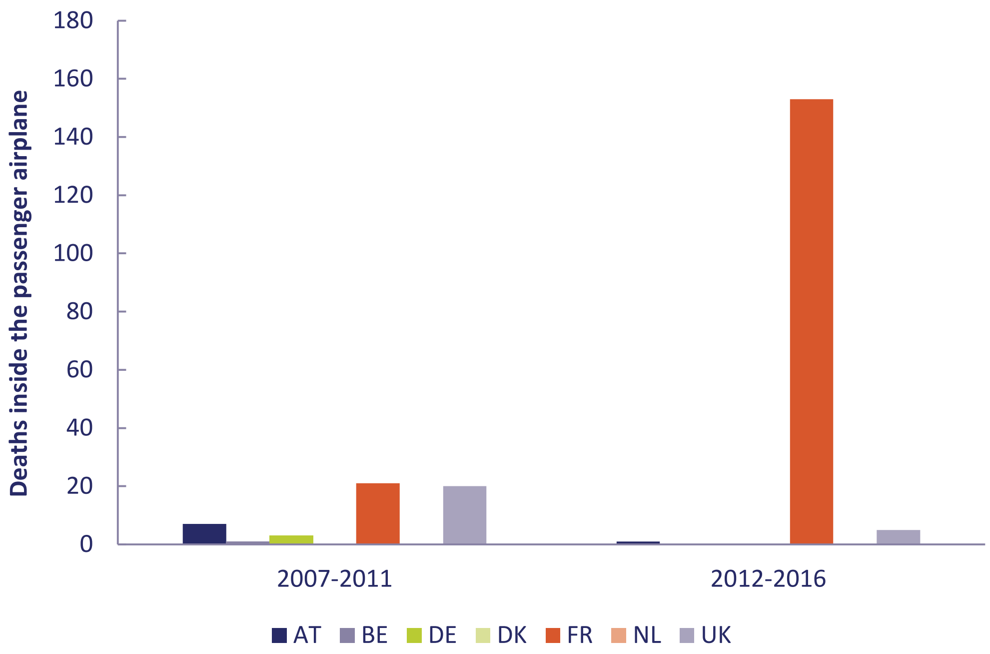



*Figure 5.9. Deaths in passenger airplane crashes in AT, BE, DE, DK, FR, NL and UK in the periods 2007-2011 and 2012-2016.*

Commercial airplane crashes are rare. This is not the case for general aviation with lightweight aircrafts, which include helicopters, balloons, para- and motorgliders, private and business airplanes, et cetera. *Figure 5.10* shows the number of deaths for this lightweight category: general aviation with maximum take-off weight (MTOW) below 2250 kg. Airplane deaths with MTOW above 2250 kg are very rare, with 9 for DE, 2 for NL and 18 for UK over 2007-2016.


*Figure 5.10. Deaths in general aviation with MTOW below 2250 kg in AT, BE, DE, DK, FR, NL and UK in the periods 2007-2011 and 2012-2016.*

# 6 Comparing risks

**This chapter compares the fatality risk in the relevant countries for travel by bus, car, train and airplane by combining the mobility and number of deaths from *Chapters 4* and *5*.**

The fatality risk is defined as the number of deaths per distance travelled. As with deaths inside or outside the bus or car, we will compare these risks separately. For trains and airplanes, we only calculate the risk inside the vehicle.

## 6.1 Buses

*Figure 6.1* shows the number of deaths inside the bus per billion vehicle km and *Figure 6.2* shows the number of deaths with the bus as the crash opponent.

*Figure 6.1. Number of road deaths among bus occupants per billion vehicle km in AT, BE, DE, DK, FR, NL and UK in the periods 2007-2011 and 2012-2016.*

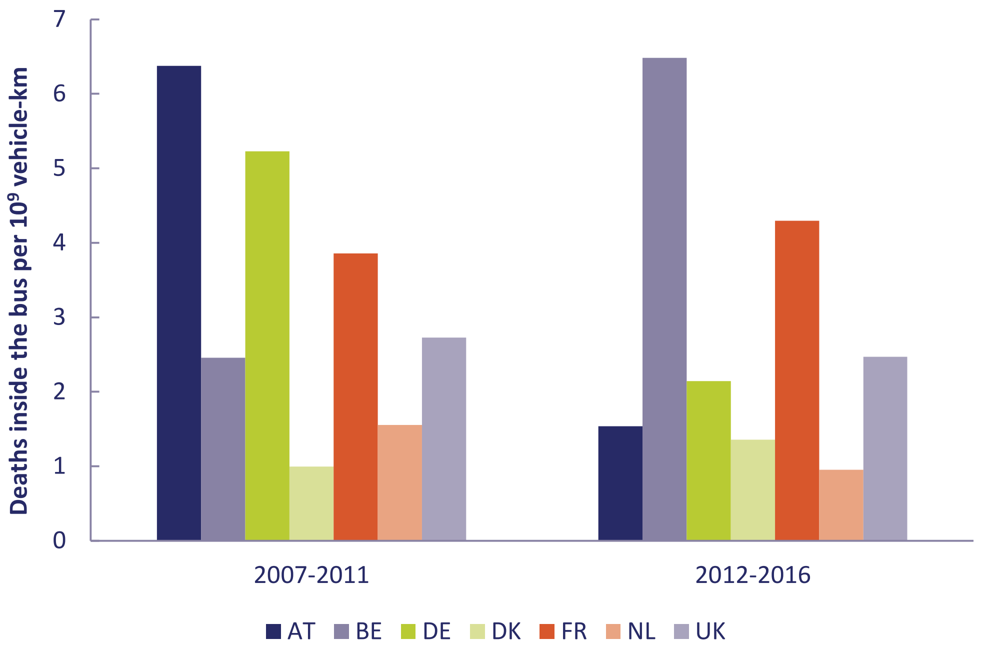


Figure 6.2. Number of road deaths with a bus as the crash opponent per billion vehicle km in AT, BE, DE, DK, FR, NL and UK in the periods 2007-2011 and 2012-2016.

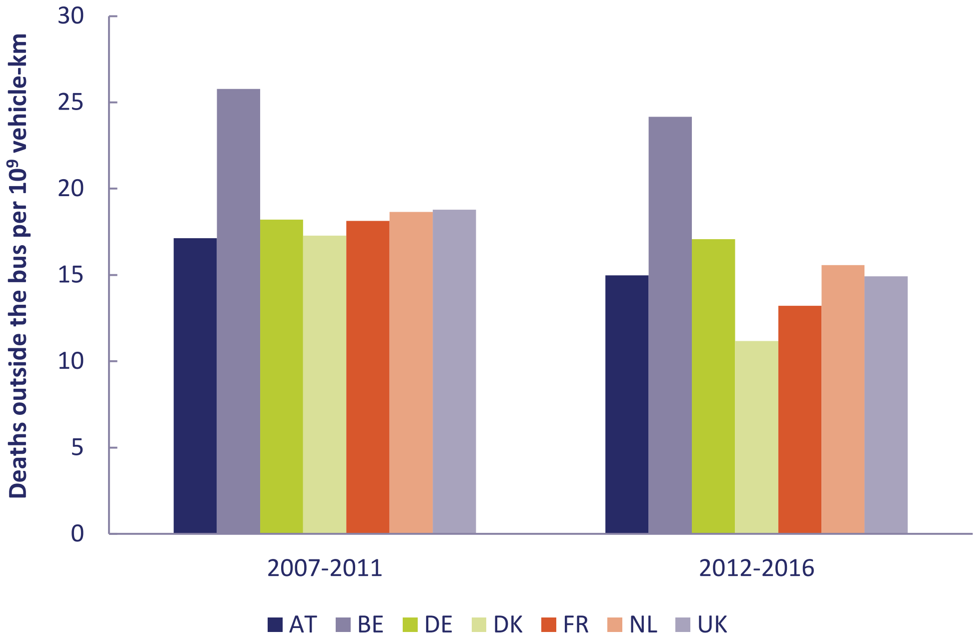



*Figure 6.3* shows the risk inside and outside the bus and *Table 6.1* shows the ratio of the risk outside/inside the bus over the whole period for each country. The risk of deaths inside the bus compared to outside the bus seems to be lowest in NL, as the risk outside the bus is almost 14 times the risk inside the bus. The risk in FR is highest, where the difference is as low as a factor 4.

Figure 6.3. Number of road deaths inside and outside the bus per billion vehicle km in AT, BE, DE, DK, FR, NL and UK during the period 2007-2016.

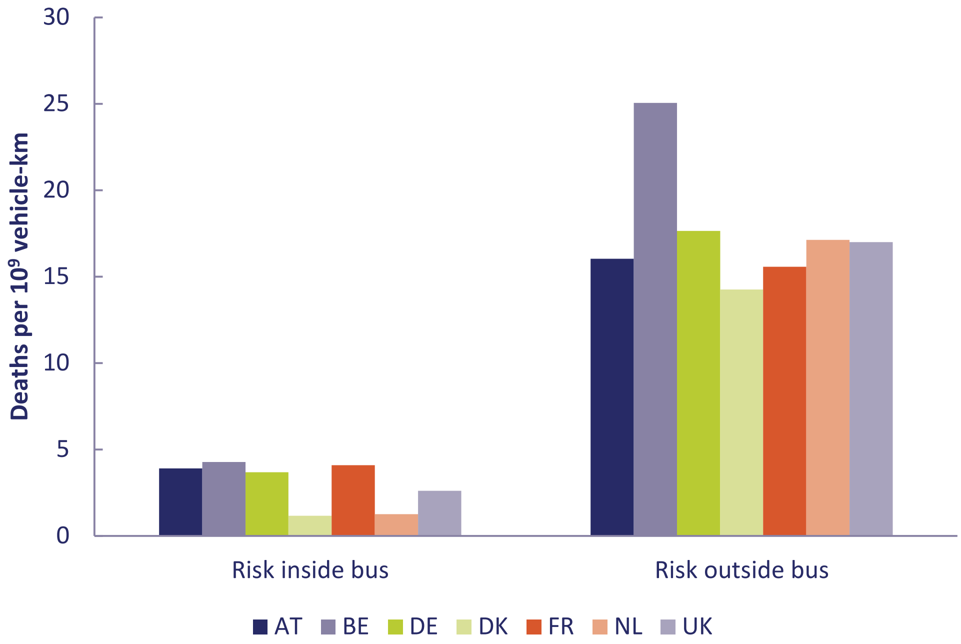



Table 6.1. The ratio of the risk outside/inside the bus over the entire period.

| | AT | BE | DE | DK | FR | NL | UK |
|---|---|---|---|---|---|---|---|
| Ratio out/in | 4.1 | 5.8 | 4.8 | 12.1 | 3.8 | 13.6 | 6.5 |

## 6.2 Cars

*Figure 6.4* shows the number of deaths inside the car per billion vehicle km and *Figure 6.5* shows those where the car was the crash opponent.

*Figure 6.4. Number of road deaths inside the car per billion vehicle km in AT, BE, DE, DK, FR, NL and UK in the periods 2007-2011 and 2012-2016.*

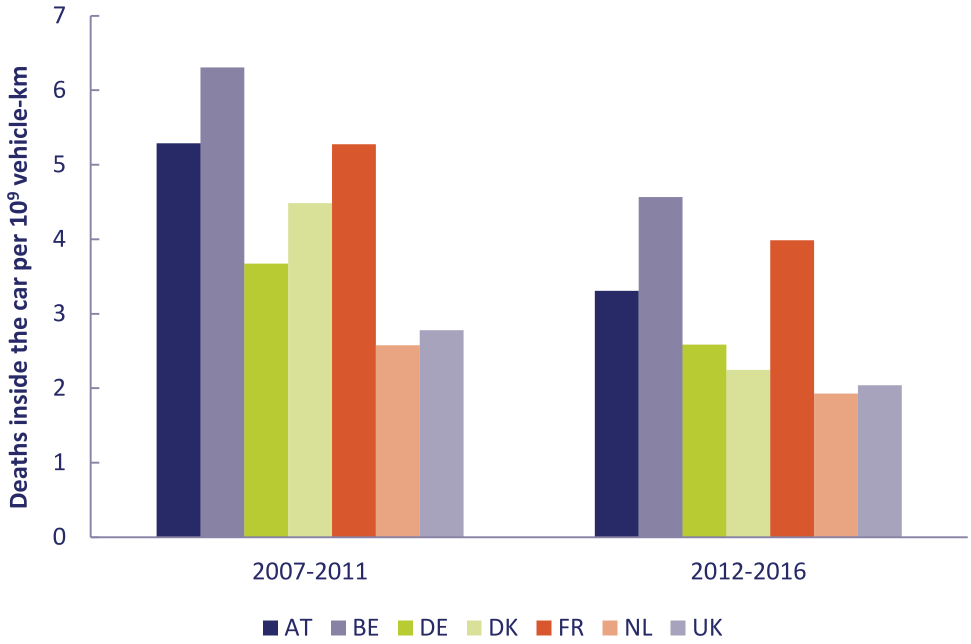



*Figure 6.5. Number of road deaths with a car as the crash opponent per billion vehicle km in AT, BE, DE, DK, FR, NL and UK in the periods 2007-2011 and 2012-2016.*

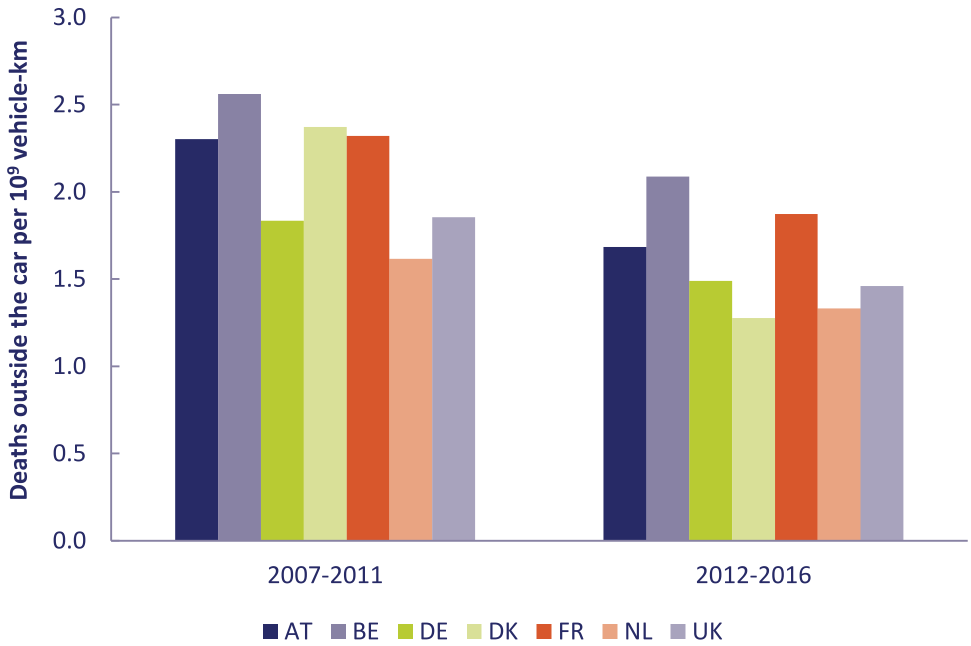


*Figure 6.6* shows the risk inside and outside the car and *Table 6.2* shows the ratio of the risk outside/inside the car per country during the entire period. The countries have similar risk ratios.

*Figure 6.6. Number of road deaths inside the car and with a car as the crash opponent per billion vehicle km in AT, BE, DE, DK, FR, NL and UK during the period 2007-2016.*

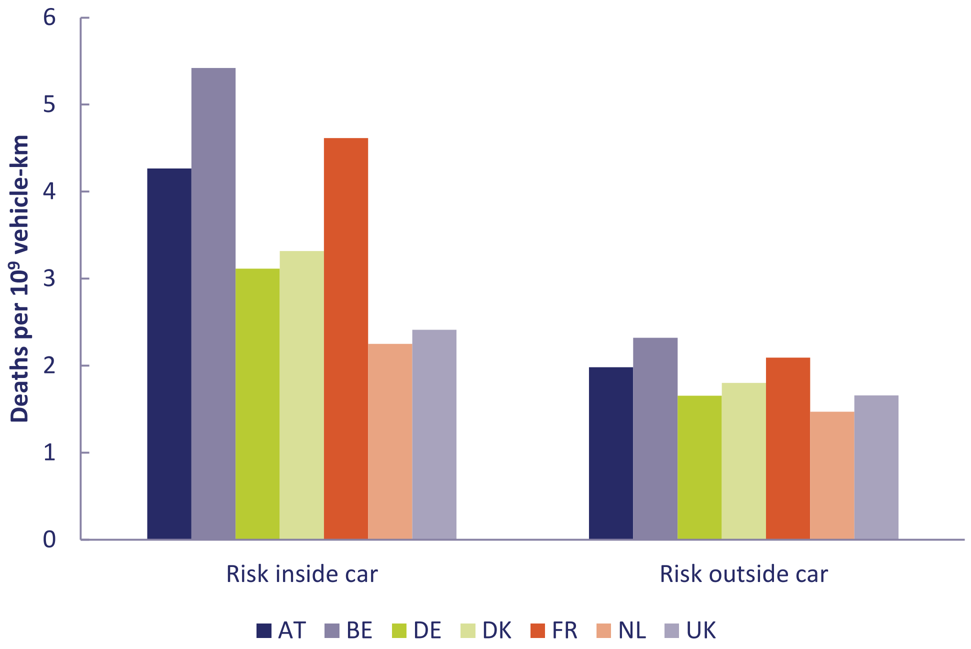



*Table 6.2. The ratio of the risk outside/inside the car over the entire period 2007-2016.*

| | AT | BE | DE | DK | FR | NL | UK |
|---|---|---|---|---|---|---|---|
| Ratio out/in | 0.5 | 0.4 | 0.5 | 0.5 | 0.5 | 0.7 | 0.7 |

For each country *Table 6.3* shows a comparison of the ratio of the risk outside/inside the bus with the same ratios for the car. In NL crashes involving buses result in almost 14 times more road deaths *outside* the bus than inside the bus. For cars in NL, the ratio is 1/0.7=1.5 times more road deaths *inside* than outside the car.

*Table 6.3. The ratio of the risk outside/inside the bus versus the same ratios for the car over the entire period 2007-2016.*

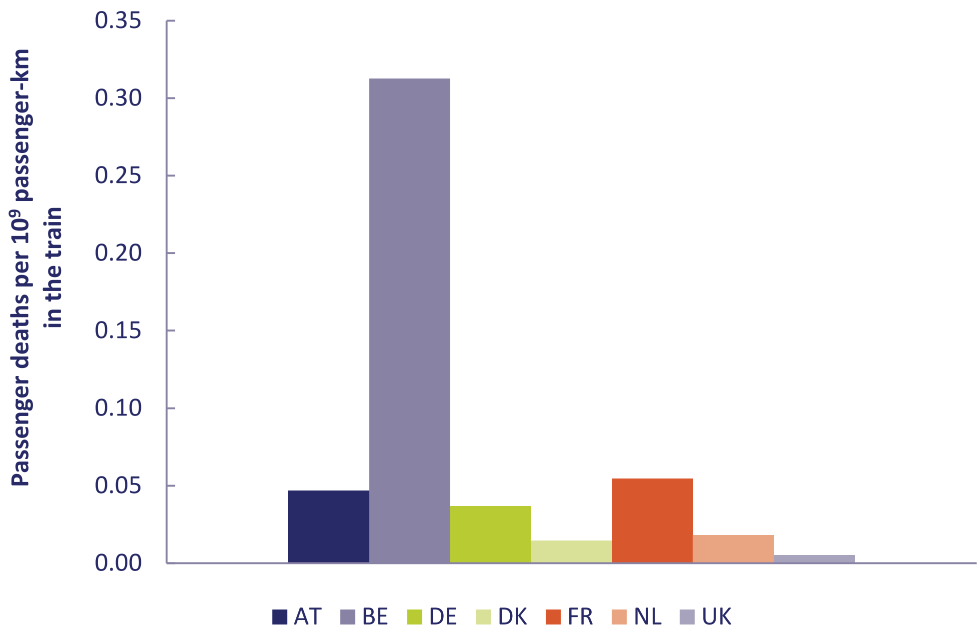
| | AT | BE | DE | DK | FR | NL | UK |
|---|---|---|---|---|---|---|---|
| Bus out/in | 4.1 | 5.8 | 4.8 | 12.1 | 3.8 | 13.6 | 6.5 |
| Car out/in | 0.5 | 0.4 | 0.5 | 0.5 | 0.5 | 0.7 | 0.7 |

The earlier study (Temürhan & Stipdonk, 2016) reported a ratio of 18.0 for buses and 1.1 for cars in the Netherlands during the period 1993-2014. These results are slightly different due to different data sets and a different time period used in that study.

## 6.3 Trains

*Figure 6.7* shows the number of passenger deaths in the train per billion passenger km. This is a difficult comparison because of many zeros for some years and countries. Train crashes where passengers get killed are rare, but in some cases many deaths do occur, for instance in Belgium in 2010. We could, however, not verify all of the Belgian train passenger deaths in the whole period.

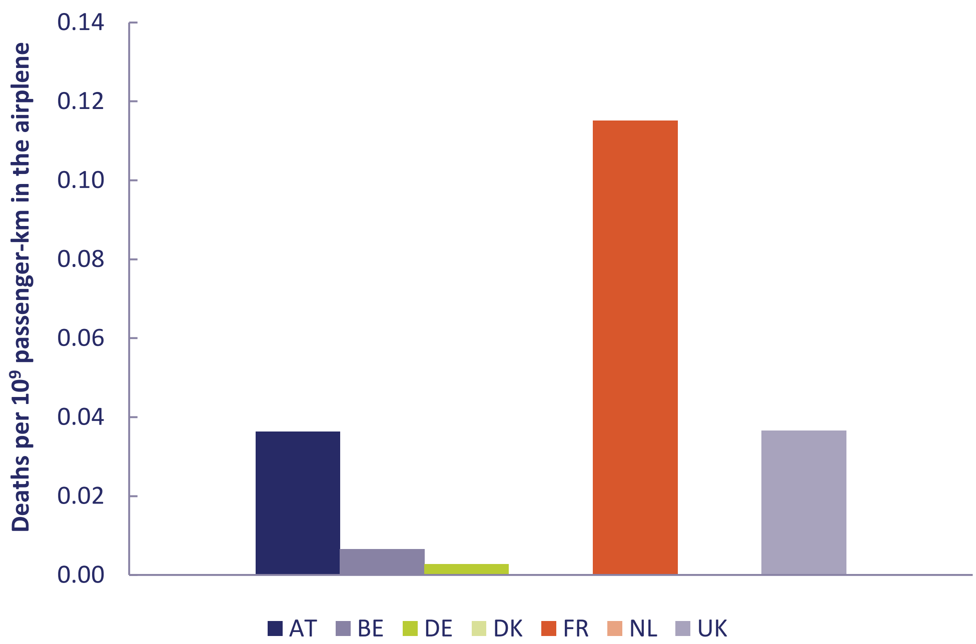
*Figure 6.7. Passenger deaths in the train per billion passenger km in AT, BE, DE, DK, FR, NL and UK during the period 2007-2016.*




## 6.4 Airplanes

*Figure 6.8* shows the number of deaths in commercial passenger air transport per billion passenger km. This data set also contains many zeros for several years and countries. Airliner crashes are very rare. This is not the case for general aviation with lightweight aircrafts (MTOW below 2250 kg; see *Figure 5.10*). Since there is no mobility data (person km) available for this category, we cannot calculate the risk. However, it can be argued that the risk of this lightweight category will be highest, with many casualties and relatively few passengers carried, or distances flown.

*Figure 6.8. Deaths in commercial passenger airplane crashes per billion passenger km in AT, BE, DE, DK, FR, NL and UK during the period 2007-2016.*



## 6.5 Vehicle occupancy

To calculate the occupant risk (so far distances travelled by vehicles were used for buses and cars), it is necessary to estimate the average number of occupants in each vehicle. All modes of transport have different capacities to carry persons.

According to the Eurostat data set, using the number of passenger flights and the number of passengers carried, passenger airplanes carry an average of 109 passengers per trip, averaged over the years 2007-2016 and the relevant countries.

For trains, combining the data on train passenger kms from World Bank Open Data and the vehicle kms for trains from Eurostat, we have calculated an average of 127 passengers per trip, averaged over the same years and countries. This number may not be accurate due to the mixing of two data sets from different sources.

According to the earlier Dutch study, based on mobility during the years 2010-2014, cars in the Netherlands carry an average of 1.5 persons per trip (p. 24, Temürhan & Stipdonk, 2016). We assume that this value is sufficiently accurate for the risk estimate in this report.

The same study reports an average of 10.3 passengers in buses over the same period in the Netherlands, also based on mobility. This average includes public transport buses. A study conducted for the Royal Dutch Association of Transport Companies (KNV) reports 40 passengers on average in coaches over the years 2004-2015 (KNV, 2015). We assume that this will be similar for the other countries in this study, as no accurate data was found.

Hence, based on these assumptions and on data from literature, for the occupant risks defined as the number of deaths inside the vehicle per person km travelled, we use averages of 109 passengers per airplane, 127 passengers per train, 10.3 passengers per bus, and 1.5 occupants per passenger car, as presented in *Table 6.4*.

*Table 6.4. Risk as the number of deaths inside the vehicle per person distance travelled for each mode of transport averaged over 2007-2016.*

| | In the bus | In the car | In the train | In the airplane |
|---|---|---|---|---|
| Deaths inside the vehicle per $10^9$ person km | 0.32 | 0.63 | 0.045 | 0.054 |

According to *Table 6.4*, car occupant risk is an order of magnitude higher than that of occupants of the most safe of the other three transport modes. These show relatively similar risk values, with the risk of bus occupants being about half-way between car and train or airplane occupant risk.

# 7 Conclusion and discussion

This study compared the safety of coaches in traffic with the safety of other modes of transport (passenger car, train and airplane) in the European countries Austria, Belgium, Germany, Denmark, France, the Netherlands and the United Kingdom, over the years 2007-2016.

The available road crash data did not allow distinguishing coaches and public transport buses. Therefore, this study uses the umbrella category “buses”.

The comparison of the safety of these modes of transport was carried out by comparing risk. Vehicle risk is defined as the number of casualties per vehicle distance travelled, and person risk is defined as the number of casualties per distance travelled by the vehicle occupants. In this report casualties are fatalities: people killed in traffic within the borders of each relevant country. This also includes non-residents.
Severely injured were not a part of this study for two reasons:

- data was often not available, and
- the definition of severely injured is not equal in the countries investigated in this study.

The following data sets have been used:

- Community Road Accident Database (CARE) maintained by the European Commission
- International Traffic Safety Data and Analysis Group (IRTAD) maintained by OECD
- European Statistics (Eurostat), maintained by the European Commission
- World Bank Open Data

These data sets were not always complete. First and foremost, there is not sufficient data specifically for coaches, just for buses in general. Although the numbers of deaths in the different transport modes were available and assumedly relatively reliable for all relevant countries for all of the years, we could not find most of the nine train passenger deaths in Belgium in 2010 reported in the Eurostat database when we checked these in the ERAIL-ERA database erail.era.europa.eu. Furthermore, we found more than the one train fatality reported in the Eurostat database in Denmark in 2016, when we checked this in the ERAIL-ERA-database: erail.era.europa.eu. This may be due to definition issues or issues retrieving the reports, therefore it is *assumed* that the Eurostat data provides a sufficiently accurate picture of railroad safety outcomes for the purpose of this study.

For comparison of the different transport modes, only deaths among occupants (inside the vehicle) were taken into account. This was a consequence of the decision to exclude all non-passenger rail deaths, a large group (85-99% of all reported rail deaths) of which it was not clear how they were defined (e.g. inside or outside the train, whether a passenger train was or was not involved). This may have resulted in a calculated train fatality risk (the occupant risk) with a lower value than the factual train fatality risk.

In general, however, fatality data is available for the entire period and for all countries considered. This was not the case for the distances travelled by vehicles and vehicle occupants.

When necessary, missing values were imputed, which affects the accuracy of the results. It is not certain how large the effects are.

Compared to crashes with cars, crashes with buses, coaches, passenger trains and airplanes involve many more (potential) casualties in a single event. This results in substantial problems generalizing the results. The frequency of occurrence of such events, for instance, is difficult to determine reliably. The airplane crash in France in 2015 with 150 deaths was included in the Eurostat data set even though it had already been determined to have been caused deliberately by the co-pilot. This has a negative effect on the result for the safety of passenger airplanes. It also seems nearly impossible to assess the probability of such an event occurring. We cannot say whether this will happen again. This is one of the reasons to limit the scope of this report to the results based on the data available for the period considered, and refrain from making inferences. In summary, we are hesitant to say what we expect to happen or, in general, what the results would be, for instance next year.

To calculate the occupant risk the average number of occupants in each vehicle was estimated. For trains and airplanes, this could be calculated from the available data sets. For buses and cars, this was not possible and it was decided to use the values from an earlier study in the Netherlands (p. 24, Temürhan & Stipdonk, 2016). Based on mobility during the period 2010-2014, cars in the Netherlands carry 1.5 persons per trip on average and buses carry 10.3 passengers per trip on average. This latter average includes public transport buses. We assume that these values are sufficiently accurate for the risk estimate in this report. A study conducted for the Royal Dutch Association of Transport Companies (KNV) reports an average of 40 passengers in coaches in the years 2004-2015 (KNV, 2015). We assume that this will be similar for the other countries in this study, as no accurate data was found.

Hence, based on these assumptions and on data from literature, we use averages of 109 passengers per airplane, 127 passengers per train, 40 or 10.3 passengers per coach/bus and 1.5 persons (occupants) per passenger car.

The accuracy of the following results is therefore dependent on the correctness and the limitations of the data sets and the assumptions that have been made.

### Risk for buses and cars per country for all years

Comparing the risk for buses and cars between countries, it was possible to make a distinction between casualties *inside* the vehicle and casualties of which the vehicle was the crash opponent.

For buses and cars, the following ratios of the risk outside the vehicle versus the risk inside the vehicle were found for each country separately, over the years 2007-2016:

*The ratio of the risk outside/inside the bus versus the same ratio for the car during the entire period 2007-2016.*

| | AT | BE | DE | DK | FR | NL | UK |
|---|---|---|---|---|---|---|---|
| Bus out/in | 4.1 | 5.8 | 4.8 | 12.1 | 3.8 | 13.6 | 6.5 |
| Car out/in | 0.5 | 0.4 | 0.5 | 0.5 | 0.5 | 0.7 | 0.7 |

For buses, NL seems to have a relatively low number of road deaths among bus occupants compared to casualties outside the bus, while in FR this ratio seems to be relatively high (but still less inside than outside).

For cars, the ratio of risk inside and outside the car appears to be similar for all individual countries.

All in all, a bus seems more dangerous to casualties outside the vehicle than a car, which was to be expected. The reverse appears to be true for occupants of the vehicle. It was safer for the occupants to travel by bus than by car.

## Risk per mode of transport for all countries and all years

Comparing the average number of casualties *inside* a vehicle per billion vehicle km travelled in the period 2007-2016 and for all the relevant countries together, the following risks were found:

| | In the bus | In the car | In the train | In the airplane |
|---|---|---|---|---|
| Deaths inside the vehicle per $10^9$ vehicle km | 3.2 | 1.0 | | |

Using the (assumed) number of occupants per vehicle, the occupant risk can be calculated:

| | In the bus | In the car | In the train | In the airplane |
|---|---|---|---|---|
| Deaths inside the vehicle per $10^9$ person km | 0.32 | 0.63 | 0.045 | 0.054 |

The lowest occupant risk was in trains, keeping in mind the probable underestimation due to the large group of rail deaths excluded. The risk in airplanes was similar, keeping in mind the relatively big crash in France in 2015 with 150 casualties. The highest occupant risk was in cars. The occupant risk in buses was between the occupant risk in cars and that in trains and airplanes.

If we take the risk in buses to be 1, the relative risks of other modes of transport become:

| | In the bus | In the car | In the train | In the airplane |
|---|---|---|---|---|
| Deaths inside the vehicle per $10^9$ person km | 1 | 2.0 | 0.14 | 0.17 |

Given these risks, it seems safer to travel by bus, train or airplane than by car. Note that the above results only include deaths among the vehicle occupants. All modes of transport also result in non-passenger deaths.

Furthermore, about coaches can be said that:

– if it is assumed that coaches drive the same trips as all other buses (mostly public transport);
– ánd if it is assumed that coach travel results in external (non-passenger) deaths at the same rate per bus-kilometre as the other buses;
– ánd if coaches indeed have an occupancy rate of 40 – which is substantially larger than that of general buses;

then it is plausible that the effective number of deaths per passenger kilometre traveled by coach will be (substantially) lower than that of buses in general, as was studied here.

# References

**Databases**

CARE: Community Road Accident Database
http://ec.europa.eu/idabc/en/document/2281/5926.html

Eurostat Database
https://ec.europa.eu/eurostat/data/database

ERAIL-ERA database
https://erail.era.europa.eu/investigations.aspx

IRTAD Road Safety Database
https://www.itf-oecd.org/IRTAD

World Bank Open Data
https://data.worldbank.org/

**Other references**

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