SAFETY IN TRANSPORT AND TRAFFIC

In his column Every-day Science in the section Science & Education for the newspaper NRC-Handelsblad, Karel Knip argues on November 17, 2001 under the title *"Back-of-the-envelope calculations"* against the myth that airplanes are safer means of transport than automobiles. He quotes a reader from Nijmegen who had written to Knip. I was interested in that since I travel often by air and little by automobile.

Note added: The argument of Knip in his column runs as follows based on the letter he had from Nijmegen (my translation): *"There are about 15,000 commercial jet-driven airplanes that each travel about 2 million kilometers per year. On average there are 17 crashes where on average 75 persons die, that means 1275 deaths per year. That results in a score of 25 million airplane-kilometers per death. Now consider automobiles, he says on the back of his envelope. In the Netherlands there are annually about 1000 death related to automobiles, these occur against a total of six million cars that on average travel about 12,000 kilometers. That corresponds to 72 million kilometers per automobile-related death."* Knip continues to update that with more recent information and arrives at a number if 164 million kilomters.

My counterargument was that airplane accident occur mostly during take-off or landing (or respectively shortly before or after that) andthat the length of the trip and therefore the chance of an accident *per kilometer* is not relevant. To gain more insight I visited after using a search engine the Web-site *"Safe Skies International"*. There I found a table with statistics of when during a flight accidents occured. And indeed! Only 9% of all accidents occur during the flight at cruising altitude. All other parts of the flight are present independent of the distance coverd during the flight. If we add taxiing, take-off and initial climb (together 28%) and later stages of the flight, approach and landing (together 53%), that are after all part of each flight, than we account for more than 80% of all accidents. So, to judge the safety of airtravel you have to examine accident per flight.

The same Web-site also provides detailed statistics of flights with American airlines. There is a distinction between major airlines and commutors. I restrict myself to the first category. The relevant numbers (over the period 1982-1999) show for the fatal accidents 0.030 per 10^5 hours in the air, 0.00074 per 10^6 mile and 0.043 per 10^5 take-offs. These American airplanes cover almost 10^{10} km for about 250 deaths under the people on board (passengers and crew). These are in my view broadly consistent with Knip's reader fron Nijmegen, who found worldwide 3×10^{10} km and 1275 deaths.

As an aside the following. The Web-site gives a nice lesson in use of statistics. For the middle of 2000 the Concord had a perfect *safety record* of no accident in 80.000 flights. After the Paris accident this turned into 12.5 accidents per million flights, in one sibgle step from perfect to worse than the Airbus 320 (0.68) and the Boeing 737 (0.33). It should in addition be realised that there are twice as many accident with an 737 (10) than with an A320 (5), but on the other hand there have been many more flights with a 737 (30.8 million) than with an A320 (7.3 million).

For the statistics of deaths in car traffic I take the numbers as in the column itself. For a trip by automobile the chance to experience an accident is in principle the same for every kilometer. In that case it is useful to calculate a chance per kilometer. You have to be careful here as well though. In Knip's column the number of deaths is divided by number of kilometers covered by automobiles (both per year) and then one gets 1.4×10^{-8} (or one death per 73 million automobile-lilometers). But you may ask if that is indeed what you want to know? I one way

possibly, since it tells you how many kilomters an automobile has to travel before it is involved in an accident in which at least one deat occurs and it is therefore a measure for safety. On the other hand you would like to know what risk you take when you get into an automobile, i.e. what the chance is when you cover one kilometer by automobile (be it as driver or as passenger) to be involved in a fatal accident. For that you need to take into account that often more than one person riding anautomobile when an accident occurs and that often there are survivors. The you should consider passenger-kilometers.

From statistics that I found on the Web (for around 1995), I see that twice as often a driver of an automobile dies than a passenger. When the chances to die are the same, this meas that on average an automobile holds one-and-a-half persons when an accident with deaths occurs and therefore that the number of passenger-kilometers is at least twice as large as the number of automobile-kilometers. On that basis I estimate that the chance to die in a automobile-accident per kilometer, either as driver or as passenger, is one-and-a-half times as small. This in round numbers 1×10^{-8} per *passenger*-kilometer. Or you may say that there are 615 automobile-deaths for about 400 accidents (not precisely of course, since sometimes only a passenger dies and the driver does not; however that is only a small correction with respect to the other estimates that can be made).

This is of course how one should appraoch the question in case of airplanes also. But with accidents in airtraffic usually most persons on board die. I assume that on average an airplane has roughly 100 persons on board (including crew). Therefore the number of person-kilometers per year is more than 100 times as large as the number of airplane-kilometers. To point directly to the inconsistency that you get if you ignore this, I look at my own situation. In 2001 I have travelled professionaly (I am an astronomer) twice to Australia, once to the US and I have made 15 trips by air to destinations in Europe. And that is not reasoning after the fact, since I knew about the intercontinental before the start of the year and would have estimated a similar number of European flights. All together is has involved more than 100,000 kilometers. When I then use the numbers of the Nijmegen letterwriter I find that I had a chance of 1 in 250 or so to have died in an airplane accident. I would never have taken such a risk. And think of airplane crews. They cover much more airplane-kilometers per year than I did in 2001. When you divide that by the 25 million kilometers per death in the column, thier chances run in the order of a few percent. That can simply not be correct. And the reason is of course that when one is in an airplane that is involved in a fatal accident, there are also (according to the column) another 74 persons that will have died.

So, what is the correct approach? Well, with all connecting flight included, I have during 2001 been in about 45 take-offs (and luckely the same number of landings). We saw in the American statistics above (I usually fly KLM, which will have a similar safety record) that of 10^5 flights we have 0.043 flights with a fatal accident. Assume that all peope on board die (the chance for that is of course not exactly 1.0, but that will not change the answer considerably). The chance that you board an airplane and that that plane has a fatal accident is then 1 in 2.3×10^6 and that does not really depend on the distance. For myself that results in a risk of 1 in 50,000 and had I made that calculation towards the end of 2000 I would have judged that acceptable. For crews on commecrcial airlines, who are in say twohunderd take-offs per year the chance for a fatal accident are 1 in 10,000 or so per year; 10 years as an airline pilot or a stewardess and you have the chance that you will not survive that of 0.1%[1].

[1]The correct calculation goes somewhat differently. With the small numbers involved the difference is small, however. The chance that you survive your first flight is $2.3 \times 10^6 - 1$ divided by 2.3×10^6 and for the next flight it is the same. The chance that you survive both flights then is the product of the two. Now look at a stewardess

Compare this to a trip by automobile over 100 km. The chance to be involved in a fatal accident per traveller-kilometer was 1×10^{-8}. For that trip the chance then is 1×10^{-5} or 1 in 100.000. That is clearly more dangerous than flying. The larger the distance the larger relatively speaking travel by automobile becomes. Not so strange since the risk for a trip by automobile increases with distance covered and that is not the case for airtravel. Per kilometer an automobile may be relatively safe, but for larger distances it is safer to fly and that is what counts.

I have made further estimates of the safety of other means of travel. I will not repeat all the details of the calculations here, but I will compare the chance for a fatal accident for a number of typical cases. These vary be a factor 500 or so between the largest and the smallest from 1 in 100 million to 1 in 200 thousand. The estimates are not all equally reliable, but should in broad terms be correct to within a fator 2 or so, I would say.

	Means of transport	distance (km)	chance (1 in)
1.	train	200	1×10^8
2.	pedestrian	1	4×10^7
3.	bicycle	20	1×10^7
4.	moped	20	5×10^6
5.	airplane	–	2×10^6
6.	automobile	100	1×10^6
7.	coach	1000	3×10^5
8.	motorcycle	100	2×10^5

When I need to travel 200 km I usually take the train. That makes good sense. I always fly when I have to travel abroad (except to Belgium when I take the train) I fly. I make little use of an automobile and never a coach to holiday destinations or a motorcycle. I have contained the risk as much as possible.; in spite of that I run a risk for a year like 2001 to die in an accident of 1 op 50.000 or so and that is almost entirely due to flying. Would I travel by car whereever I travel by train and airplane (at least for those cases where it is possible) I run a risk of 1 in 700. Public transport is a lot safer.

Haren, December 29, 2001.

Piet van der Kruit

Note added: In his column of January 12, 2002, Karel Knip ame back to this issue. He writes: *"...And indeed, the calculation was wrong and there is no point in denying that. What was calculated was the number of deaths per vehicle- or plane-kilometer. No account is taken of the fact that an airplane often contains 50 to 100 times more passengers than an automobile. The majority of the letters that I got feel that one should use the number of passengers per passenger-kilometer as meassure for safety. That is indeed common use. But a passionate minority feel that is also not a good measure and want safety expressed per passenger-hour. Others still, as*

or pilot that in his/her career makes 5000 flights. The chance of not surviving that is 1 in 460. That is a larger risk than one might infer intuatively. On the other hand you can look at the case of a person that travel to work every day by car. Assume a distance between home and work of 20 km. That is then travelles twice a day for say 235 days per year over a period of 40 years. The chance for a fatal accident per traveller-kilometer was 1×10^{-8} and that gives over this period a chance to die in an accident of 1 in 265. So, it is more dangerous to travel 20 km per automobile every day during one's career than working in an airplane; however you will have to realise that one has to travel to the airport when going to work.

the Groningen astronomer Prof. dr. P.C. van der Kruit, feel that one should rather compare the number of deaths per flight. All flight accidents occur after all during take-off and landing and what is in between does not contribute significantly to the risk. Deaths per flight seems indeed a good measure to compare safety records of countries or airlines but does of course not allow an easy comparison between flying and car driving. In those cases take-off and landing are ususally least dangerous."

Note added: In the same original column, Knip also addressed the matter of what the cost is (in terms of use of fuel) of driving automobiles with their lights on during the day. *"An automobile driver in Heeze writes that some people such as environmentalist-oriented cyclists (that do not carry any lights on their bicycles at night themselves) maintain that this costs 2 to 3 percent more fuel. But my car has bulbs adding up to only 150 Watt, he continues, and the maximum power of my car is 70 kiloWatt. If the actual power used is on average 50,000 Watt during driving then the lights only use 0.3 percent in additional power. And not 3 percent. Or am I stupid?*
Probably not. One may remark that there is more than 150 Watt mechanical power necessary to make 150 Watt of electric power, that the average power may be lower than 50 kW, but in general terms it is correct. But that does not mean it is negligible. In reply to a reader in Groningen I add that the statement that 'light-during daytime' does not require any extra fuel at all as the motor is on anyway, is wrong. Most dynamo's in automobiles produce their own magnetic field in which the rotor rotates through electric means. When there is no need to produce electricity there is no field and the rotor move without much resistance...."
In the same second column, Knip says that in his original column also with respect to this other issue *"truth was far from the text.... Some critical readers wrote in addition to bulbs there are fuses that use electricity. Others have very low estimates for the efficiency of the chain explosion-engine – V-belt – dynamo – lights of even less than 50%. But most important is the estimate of the average power an automobile needs these days. Even at 100 km/h only a quarter of the maximum power would be required. Then the estimate is only 15 kiloWatt of power used. That easily results in an extra use of fuel of 1.5 to 2 percent. An automobile magazine (Automobil Revue) came up with an even higher number."*