Environmental effects of carsharing – results from the moses project

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Complete report can be downloaded at http://213.170.188.3/moses/Downloads/reports/del_6.pdf

Abstract

This study shows that car-sharing reduces car mileage by 28-45% among private users, which is quite in line with other studies of car-sharing. Some people increase their driving when joining car-sharing (mainly those who did not own a car before), but the increase is rather small in absolute figures. Some people decrease their driving when joining car-sharing, mainly those who got rid of a car when joining. But all changes put together mean an average decrease with 3000 km per member and year in both Bremen and Belgium. On the other hand the use of public transport is increased by 1100 km per car-sharing member and year. Car-sharing cars are smaller and newer compared to the private cars they replace. Among the total fleet of cars, the share of medium sized cars is reduced by 40%. 65% of abolished cars in Belgium were from 1995 or earlier, which can be compared to the car-sharing fleets average production year of 2002 (these figures are estimated to be relevant also for Bremen). Due to the above factors, car-sharing is estimated to reduce CO2 emissions from car transport by 40-50% (among its members), and other pollutants are estimated to decrease even more than 50%. Car-sharing reduces the need for a private car and therefore also reduces the amount of cars in urban areas. In Bremen each car-sharing car replaces 7-10 private cars and in Belgium each car-sharing car replaces 4-6 private cars. This in turn reduces the need for parking space by 90-135 m2 in Bremen and 45-75 m2 in Belgium for each car-sharing car.

Background

moses - mobility services for urban sustainability – was a European project aiming to develop mobility services to reduce dependence on the private car on a European scale - without restricting mobility. The existing small-scale system of carsharing should be improved significantly, with better service, integrated innovative technologies, intermodal co-operation with other mobility services (e.g. public transport, taxi, cycling etc.) and integration of these innovative services into strategies of urban revitalization and new developments to increase urban efficiency. The *moses* project was practice orientated and examined the demonstrator sites (London, Stockholm, Genoa, Palermo, Turin, the Walloon Region, Bremen and Bucharest) under real-life conditions.

This paper is focused to explore the direct impacts (on space consumption, CO2 emission, local emissions etc) of the implemented measures in the moses project. In order to calculate this, a lot of other areas have been investigated such as changes in car ownership and transport mode usage. Both private users an corporate users of car-sharing has been surveyed in the moses project, but this paper focuses on the private users.

Method

To assess the effects of car-sharing, information has been collected by questionnaires from users as well as providers of car-sharing. At the Bremen site, with some 2,000 private customers at the time, questionnaires were sent to 30% of the private users. At all other sites – where the number of users at this time has reached only a few hundred – every user received a questionnaire, in order to get a high quality result.

Response rates

For private users it was only possible to collect results from Bremen and Belgium (Brussels and in Wallonie: Namur, Liege, Louvain la Neuve, Dinant). Stockholm, London and Bucharest did at the time of the survey not reach enough private customers to produce results that prove to be statistically valid (in some cases it was never planned to have a large private customer base, as in Stock-

holm for example). In Italy a large national survey was done just before this *moses* survey was planned, which made it inadequate to launch another survey at about the same time.

The response rate among private users was 38% in Belgium and 45% in Bremen which means about 300 respondents from each site. These figures are reckoned to give a valid result.

Possible sources of error

Evaluations based on questionnaires are in general faced with two major questions that can be problematic:

1) are the responses received representative for the whole population we would like to describe?
2) did the respondents answer the questions correctly?

In this case we do not expect the representativeness to be a major problem due to a relatively high response rate. The correctness of each respondents answer is of course hard to estimate, but we have not experienced any critical issues that indicate this. The biggest problem is probably the estimation of mileage before joining car-sharing, but there is however very few other ways than using a questionnaire to estimate the change in mileage. A few calculations of variations have been made which did not show any major changes, and together with the fact that the results are in line with previous studies the results are judged to be reliable.

Car ownership

The majority of the respondents in both countries (60-65%) have owned a car before but do not own a car today. Slightly more than 10% own a car today and the remaining (20-30%) do not own a car and have never owned one before.

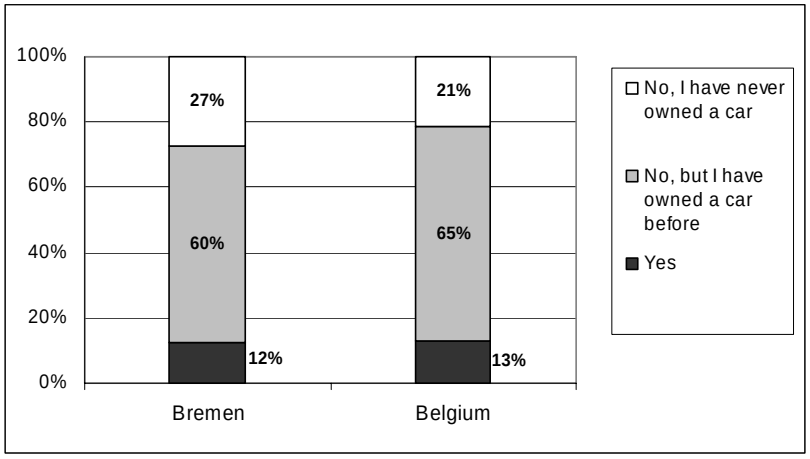

Figure 1. Does your household own a car today?

Car abolition influenced by car-sharing

The users who do not own a car today but have owned a car before were asked whether the abolition was influenced by car-sharing. In Bremen 57% of the former car owners stated that car-sharing did influence them, which means that 34% of the respondents in Bremen have got rid of a car at least partly because of car-sharing. The corresponding figures for Belgium are 33% percent of the former car owners influenced by car-sharing, which means that 21% of the respondents got rid of a car at least partly because of car-sharing.

If not joining car-sharing

The previous section deals with the actual effect of car-sharing on car abolition. But it is probable that car-sharing also make people give up plans to buy a car. A question was therefore asked

about if they had not joined car-sharing, would they then have bought a car? By looking at answers of the respondents who did not get rid of a car, we can make an interesting estimate of the potential of cars that is not bought because of car-sharing. The responses to the four possible answers are presented in the figure below.

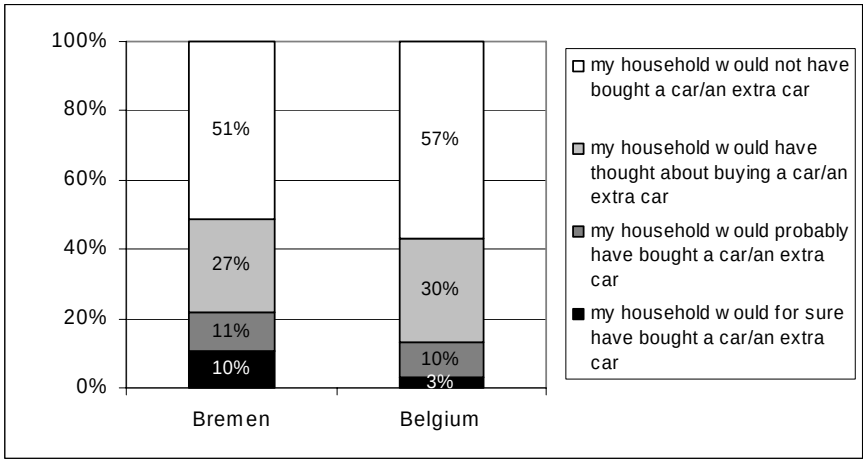

Figure 2. Respondents who did <u>not</u> get rid of a car due to car-sharing, would they have bought a car if they had not joined car-sharing?

In order to calculate the effect of cars not bought, the responses are assumed to give the following results.

The answer	"would not have bought"	means	0% chance of purchase
	"thought about buying"	means	25% chance of purchase
	"probably have bought"	means	75% chance of purchase
	"would for sure have bought"	means	100% chance of purchase

This means for Bremen that 25% of the members who have not got rid of a car influenced by car-sharing would have bought a car if they had not joined car-sharing (0%*51% + 25%*27% + 75%*11% + 100%*10% = 25%). This corresponds to 17% of all members (25% * 66% = 17%).

This means for Belgium that 18% of the members who have not got rid of a car influenced by car-sharing would have bought a car if they had not joined car-sharing(0%*57% + 25%*30% + 75%*10% + 100%*3 = 18%). This corresponds to 14% of all members (18% * 79% = 14%).

Conclusion on car replacement

In Bremen 34% percent of respondents say they were influenced by car-sharing and got rid of a car, while the corresponding figure for Belgium is 21%. This can be considered the actual or minimum effect of car replacement by car-sharing.

To this minimum effect the potential effects of reduced buying of cars can be added (as calculated in the previous section), which gives a maximum effect. The maximum effect of car replacement would then for Bremen be 51% (34%+17%) and for Belgium 35% (21%+14%).

The car-sharing operator in Bremen has 5 cars per 100 private members[1], which means that as a minimum 34 cars are replaced with 5 cars (per 100 members), or more simplified: each car-sharing car replaces close to 7 private cars (34/5=6,8). Using the maximum replacement, 51 cars are replaced with 5 cars (per 100 members), which means that each car replaces 10 cars.

[1] 91 cars are used by 1727 household clients (91/1727=0,05 cars per client) but also by 648 corporate clients. Considering this cross-use of the cars, the replacement effect could be considered to be even higher than calculated above.

The car-sharing operator in Belgium has 5,6 cars per 100 members,[2] which means that as a minimum 21 cars are replaced with 5,6 cars (per 100 members), or more simplified: each car-sharing car replaces close to 4 private cars (21/5,6=3,75). Using the maximum replacement, 35 cars are replaced with 5,6 cars (per 100 members), which means that each car replaces 6 cars.

Car-sharing reduces the need for a private car and therefore reduces the amount of cars in urban areas.

In Bremen, each car-sharing car replaces 7-10 private cars.
In Belgium, each car-sharing car replaces 4-6 private cars.

Change in parking space needed

The reduced number of cars according to the above section also reduces the need for parking bays. Space needed for parking varies between on street parking and parking lots or garages. Average size for a parking lot or garage is 20-30 m^2 per car, including space needed for driveways etc. For on street parking only about 10 m^2 is needed. An average figure of 15 m^2 is used here, which means a mix of about 70% on street parking and 30% in parking lots.

In Bremen each car-sharing car replaces 7-10 private cars, which means that each car-sharing car also reduces space of 6 to 9 bays which is equivalent to 90-135 m^2. The saved space in Belgium is calculated to be 45-75 m^2 per car-sharing car.

Since car-sharing reduces the need for a private car, a lot of space for parking can be saved and used for other purposes.

In Bremen, each car-sharing car reduces the need for parking space by 90-135 m^2.
In Belgium, each car-sharing car reduces the need for parking space by 45-75 m^2.

Change in type of cars used

It is sometimes said that car-sharing changes the type of cars used to newer and smaller cars, which are more efficient and less pollutant compared to the cars replaced. The respondents who got rid of a car influenced by car-sharing were therefore asked what type of car they abolished in terms of size, year of production and fuel type.

In Belgium 54% percent of the cars abolished were medium sized or larger (30% medium, 16% large and 8% extra large). This should be compared to the car-sharing fleet consisting of only 15 percent medium sized cars (the rest is small cars) which means a replacement of this type of car with about 40%. A possible explanation for this is that the private car is often bought to suit the owners most extreme need in terms of size, for instance family summer vacation etc. Car-sharing build on the principle to have cars that meet the specific need each time of usage, which means that a much smaller share of the fleet need to be large cars. Another theory is that car-sharing customers are less likely to use cars as status symbols, which make smaller cars more adequate and popular.

65% percent of the Belgian cars gotten rid of were manufactured in 1995 or earlier. 17 percent were even from 1987 or older and therefore did not have catalytic converters, which means they were relatively heavy polluters regarding carbon monoxide (CO), hydrocarbons (HC) and nitrogen

[2] 63 cars are used by 1126 household clients (63/1126=0,056 cars per client) but also by some corporate clients. Considering this cross-use of the cars, the replacement effect could be considered to be even higher than calculated above.

oxides (NO_x). This should be compared to the car-sharing fleet where the average production year was 2002 (which is not only due to the fact that car-sharing in Belgium started in 2002 but also that car-sharing usually keep their cars for 3 years and then they are replaced with new cars).

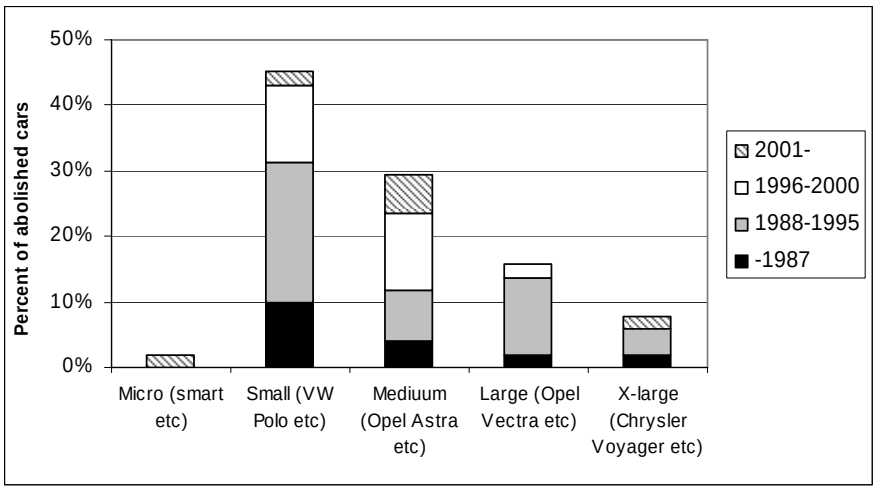

Figure 3. Type of cars abolished in Belgium (influenced by car-sharing membership). Total numbers of cars abolished was 51.

The age and size of cars abolished in Bremen is shown in the figure below. 69 % of the cars were medium sized or larger, to be compared to the car-sharing fleets share of only 30% (which equals a replacement of this type of car with about 40%). More than half of the cars were older than from 1987, but since some of the respondents in Bremen joined car-sharing already in the early 1990's it is not fair to compare these replaced cars with the newer car-sharing cars (if car-sharing was not an option in Bremen it is likely that some members would have replaced their cars with newer ones). However, the results should not be very different from the Belgium results (especially not since the average joining year for Bremen respondents abolishing a car is as recent as 1999, and the cars abolished are still much older than the Belgium cars).

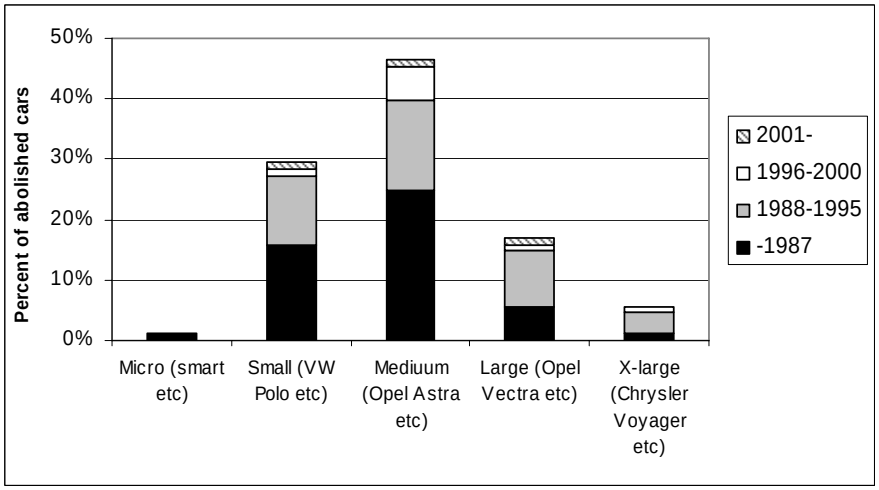

Figure 4. Type of cars abolished in Bremen (influenced by car-sharing membership). Total numbers of cars abolished is 88.

A shift in fuel used (diesel or petrol) can also be noticed when abolishing a private car and using car-sharing instead. Both in Bremen and Belgium about 25% of the abolished cars run on diesel, while the share of diesel cars in the car-sharing fleet is lower than 5%. Whether this effect is good or bad is however somewhat ambiguous, but a general view is that petrol is better for city traffic

and diesel better for highway traffic (this view is based on the fact that diesel usually means lower emissions of CO_2, but higher emission of pollutants that are more directly hazardous to human health such as NO_x and particulates etc). Since the level of pollution in cities usually is a health problem, and most of car-sharing traffic can be assumed to take place in urban areas, the shift from diesel to petrol due to car-sharing can be considered to be positive. To which extent is however extremely difficult to calculate, and therefore no further analysis is made here.

Car-sharing cars are smaller and newer compared to the private cars they replace.

Among the total fleet of cars, the share of medium sized cars is reduced by 40% of the total fleet (in Belgium from 54% to 15%, in Bremen from 70% to 30%).

65% of abolished cars in Belgium were from 1995 or earlier, which can be compared to the car-sharing fleets average production year of 2002 (these figures are estimated to be relevant also for Bremen).

Transport mode usage

Car usage

The car usage before joining car-sharing was on average 9 400 km in Belgium and 6 900 km in Bremen. The distribution of mileage among the clients is shown below.

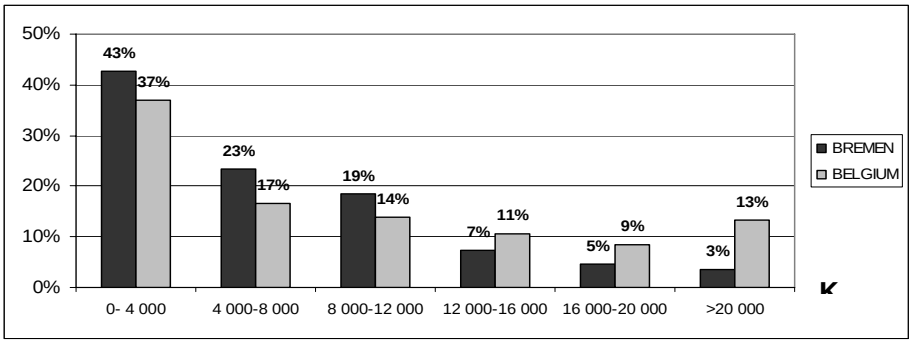

*Figure 5. Annual mileage (km) by car **before** joining car-sharing*

The respondents were also asked to estimate their change in mileage since joining car-sharing. Among those who increased their driving the average increase was 800 km in Bremen and 1200 km in Belgium (which means +60% and +14% increase compared to their own previous mileage. However, because of the low share of "increasers" this only corresponds to 1% of the total previous mileage of all respondents.

Among those who decreased their driving, the average decrease was 6 600 km in Bremen and 11 100 km in Belgium. In Bremen this corresponds to -46% and in Belgium -29% of the total previous mileage of all respondents.

If the groups of decreasers, increasers and "no change" are put together, the average change in Bremen is -45% and in Belgium -28%.

Table 1. Change in car usage since joining car-sharing (N_{Bremen}=267, $N_{Belgium}$=234)

	Share of respondents	Mileage before CS, km per person and year	Change km per person and year	Change % of own group's previous mileage	Change % of all respondents previous mileage
Bremen	**100%**	**6 900**	**-3 100**		**-45%**
"Increasers"	7%	1 300	+800	+60%	1%
"No change"	45%	5 500	-	-	-
"Decreasers"	48%	9 000	-6 600	-73%	-46%
Belgium	**100%**	**9 400**	**-3 000**		**-28%**
"Increasers"	7%	8 800	+1 200	+14%	1%
"No change"	65%	9 000	-	-	-
"Decreasers"	28%	15 500	-11 100	-72%	-29%

Car-sharing reduces car mileage by 3 000 km per member and year, which corresponds to 28-45% of previous mileage.

(Belgium 28% and Bremen 45%)

It should be mentioned here that the above calculations regarding mileage are dependent on respondents' memory, which of course can be a source of error. The results are however rather well corresponding to other studies of car-sharing (see table below). Those studies usually report around 30-50% reduction of mileage. In Bremen a reduction of 45% can be seen, which is higher than the study in Bremen preformed in 1998, but more similar to a study made in 2003 (which has not yet been published).

Table 2. Change in car usage since joining car-sharing, from previous studies.

Country/City	Change in mileage		Source
Netherlands	-33%	-2 700 km	Meijkamp, 2000
Switzerland	-36%	-1 500 km	Muheim, 1998
Bremen	-32%	-2 600 km	Koch, 1998
Bremen	-54%	-2 480 km	Koch, 2003 (not yet published)

Public transport usage

Before car-sharing has been introduced in a city, region or country, the relation between car-sharing and public transport can be strained. PT operators sometimes suspect that car-sharing is a competitor to public transport. When the relation between the modes has been studied more in detail, car-sharing is usually considered to benefit public transport. In this survey the total effect on public transport usage is on average +1 100 km/year for respondents both in Bremen and Belgium. This can be compared to Muheim (1998) who reports a 2000 km increase and Baum & Pesch (1994) who reports a 1500 km increase[3]. In the table below the changes in use of public transport is shown in total as well as separated in the groups increasers, decreasers and no change.

[3] Baum, H. Pesch., Stephan (1994). Untersuchung der Eignung von Car-Sharing im Hinblick auf die Reduzierung von Stadtverkehrsproblemen. Köln.

Table 3. Change in public transport usage for different groups since joining car-sharing (N_{Bremen}=291, $N_{Belgium}$=256)

	Share	**Change**
	of respondents	km per person and year
Bremen	**100%**	**+ 1 100**
"Increasers"	32%	+3 900
"No change"	63%	-
"Decreasers"	5%	-1 900
Belgium	**100%**	**+ 1 100**
"Increasers"	22%	+5 200
"No change"	73%	-
"Decreasers"	5%	-1 700

Car-sharing increases the use of public transport by 1 100 km per year and member.

Emission reduction

Change of emission volumes due to car-sharing can be derived from the following three aspects:

- Change in car mileage
- Change in vehicles used
- Change in public transport usage

This type of calculations is extremely difficult to make, but the estimates below are made to give an idea on what effects that can be expected.

The focus of the calculations is CO_2 emissions, based on reduction of fuel consumption. Changes of other pollutant emissions are more difficult to estimate, but it is clearly not lower than the reduction in CO_2 (see below for further discussion on this).

Change in car mileage

The average mileage reduction is calculated to 45% in Bremen and 28% in Belgium. It is reasonable to believe that this means a reduction in fuel consumption as well as CO_2 emissions by the same amount. Actually the effect is probably a little bit higher, since car-sharing tends to reduce the shorter trips more than longer trips – and shorter trips need more fuel and cause larger emissions per km due to cold start of the engine.

Change in vehicles used

Car-sharing in Bremen is over 10 years old, hence the respondents of the survey are partly car-sharers who got rid of their cars a long time ago which would make the calculations in this section less reliable and adequate. This section therefore focuses on the Belgium situation, but the case of Bremen should not be very different (which is also shown by other studies referred to below).

As stated above, car-sharing means that smaller and newer cars are used compared to the private cars they replace. Among the total fleet of cars, the share of medium sized cars is reduced by 40% (In Belgium from 54% to 15%, in Bremen from 70% to 30%).

The fuel consumption of car size is difficult to estimate since there is a large variety depending on brands and models as well as engine.[4] To be able to get some idea of the effects though, a very general estimate has been done in the table below.

Table 4. Estimated average fuel consumption for different car sizes and the share of different sizes among abolished cars and car-sharing cars.

Car size	Fuel consumption (l/100 km)	Share of abolished cars	Share of car-sharing cars
Micro	5,0	2 %	0 %
Small	6,0	45 %	85 %
Medium	7,0	30 %	15 %
Large	8,5	15 %	0 %
X-large	10,0	8 %	0 %

Average fuel consumption of the abolished cars regarding size is from the above estimations calculated to 7,0 l/100 km and car-sharing cars to 6,2 l/100 km, which means a reduction of 11%.

Regarding change due to abolished cars being older than the car-sharing fleet, a study from the EU is helpful. CO_2 emissions of new petrol cars within the EU have on average gone down 9% between 1995 and 2002.[5] Between 1985 and 1995 no improvement among new cars in Sweden could be observed,[6] and this is assumed to be valid for assessed countries too. During 2004 there have however been discussions about the validity of these calculated emissions, and the European Environmental Agency (EEA) claims that emissions are underestimated since "current test cycles do not reflect how engines are used in the real world".[7] The table below shows the shares of car age among the abolished cars and car-sharing cars, concluded with the estimated fuel efficiency improvements.

Table 5. Estimated fuel efficiency improvements depending on production year, and the share of production year among abolished cars and car-sharing cars.

Year of production	Share of abolished cars	Share of car-sharing cars	Fuel efficiency improvements until 2001
-1987	18 %	0 %	10%
1988-1995	45 %	0 %	10%
1996-2000	25 %	0 %	4%
2001-	12 %	100%	0%

Average improvements in fuel efficiency of car-sharing cars compared to the abolished cars only due to age of cars used are from the above estimations calculated to 7 %.

When the effects of size and age are multiplied the reduction in fuel consumption comes to 17%. This can be compared to a study by Muheim (1998) who estimated a reduction of 24%[8] and Meijkamp (2000) estimating the reduction to 14%.[9]

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4 According to VCA, fuel consumption among similar size cars can vary as much as 45% (www.vcacarfueldata.org.uk).

5 COMMUNICATION FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT. Implementing the Community Strategy to Reduce CO2 Emissions from Cars: Fourth annual report on the effectiveness of the strategy (Reporting year 2002). 2004.

6 Bilismen i Sverige 2004, Bil Sweden, 2004.

7 TERM 2004: Ten key transport and environment issues for policy-makers, European Environmental Agency (EEA), 2004.

8 Muheim, P. P. (1998). CarSharing - the key to combined mobility. Bern, Switzerland, Energie 2000, Bundesamt für Energie.

Regarding emissions other than CO_2 it is very risky business to estimate the reductions over the years. There are no good average figures available that are suitable for Germany as well as Belgium, and it can differ a lot between different cars. Swedish studies show decreases of 40-60% among all cars in Sweden between 1990 and 2000 regarding CO, HC and NO_x, and if looking at only new cars the reductions would probably be even higher. But due to the lack of good data and the extreme differences in such emissions depending on driving conditions and driving patterns, no specific calculations of emissions other than CO_2 is made here. However, the reduction of these substances is at least the size of the CO_2 reductions.

Change in public transport usage

Above it has been shown that use of public transport increases by 1100 km per year when joining car-sharing (same figure for both Belgium and Bremen). If this is done mostly during peek hours it might mean that extra buses and trams etc would need to be put in service, which in turn would generate extra emissions. If the increase takes place during off peak hours it is not likely it will cause any new traffic and thereby it will not generate any extra emissions – only increased revenues for public transport.

To get some kind of idea of the magnitude of this increase, the following data and very rough assumptions have been made:

- 50% of the increase in public transport is made during peak hours
- Average change in car mileage is -36%
- In terms of mileage, the public transport increase is 35% of the car reduction
- All public transport is made by diesel bus
- A bus emits 5 times the amount of CO_2 as an average car per vehicle km
- A bus has 15 times more passenger than the average car

These assumptions mean that increased use of CO_2 is about 2% of the previous emissions from car use (50% * 36% * 35% * 5 ÷ 15 = 2%).

Total estimate of emission change

The estimated total change in emissions is for Belgium about -40% and for Bremen over -50% (see table below).

Table 6. The estimated total change in emissions of CO_2

	Belgium	Bremen
Change in car mileage	- 28%	- 45%
Change in vehicles used	- 17%	- 17%*
Change in public transport usage	+ 2%	+ 2%
Total	- 39%	- 54%

** This figure is estimated from calculations from the Belgium case.*

Changes of other pollutant emissions are at least at the same levels as the CO_2 reductions, probably even a bit higher (see discussion under section “Change in vehicles used” above).

Car-sharing reduces transport CO_2 emissions by 40-50% (among its members).

Other pollutant emissions are estimated to decrease even more.

[9] Meijkamp, R. (2000). Changing Consumer Behaviour Through Eco-Efficient Services; an Empirical Study on Car Sharing in The Netherlands. Faculty of Industrial Design Engineering. Delft, Delft University of Technology.