Environmental Benefits of Car Sharing –

Case: City Car Club

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1. Executive Summary

The goal of this study is to estimate the relative reduction of private car pollution caused by people who start using City Car Club's (CCC) services in Helsinki area. The reduction percentage is calculated separately for each compound, e.g. CO_2 and SO_2.

The relative reduction turned out to consist of two major factors. The first factor is that according to previous studies people drive less when they start using car sharing services. The studies say that this reduction is around forty percent. The second factor is that newer cars, used by CCC, pollute less than average cars in Helsinki area.

The most significant results of this study is that when people start using CCC services the examined pollution compounds reduced approximately by 30 – 90 %. However, particles turned out to be an exceptional compound that did not reduce but on the contrary increased by more than hundred percent. This can be explained with the fact that the cars used by CCC are mostly run by diesel that causes more particle emission than petrol.

Finally, as a generalisation of these results, we approximated the relative reduction of the total pollution caused by private car driving in Helsinki area. The optimistic result was that other pollution compounds except particles could reduce by 2 – 5 %. Particle emissions were approximated to increase by six percent.

2. Table of Contents

3. Introduction

The objectives of this study is *to estimate the average relative reduction of private car pollution caused by City Car Club's* (later CCC) *customers* in the capital area (later Helsinki area) of Finland. The reduction is going to be calculated from the numeric material collected from different sources. The calculations are done for each types of pollution separately: CO_2, NO_x, SO_2, CO, HC, N_2O, CH_4 and particles.

We are going to study only the group of people that uses cars less than 12.000 km. This limit was chosen because according to CCC their services are economical only for people whose driving mileage is less than this limit. The fact that car sharing helps to reduce the number of vehicles required (and thus reduces the need of parking space) together with some other environmental influences, e.g. noise, are excluded from this study.

There were some problems faced during this study. The most significant problem was finding enough comparable data. Although the calculations seem to be a simple task, another major problem was the complexity of these calculations due to many factors that separate the calculated average reduction from the true reductions. These and other factors will be further discussed in the Chapter 7, Analysis.

One of the difficulties is that the ages of the cars that people used before CCC services are variable and difficult to find out. Because of that we calculated separately the pollution reductions for four different age groups of previously used cars. However one must keep in mind that these calculations are not accurate and they only give a reasonable range of magnitude of pollution reduction in CCC's case.

There are three reasons why this study was done. The first one is that the CCC doesn't have calculations or academic evidence for the pollution reduction. The second reason is that this study is a part of the Continuation Course in Environmental Management in the Helsinki University of Technology. The third reason for doing this study is that quite few public studies are done about pollution reduction caused by car sharing organisations.

In the next Chapter, Car Sharing, we are going to give a compact overview about certain topics relevant to car sharing. In Chapter Five, two major factors that lead to reduction of pollution are going to be discussed. The Calculations of pollution reduction are presented in Chapter Six. In Chapter Seven, we are discussing errors in the calculations and making analysis of the results. Generalisation of the results to wider perspective is discussed in Chapter Eight.

4. Car Sharing

4.1. What is car sharing?

Car sharing means the common use of vehicles by various users in succession and independent of each other. The duration and target of individual car trips is self-determined by the respective car users. If various persons make use of the same car *at the same time* (e.g. several people going to the same workplace in the same car) one speaks of car-pooling (Muheim 1996).

Organised car sharing started in the eighties. The pioneer countries in car sharing have been Austria, Germany, Netherlands and Switzerland. Today, about 70.000 people are members of a car sharing organisations in those four countries. Car sharing is also spreading to North America and rest of the Europe. Nevertheless, about ninety percent of the car sharers are in Central Europe.

4.2. City Car Club

CCC is a private profit-seeking car sharing organisation operating in Helsinki area. CCC was established in late 1999 and its operations in present form started in September 2001. It is the first car sharing organisation in Finland and has only indirect competitors e.g. car leasing companies and taxi services. The customers of CCC are both private persons and companies. CCC has more than fifty pick-up points for their cars in the Helsinki area.

The costs of using CCC's services consist of fixed monthly cost, usage time cost and driving mileage cost. The prices include the insurance, car service and maintenance. Before using the service the member has to make a reservation by phone or on the internet. After this the car can be unlocked with a mobile phone and a PIN-code. When finished usage the user locks the car by mobile phone. The technology used by CCC with car sharing is advanced in international comparison. (www.citycarclub.net)

4.3. Diffusion of car sharing

There are three types of factors that prevent or promote the diffusion of car sharing: sociocultural, infrastructure and economical. Sociocultural factors include status reasons to own a car, environmental awareness, bureaucracy of officials' etc. Status reasons could be one of the most significant preventive factors in car sharing diffusion.

Infrastructural factors are for example city (country) density, parking problems and public transport availability. Note that public transport promotes car sharing usage because it makes regular car usage unnecessary. Economical factors are e.g. cost of car ownership, structure of car ownership costs, prosperity, city (country) population and number of cars and driver's licenses.

As mentioned above, CCC uses high technology with its services. This leads to certain factors affecting diffusion of car sharing organisation like CCC. These factors are for example internet penetration, GSM coverage, mobile penetration, mobile lifestyle, etc. (City Car Club Internationalisation Process, Feasibility Study 2000)

4.4. Business opportunities in car sharing

Car sharing can be a viable business enterprise, in spite of its significant start-up expenses. Additionally, the financial returns of a car share organisation are quite sensitive to the scale of the enterprise. This is partly because the member-to-vehicle ratio is assumed to be higher in larger car sharing organisation. The ratio is estimated to be 7,5 : 1 with 150 members and 12,5 : 1 with 600 members. (www.metaresource.com/csbusplan.html)

A total of 4.804 (11.7%) out of 40.930 licensed drivers in Portland, are estimated to be very likely to join a car sharing organisation. The car sharing organisation's break even point is estimated to be in about 480 members using 43 vehicles. Time spent for the car sharing organisation on growing to scale of 600 members and 48 vehicles is estimated to be four years. In this scale the car sharing organisation is expected to have an operating income of around 48.000 US dollars. (www.metaresource.com/csbusplan.html)

5. Factors that change the amount of pollution

5.1. Change of driving mileage

When thinking of environmental benefits, one clear advantage of car sharing is the fact that people using shared cars are normally more sparing in their car use. They also make significantly more use of other, more sustainable means of transport like bicycling and public transportation. In short, car sharing supports a conscious car use. (Ecoplan, 2001; Britton, 2000)

Reasons for this change are quite simple: time and money. While using car sharing, former car-owners learn about the true costs of car driving. As all costs are included in driving fees, they slowly adapt to the driving costs by planning routes more carefully and trying to avoid cost-intensive car trips. Moreover, habitualised fixation for using an own car for every journey will not be dominant anymore. Car sharers are now forced to consciously decide about which means of transport to take. (Harms and Truffer, 1998)

Car, public transport and bicycling are suddenly equalised with respect to their availability. It gets attractive to test and more frequently make use of other means of transport as well. Car-sharer might learn that for some trips car is actually slower and more expensive option than for example public transportation. After learning about the strengths and weaknesses of each means of transport, car-sharers use the car only in cases where public transport does not hold anymore. This change can also be seen from Table 1. (Harms and Truffer, 1998; Klintman, 1998)

Means of transport	Without car sharing	With car sharing
Own car or car from friends, family etc.	60,5%	13,4%
Car sharing	-	24,9%
Car rental	2,9%	3,1%
Taxi	0,8%	1,3%
Public transport	35,8%	57,3%
TOTAL	100%	100%

Table 1. Change in modal split, % of annual kilometres (Baum & Pesch, 1994)

In consequence, after entering a car sharing organisation former car owners drive less than before. A study conducted in Switzerland showed that people who gave up their car as a result of joining car sharing organisation reduced their car travel by around 6,700 km (approximately 72%) per annum. This is partly compensated in travelling more by motorbike (+ 1,300 km p.a.), bicycle (+ 800 km p.a.) and above all by public transport (+ 2,000 km p.a.). (Britton 2000)

On the other hand, a study carried out in Austria showed 61,7% decrease of driving mileage for former car owners, but an enormous 117,9% increase of driving mileage for people who previously did not own a car. However, this is only due to fact that non-car owners simply used to drive so short distances (25,7 km/week compared to car owners 312,2 km/week), that even a small increase in mileage caused huge percentual increase. The total reduction of both groups in car mileage was still 46,8%. (Klintman 1998)

The study among the participants of four different car sharing schemes in Netherlands showed that their car mileage went down with 33% from 8450 to 5660 kilometres a year. A clear difference between the groups of non-car owners and owners was noted in this study as well. There emerged 29% reduction for the people who did not own car before and a 65% reduction for previous car owners (Britton 2000). In Germany, Baum and Pesch found out in 1994 that car sharers diminished their car use by 42,1% from 7000 km/year to 4050 km/year. (Klintman 1998)

Car sharing proves to be a system that opens ways to a more sustainable transport system. Former car owners continuously reduce their car use and make use of public transport more frequently, whereas former non-car owners keep their low level of individual mobility or rise it only marginally. It also seems that shares of these two car sharing groups are quite similar and standard: Britton presents two studies where shares for former car owners are 64% and 59% whereas a study from Austria gives for the share of car owners value 47,5%. (Britton 2000; Klintman 1998)

5.2. Newer cars pollute less

Basically all car sharing organisations are committed to use only new, ecological cars – City Car Club does not make an exception. Joining a car sharing organisation is normally much cheaper than buying a new vehicle. For people who cannot afford to buy a new car, car sharing offers thus an easy and cheap way to make use of newer cars.

New cars use latest technological innovations and are therefore more ecological and energy-efficient than older ones. For example VTT (Technical Research Centre of Finland) states that emission from a new car was 1.5 - 3.3 fold in 1975 compared with 1993 (cars without catalytic converters) and is forecast to be 0.5 - 0.8 fold in 2015 compared with 1993 models (equipped with catalytic converters). Newer cars and their engines are also in better condition, which means fewer emissions as well. (VTT: LIISA 2000)

To calculate how much less new cars actually pollute is not an easy task. Values of emissions that can be found from every new car model are obtained in laboratories through certain test process and are meant only for comparison with similarly obtained values. They are not equivalent to emission values in real driving conditions and cannot therefore be compared to actual emission values given by different measurement and calculation systems. This means that we were not able to use emission values for specific car models (Ford Focus, Ka and Galaxy) used by City Car Club.

In result, we decided to use emission values measured by VTT's LIISA 2000, road traffic exhaust emissions calculation software. LIISA offers accurate and up-to-date information on exhaust gas emissions of different municipalities and provinces of Finland. For more information on LIISA and the principles of its calculation software see the web page http://www.vtt.fi/rte/projects/lipastoe/index.htm.

The emission compounds calculated by LIISA include carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), particles (PM), methane (CH_4), nitrous oxide (N_2O), sulphur dioxide (SO_2), carbon dioxide (CO_2) and fuel consumption. The results are classified by vehicle and road type. The age of vehicle and the type of their engine (Table2) also classify passenger cars. Group no-cat (i.e. cars without catalytic converter) is the only one that does not include cars with any kind of catalytic converter. (VTT: LIISA 2000)

Name of the group	Year of manufacture
no-cat	Before 1989
Euro 1	1990 – 1995
Euro 2	1996 – 1999
Euro 3	2000 -

Table 2. Name of the passenger car groups and the years of manufacture.

After conversations with Kari Mäkelä and Juhani Laurikko from VTT we decided to use mean emission values. This means that we have made a general assumption that approximately 35% of driving for both car-sharers and other drivers take place in urban streets and 65% elsewhere. We decided to use this share of driving after realising that most of the private car sharers in City Car Club use cars also for longer, non-urban trips outside and inside Helsinki Area. Exact share between urban and non-urban car usage depends naturally from each and every user, but we believe that average value is somewhere quite close to presented one. For comparison, values for urban streets are presented in appendixes for Euro 1- and Average-groups as well. (VTT: LIISA 2000)

From Chapter 6 and appendixes can be found detailed values and calculations on different emission compounds for petrol and diesel cars as well as for the combined emission value (petrol & diesel). In the combined emission values the share of diesel cars varies between CCC and other groups. This is simply due the fact that in CCC most of the cars (at the moment 83%) are run by diesel, whereas in Helsinki area the share of diesel cars is much smaller, approximately 7,1% (Autoalan faktat 2001).

Since the average age of CCC's car is less than one year, values for CCC-group are based on Euro 3 –group. Main comparison is made between CCC-group and Euro 1-group. This results from the fact that in Helsinki area the average age of a car is approximately 8 years (Helsingin Sanomat, 4.3.1999), which puts it into Euro 1-group.

6. Calculations

6.1. Change of driving mileage

It is of course extremely difficult to estimate how much car sharers will decrease their driving mileage in Helsinki Area. Even so, some kind of estimation can be worked out based on the studies presented in Chapter 5.1 – easiest way is to calculate the average value. The table below shows percentual values for three different studies and presents the average value for decrease for car sharers in total.

Country	Decrease for car sharers in total	Decrease for previous non-car owners	Decrease for previous car owners
Austria	46,8%	-117,9%	61,7%
Netherlands	33%	29%	65%
Germany	42,1%	Not available	Not available
AVERAGE	40,6%	-	-

Table 2. Change of driving mileage in three case studies and their average.

Based on the calculated average value from the different studies we decided to use in our calculations an approximate value of 40% for the decrease of total driving mileage. It is obvious that the average figure doesn't give very accurate information about the reduction in driving mileage in Helsinki area. This is because the conditions in Helsinki area are probably very different from the conditions where the studies have been done.

6.2. Newer cars pollute less

Table 3 shows the decrease in percents between emission value of CCC-group and each emission value of other groups (no-cat, Euro 1, Euro 2, Euro 3, Average). Percentual values for Euro 1 are bolded since the main comparison is made between CCC- and Euro 1-groups.

	CO	HC	NO_x	PM	CH_4	N_2O	SO_2	CO_2
No-cat /combined	97 %	95 %	81 %	-45 %	96 %	-138 %	68 %	19 %
Euro 1 /combined	**85 %**	**74 %**	**-10 %**	**-279 %**	**88 %**	**65 %**	**66 %**	**12 %**
Euro 2 /combined	66 %	68 %	-95 %	-355 %	83 %	56 %	65 %	11 %
Euro 3 /combined	58 %	54 %	-263 %	-455 %	76 %	42 %	65 %	10 %
Average /combined	94 %	90 %	62 %	-138 %	93 %	38 %	67 %	15 %

Table 3. Comparison of mean emission values between CCC- and other groups.

Presented combined emission values (=petrol & diesel) were calculated by multiplying emission values of diesel cars by specific diesel-coefficient and emission values of petrol cars by petrol-coefficient. After this these two values were summed up. Since share of diesel cars in CCC is 83%, diesel-coefficient for CCC is 0,83 and petrol-coefficient 0,17. Correspondingly, since share of diesel cars for other groups (i.e. in Helsinki area) is approximately 7,1%, diesel-coefficient for other groups is 0,071 and petrol-coefficient 0,929.

Table for comparison of mean emission values shows the decrease in percents between combined emission value of CCC-group and each emission value of other groups. For example value 85% indicates that the combined emission value of CCC-group is 85% smaller than the emission value in question. On the other hand, negative value -279% indicates 279% growth i.e. the combined emission value of CCC-group is almost fourfold compared to the emission value in question.

Comparison values were calculated by dividing the emission value of CCC-group by corresponding emission value of the group in question and subtracting this result from numerical value 1 (equals 100%). The result in percents is then obtained by simply multiplying the result by 100. For more specific information on different values and their calculations see the appendixes.

The values of emission reduction percentage (ERP) for different emission compounds between CCC-group and other groups (no-cat, Euro 1, Euro 2, Euro 3, Average) can thus be obtained from equation

$$ERP = 1 - \frac{x_p \cdot k_p^{ccc} + x_d \cdot k_d^{ccc}}{y_p \cdot k_p + y_d \cdot k_d},$$

where k_p^{ccc} indicates petrol-coefficient of CCC-group, k_d^{ccc} diesel-coefficient of CCC-group, k_p petrol-coefficient of other group in question, k_d diesel-coefficient of other group, x_p emission value of petrol cars for CCC-group (Euro 3), x_d emission value of diesel cars for CCC-group (Euro 3), y_p emission value of petrol cars for other group and y_d emission value of diesel cars for other group.

6.3. Total reduction of emissions

In this chapter we combine earlier presented two main factors having an effect on emission reduction of car sharing. Multiplying the emission values of CCC-group does this. Value 0,6 results from the reduction effect that car sharing has to the car usage: in Chapter 6.1 we calculated that car sharing on average reduces car usage by 40%. These new values for CCC (Final CCC -values) are then used in exactly same kind of comparison than in Table 3.

Therefore, Table 4 shows the decrease in percents between final emission value of CCC-group and each emission value of other groups (no-cat, Euro 1, Euro 2, Euro 3, Average). Since the main comparison is made between Final CCC- and Euro 1-groups, percentual values for Euro 1 are again bolded. In other respects calculations are similar to the ones calculated for Table 3, so more precise information on calculations can be found from Chapter 6.2 and appendixes.

	CO	HC	NO_x	PM	CH_4	N_2O	SO_2	CO_2
No-cat /combined	98 %	97 %	89 %	13 %	97 %	-43 %	81 %	51 %
Euro 1 /combined	**91 %**	**84 %**	**34 %**	**-127 %**	**93 %**	**79 %**	**79 %**	**47 %**
Euro 2 /combined	79 %	81 %	-17 %	-173 %	90 %	74 %	79 %	46 %
Euro 3 /combined	75 %	72 %	-118 %	-233 %	86 %	65 %	79 %	46 %
Average /combined	96 %	94 %	77 %	-43 %	96 %	63 %	80 %	49 %

Table 4. Final comparison of mean emission values between Final CCC- and other groups.

The values of emission reduction percentage (ERP) for different emission compounds between final CCC-group and other groups (no-cat, Euro 1, Euro 2, Euro 3, Average) can this time be obtained from equation

$$ERP = 1 - p \cdot \frac{x_p \cdot k_p^{ccc} + x_d \cdot k_d^{ccc}}{y_p \cdot k_p + y_d \cdot k_d},$$

where p indicates a coefficient of reduction effect for driving mileage (i.e. 0,6), k_p^{ccc} petrol-coefficient of CCC-group, k_d^{ccc} diesel-coefficient of CCC-group, k_p petrol-coefficient of other group in question, k_d diesel-coefficient of other group, x_p emission value of petrol cars for CCC-group (Euro 3), x_d emission value of diesel cars for CCC-group (Euro 3), y_p emission value of petrol cars for other group and y_d emission value of diesel cars for other group.

7. Analysis

One thing that has an influence to the emission reduction is the clear difference on share of diesel cars. Whereas most of the CCC-cars (~83%) are run by diesel in Helsinki Area the share of diesel cars is only 7,1%. This difference can also be seen in the values of different emission compounds. Although total environmental impacts for newest diesel and petrol cars are said to be quite similar, there do exist differences in different pollution compound groups. In most of these groups emissions of diesel cars are smaller. The only exception is particles (PM), where diesel cars are far more polluting. Therefore, it might be possible that the large share of diesel cars in CCC corrupt the results in some ways. It must also be kept in mind that the number of cars in CCC is small: at the moment they have 18 passenger cars, out of which 16 are diesel cars. However, this study is based on the assumption that the share of CCC's diesel cars will stay approximately same in the future as well.

As can be seen from Chapter 6.2, a quite remarkable part of emission reductions is only due to the fact that newer cars are more ecological and cleaner. Actual emission reduction has therefore a clear connection to the age of the car that car sharing replaces. Predominantly most of the CO, HC, CH_4, N_2O and SO_2 emission reductions are caused by the facts that newer cars pollute less and diesel cars pollute less these specific compounds. On the other hand, most of the CO_2 and all of the NO_x emission reductions are due to change in driving mileage. As a conclusion of all this can be said that using CCC services is an economical way to replace the previously used old car with a new one, assuming that the total mileage is less than 12.000 km/a. This replacement leads to significant reduction of pollution, as calculated in Chapter Six.

It is also good to point out that we did not calculate the possible emission growth caused by increased public transportation since we did not regard it that significant to this study. However, if the scale and share of car sharing would grow significantly, public transport would of course have some impacts as well. In the final results we assumed that an average car sharer would use Euro 1-type of car since the average age of car is eight years in Helsinki area. It is still possible that the companies who use CCC services would use newer than Euro 1 type cars if they did not use the CCC services. This could mean that the results of reduction percentages in this study are exaggerated.

8. Generalisation to larger scale

The relative pollution reductions calculated above concerns only the group of people who start using CCC services. This does not give direct information about the relative pollution reduction in the scale of all private car pollution in Helsinki area or in the whole nation of Finland. The generalisation is discussed and an approximation is presented below.

According to research by Karimo and Tarkkala, a justified goal for car sharing usage is ten percent of the households in Helsinki area. If this would be the case, the total private car pollution would be reduced significantly less than ten percent from the reduction percentage calculated in Table 4.

This is a consequence from the fact that people using CCC-services represent those who did not own a car before and those who owned a car but used to drive significantly less than an average car-driver. A harsh and optimistic approximation for the share of the car sharers' original total pollution could then be half of the presented ten percent, i.e. five percent. This leads to that private car pollution reductions in Helsinki area, due to operations of CCC, could be of following magnitude:

	CO	HC	NO_x	PM	CH_4	N_2O	SO_2	CO_2
Helsinki area	5 %	4 %	2 %	-6 %	5 %	4 %	4 %	2 %

Table 5. An approximation for relative total pollution reduction of private car driving in Helsinki area

Values in Table 5 are obtained from the combined total reduction of pollution in Euro 1-class that best represents cars in Helsinki area. These figures are multiplied by 0,05 that represents the portion of car sharers' pollution from all private car pollution in Helsinki area.

If we think in terms of the whole nation of Finland the relative reduction goal should be divided at least by two. This is because Karimo and Tarkkala's goal of ten percent cannot directly be generalised to whole Finland. One reason for this is that the density of population is clearly higher in Helsinki area than in the rest of Finland. In conclusion the relative reduction of private car pollution can be roughly approximated to be the figures in Table 5 divided by two. Note that these approximations are optimistic and many assumptions had to be made to approximate these figures.

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10. Appendix

Appendix 1: Mean emission values, excel sheet

Appendix 2: Comparisons of mean emission values, excel sheet

Appendix 3: Final mean emission values, excel sheet

Appendix 4: Final comparisons of mean emission values, excel sheet

Appendix 5: Emission values for urban streets, excel sheet