Changes in the mobility pattern of households due to the introduction of electric vehicles

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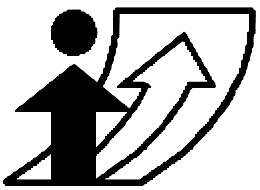

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Title

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Abstract

The introduction of new vehicles may change the households' mobility pattern in undesired ways, e.g. in increased mobility or in displacement of environment-friendly modes. In this investigation the influence of electric vehicles (four-wheelers and two-wheelers) on Swiss households was analysed. The findings of this study are discussed. All in all, lightweight electric vehicles (LEVs) can cover a substantial part of daily mobility. They do not generate additional mobility at the level of private motorised travel though most of them were purchased as additional vehicles. %. Considering the level of households the fuel consumption and air quality emissions could be reduced by about 5 % due to the introduction of an electric two wheeler. The effects of the electric four-wheelers were more meaningful: In the Italian speaking part of Switzerland emissions could be reduced by 30%, fuel consumption by 20%. In the German speaking part this effects were much smaller maybe because of the lower level of car mobility.

Keywords

Mobility behaviour, lightweight electric vehicles (LEVs), electric vehicles, E-Bike, E-Scooter, International Conference on Travel Behaviour Research, IATBR

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1. Introduction

Changing the mobility patterns of households towards sustainability is a key issue of transport policy in most countries. One means to achieve this goal is to introduce less polluting vehicles, for example lightweight electric vehicles (LEV). In Switzerland such "clean" vehicles have been promoted in several programs during the last decade.[1] Yet the effects of such a policy are not always indisputable since these vehicles might increase the overall level of mobility or replace non-motorised mobility which would both be undesired effects. The purpose of this research is to assess the ways in which LEVs influence mobility behaviour, i.e. by recording and analysing changes in the mobility behaviour of the LEV users. These changes are important as a basis for research into the environmental impact of LEVs. Particular attention has been paid to the following two questions:

- Whether or not LEVs result in increased mobility,
- Whether or not LEVs result in a displacement of means of transport at the expense of environment-friendly types (public transport, bicycle, walking).

The study draws a distinction between two kinds of LEVs: three- or four-wheelers (e.g. Twike and "normal" cars) and two wheelers (E-Bikes and E-Scooters).[2]

The mobility pattern of the drivers of electric three- or four-wheelers was part of the research in the framework of the large-scale fleet test in Mendrisio 1995-2001.[3] The mobility pattern of the drivers of electric two-wheelers was investigated in the framework of E-TOUR (Electric Two-Wheelers on Urban Road, a project within the 5th Framework Programme of the EU).[4]

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1 For example the large-scale fleet test of LEVs in Mendrisio and the partner communes 1995-2001, the follow-up VEL2, the Basle program "Die bessere Mobilität" (the better mobility) 2001 with subsidies for 400 E-Bikes, or the Swiss Program NewRide.

2 For information on the present situation of LEVs in Switzerland see: www.newride.ch, or www.vel2.ch.

3 Abay&Meier, Interface, University of Bern (2003), Auswirkungen der 3- und 4-rädrigen LEM auf das Mobilitätsverhalten, Schlussbericht im Rahmen der Begleituntersuchungen zum Grossversuch mit Leicht-Elektromobilen (LEM) in Mendrisio, Hrsg.: BUWAL, Bern.

4 University of Bern, Interface, Abay&Meier, Urs Schwegler Büro für Verkehrsplanung, (2003), Auswirkungen elektrischer Zweiräder auf das Mobilitätsverhalten. Schlussbericht des Schweizer Projekts im Rahmen von: Electric Two-Wheelers On Urban Roads (E-TOUR, 5. Eu-Rahmenprogramm), Bern.

2. Methods

Changes in the mobility pattern of households due to the introduction of new vehicles haven't been analysed in depth in Europe.[5] One reason might be that panel studies and longitudinal sections are considered as costly and challenging. Simultaneously the importance of such studies for transport policy made-to-measure is stressed in literature. (Zumkeller/Chlond 1995, Schlich/König/Axhausen 2000).

This investigation focuses specifically on two parameters: a survey of kilometres travelled that provides information on changes in mileage for all vehicles in the household. The mobility logbook allows statements on the number of trips, their length and duration as well as their purpose and the means of transport chosen by the persons who most frequently use the LEV. Thus, the logbook represents the mobility behaviour of individuals, not of households, whereas the survey of the mileage reflects the household level. The accompanying interviews were expected among other things to provide additional information and give the interviewer possibility to verify the results of the mobility logbook and the mileage survey.

The following methods have been applied, each of them in two stages: stage 1 before the delivery of the vehicle, stage 2 one year after the purchase of the vehicle:

Mobility logbook 1

The participants were asked to note on four sample days (two working days, one Saturday and one Sunday) all journeys *before* the vehicle was delivered in a mobility logbook.[6]

Questions concerning mileage 1

The participants were asked to note the mileage of all conventional vehicles in the household at various earlier periods (e.g. from the service book, exhaust gas control documents).

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5 The results of US studies (for example: Golob/Bunch/Brownstone 1997) cannot be transferred to the very different circumstances in Switzerland. The study of Truffer/Harms,Wächter (2000) does not focus on mobility behaviour.

6 A longer period couldn't be realised for several reasons (see Schlich 2001).

One-to-one personal interviews 1

A one-to-one personal telephone interview with the main driver lasting 15 - 25 minutes was used to analyse the mobility logbook and the distances travelled in the household. Information was obtained concerning their usual mobility behaviour (differentiated in terms of summer/winter, and the purpose of journeys). Furthermore they were asked for the planned use of the new vehicle.

Mobility logbook 2

Test participant filled in the logbook a second time, about one year after their purchase of the new vehicle.

Questions concerning mileage 2

About one year after the purchase the test participants checked the mileage on the odometer of their conventional vehicles as well as of the electric vehicles.

One-to-one personal interviews 2

Changes in mobility behaviour (obtained through direct comparison of the two logbooks and indirectly from comparison of the two questionnaires) were discussed in this interview. These changes may also be attributed to external influences (e.g. change of workplace, etc., see also below). In this second control interview lasting 25 – 40 minutes an effort was made to identify these external factors.

Special attention was paid to changes of external factors (such as for example a change of job that entails a longer way to work or the daughter of a LEV-driver obtains her driving test and uses her father's conventional car) that might have a major impact on mobility behaviour. For example journeys to work and the means of transport used could change considerably. These effects may distort the outcome of the LEV and therefore have to be taken into consideration. Two samples were created: "All persons/households" and "All persons/households without (significant) changes in the external factors".[7]

[7] External factors can differ regarding the two parts of the investigation: mobility logbook (individual level) and mileage of all vehicles in the household (household level).

To isolate the external effects the concepts of „stated“ (hypothetical behaviour) and „revealed“ (actual) behaviour were introduced. (Polak/Jones 1997, Stopher 1998).[8] Questions concerning the hypothetical behaviour were part of the interview one year after the purchase of the LEV. Figure 1 shows an overview of methods, samples and level of comparison.

Figure 1 Methods, samples and level of comparison.

Methods	**Samples**	**Level of comparison**
mileage of all vehicles in the household (household level)	all households	before-after
	households without changes of external factors	before-after
Mobility logbook (individual level)	all households	before-after
		stated-revealed
	households without changes of external factors	before-after
		stated-revealed

3. Data

3.1 Sample description

Since it is well known that mobility behaviour in the German respectively Italian speaking part of Switzerland differs systematically,[9] all the samples were split in two sub-samples: Italian speaking and German speaking sample.

All the main LEV-drivers in this area were invited to join the investigation. Therefore it is a census. Of course not all the drivers followed this invitation (especially with regard to the second part, one year after the purchase).[10] Figure 2 shows that 675 two wheelers and 114 three or four wheelers were recorded in the investigation. For a substantial part of these vehi-

8 This approach should not be confused with a stated-preference-approach.

9 Car dependence is much higher in the Italian speaking part of Switzerland. The common explanation for this difference is a mixture of cultural and topographical reason.

10 There was no financial incentive. Only the two-wheelers were equipped with an odometer by the programme E-TOUR.

cles not all the data could be collected. Because of this fact and due to the necessity of creating/forming many sub-samples the size of some sample became very small (see figure 3). Samples with less than 10 test persons were not analysed.

Figure 2: Vehicles recorded

	Italian speaking	German speaking	Total
3 / 4-wheelers	81	33	**114**
2-wheelers	146	529	**675**

Figure 3 Sub-Sample size

Mileage of households

LEV	Italian speaking Sample				German speaking Sample			
	total	*external factors changed?*			*total*	*external factors changed?*		
		Yes	No	not specified		Yes	No	not specified
E-Bikes	5	0	4	1	118	62	33	0
E-Scooter	34	17	17	0	22	16	6	0
3-wheelers	9	3	6	0	21	6	0	15
4-wheelers	43	20	22	1	12	1	0	11

* 23 households without cars

Mobility logbook

LEV	Italian speaking Sample				German speaking Sample			
	total	*external factors changed?*			*total*[11]	*external factors changed?*		
		Yes	No	not specified		Yes	No	not specified
E-Bikes	20	4	16	0	119	64	55	0
E-Scooter	31	11	20	0	22	10	12	0
3 -wheelers	10	1	9	0	4	4	0	0
4-wheelers	53	23	30	0	1	1	0	0

[11] Only persons who took part in both parts of the investigation (before-after).

3.2 Socio-economic features, characteristics

The typical LEV owner is a male with a full time job, between 24 and 44 years old and lives in households bigger than the average Swiss population (see figure 4). There are some striking differences between the owner of two and three- /four-wheelers: Drivers of two-wheelers are often older than the average LEV owner and they are also more often female. In addition, in the German part of Switzerland only every fifth of them is full time working.

The use of public transport and the number of cars per household differs according to a typical pattern in the Italian respectively German part of Switzerland.

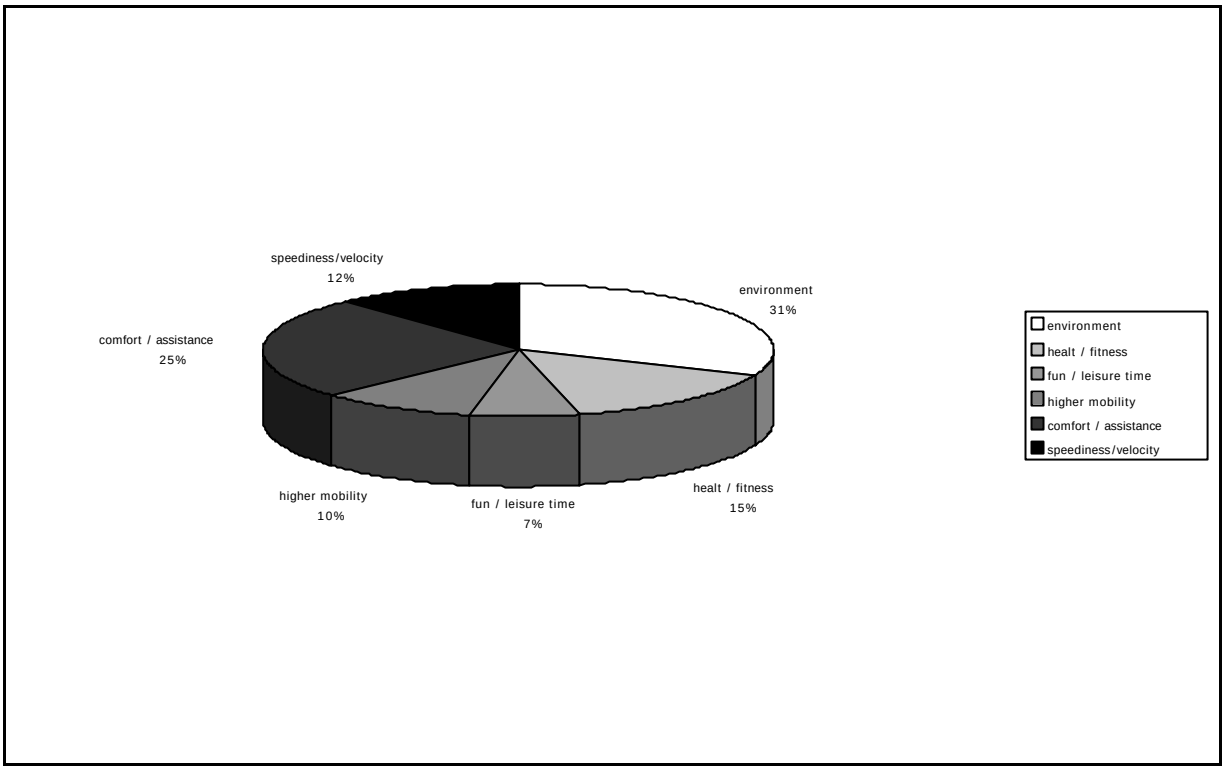
Figure 4: Socio-economic features of LEV owners in the Italian and German parts of Switzerland compared to the average of the Swiss population.

Features	*owners of electric three or four wheelers in the Italian part N=81*	*owners of electric two wheelers in the Italian part N=146*	*owners of electric two wheelers in the German part N=529*	*Average Swiss Population*
Men	74%	62%	65%	49%
Age 25 – 44	61%	39%	50%	32%
Full time working	68%	60%	18%	46%
Drivers license	97%	84%	75%	76%
Owner of public transport season ticket	26%	29%	76%	49%
1-2 persons household	26%	35%	50%	64%
Cars per household	1.3	1.6	1.2	0.8

Source: ARGE Abay & Meier / Polyquest AG, unter Mitarbeit der IKAÖ der Universität Bern: LEM-Nachfrage, Besitzertypologie und Einsatzbereiche. In: AssoVEL (Hrsg.), VEL Mendrisio 1995-2001. Mendrisio, 2001 (CD-ROM) and own data.

According to the personal interviews the motives to buy a LEV were analysed. It became very clear, that though ecological concerns were the most important motive buyers mentioned additional advantages like comfort, fitness or speediness/velocity (see figure 5).

Figure 5: Motives for the purchase of two-wheelers (German speaking part of Switzerland)



4. Results

4.1 Mileage of private motorised travel

The results can be characterised as follows (see figures 6 an 7):

- LEV could cover a substantial part of the households' mobility: Four-wheelers cover about one third of total mileage, E-Scooter one sixth and E-Bikes about one tenth.
- Mileage of four-wheelers was much higher than the mileage of two-wheelers.
- Considering all two-wheelers and the four-wheeler households in the Italian speaking parts, a slight increase in the total mileage after the purchase of the LEV was noted. The increase was bigger for four-wheelers in the German speaking Switzerland, though from a much lower level than in the Italian speaking part. There was a slight decrease in total mileage in households without reported changes of the external conditions. The German sample of the E-Bikes was distorted by three outliers. All in all, LEV did not generate additional mobility at the level of private motorised travel though most of them were purchased as additional vehicles.
- Mileage with conventional vehicles decreased.
- The variability of the results was high.

Figure 6 Mileage with the LEV

	Italian Speaking Switzerland (IS)	*German Speaking Switzerland (GS)*
E-Bike	1‘900*	1‘800
E-Scooter		2’540
4-Wheelers**	9‘700	5‘300

* E-Scooters included, **3-Wheelers included.

Figure 7 Changes in mileage 1 year after the purchase of the vehicle (* 3-Wheelers included)

LEM-category and region	*all households*		*households with external factors changed*	
	conventional vehicles	*conventional vehicles + LEV*	*conventional vehicles*	*conventional vehicles + LEV*
E-Bike GS	-5.2%[12]	6.6%[13]	0.7%[14]	11.3%[15]
E-Scooter GS	-6.8%[16]	8.6%[17]	-11%	-3.4%
E-Bike/E-Scooter IS	-6.0%[18]	2.9%[19]	-12.2%	-1.8%
4-wheelers IS*	-30.3%[20]	7.0%[21]	-29.8%	-5.6%
4-wheelers GS*	-14.4%[22]	27.9%[23]	-	-

[12] Before: mean of mileage: 12876 km/y, Min. 480 km/y, Max. 40000 km/y, StdDev. 8310 km; After: mean of mileage: 12214 km/y, Min. 492 km/y, Max. 33250 km/y, StdDev. 7459 km. P-value two tailed 0.23.

[13] Before: mean of mileage: 12876 km/y, Min. 480 km/y, Max. 40000 km/y, StdDev. 8310 km. After: mean of mileage: 14019 km/y, Min. 1900 km/y, Max. 35280 km/y, StdDev. 7708 km. P-value two tailed 0.04.

[14] Before: mean of mileage: 12034 km/y, Min. 480 km/y, Max. 40656 km/y, StdDev. 3168 km. After: mean of mileage: 12119 km/y, Min.497 km/y, Max. 34230 km/y, StdDev. 8753 km; P-value two tailed 0.94.

[15] Before: mean of mileage: 12034 km/y, Min. 480 km/y, Max. 40656 km/y, StdDev. 3168 km. After: mean of mileage: 13661 km/y, Min. 1896 km/y, Max. 35700 km/y, StdDev. 8947 km; P-value two tailed 0.18.

[16] Before: mean of mileage: 13440 km/J, Min. 1560 km/J, Max. 27000 km/J, StdAbw. 7247 km.; After: mean of mileage: 12528 km/J, Min. 600 km/J, Max. 25200 km/J, StdAbw. 6659 km P-value two tailed 0.3.

[17] Before: mean of mileage: 13440 km/J, Min. 1560 km/J, Max.27000 km/J, StdAbw. 7247 km; After: mean of mileage: 15071 km/J, Min.1600 km/J, Max. 28800 km/J, StdAbw. 6773 km; P-value two tailed 0.1.

[18] Before: mean of mileage: 21'703 km/y, Min. 5'292 km/y, Max. 41'652 km/y, StdDev. 8'432 km. After: mean of mileage: 20'393 km/y, Min. 5'268 km/y, Max. 58'020 km/y, StdDev. 10'572 km. P-value two tailed 0,27.

[19] Before: mean of mileage: 21'703 km/y, Min. 5'292 km/y, Max. 41'652 km/y, StdDev. 8'432 km. After: mean of mileage: 22'337 km/y, Min. 6'012 km/y, Max. 64'248 km/y, StdDev. 10'948 km. P-value two tailed 0,59.

[20] Before: mean of mileage: 26'101 km/y, Min. 9'473 km/y, Max. 60'036 km/y, StdDev. 10'971 km. After: mean of mileage: 18'198 km/y, Min. 0 km Max. 44'005 km/y, StdDev. 9'947 km. P-value two tailed 4.61×10^{-8}.

[21] Before: mean of mileage: 26'101 km/y, Min. 9'473 km/y, Max. 60'036 km/y, StdDev. 10'971 km. After: mean of mileage: 27'928 km/y, Min. 10'940 km/y, Max. 58'345 km/y, StdDev. 10'099 km. P-value two tailed0.13

[22] Before: mean of mileage: 12’520 km/y, Min. 1’380 km/y, Max. 21'180 km/y, StdDev. 5150 km. After: mean of mileage: 10’720 km/y, Min. 705 km/y, Max. 20’400 km/y, StdDev. 5’078 km. P-value two tailed 0.03.

4.2 Mobility logbook[24]

4.2.1 General mobility behaviour of the main LEV driver

In accordance with the typical differences between the two regions, LEV-drivers in the Italian speaking part of Switzerland relied much more on the car and much less on public transport than their colleagues in the German speaking part (see figures 8 and 9).

Figure 8: LEV-User: Modal Split (km/Person) in %, 1 year after the purchase, workday, all households

	E-Bike IS	*E-Bike GS*	*E-Scooter IS*	*E-Scooter GS*	*4- wheeler IS*
LEV	13.8	37.9	18.5	29.5	58.5
Car, Motorbike	82.5	28.1	35.5	10.3	28.7
Foot, Bike	2.8	4.4	8.8	3.9	1.1
Public Transport	0.9	29.6	37.3	56.3	10.0

Figure 9: LEV-User: Modal Split (Km/Person) in %, 1 year after the purchase, weekend, all households

	E-Bike IS	*E-Bike GS*	*E-Scooter IS*	*E-Scooter GS*	*4- wheeler IS*
LEV	4.9	15.3	6.7	33.7	50.8
Car, Motorbike	69.2	50.2	54.9	17.8	5.3
Foot, Bike	1.9	9.5	3.6	4.5	43.6
Public Transport	24.0	25.1	34.5	44.0	0

[23] Before: mean of mileage: 12’520 km/y, Min. 1’380 km/y, Max. 21'180 km/y, StdDev. 5150 km. After: mean of mileage: 16’020 km/y, Min. 5520 km/y, Max. 25’480 km/y, StdDev. 5’890 km. P-value two tailed 0.001.

[24] Because of the small sample, data from four wheelers in the German part of Switzerland have not been analysed.

4.2.2 LEV use

LEVs are commuter vehicles. Two-wheelers in the German speaking part (GS) and four-wheelers in Italian speaking part (IS) were used almost daily on workdays and less often but still regularly on weekends (see figure 10). In contrast, two-wheelers in the Italian speaking part were used less frequently which reflects the fact, that there many users had been less satisfied with their vehicles than drivers in the GS. This could be the result of very high financial incentives in the last phase of the "Large scale fleet test with LEV" which seduced people to buy LEVs without really needing them.

Figure 10: LEV-Use: Travel time in km and distance in minutes 1 year after the purchase, workdays and weekend, all households

	E-Bike IS	*E-Bike GS*	*E-Scooter IS*	*E-Scooter GS*	*4-wheeler IS*
Workday					
LEV-Use	55%	86%	65%	86%	85%
Time	20	46	21	33	54
Distance	3.1	11	7.8	14	29.3
Weekend					
LEV-Use	50%	62%	39%	67%	77%
Time	15	19	30	13	34
Distance	2.7	4.4	3.3	4.8	20.7

4.2.3 Replacement of trips by the main driver

Four-wheelers almost exclusively replaced car trips (see figures 11 and 12). Nearly all the trips shorter than 20km were covered with the LEV. This is an important fact because of the emissions (cold start and CO_2). There is no big difference between workday and weekends.

Two-wheelers replaced trips of all means of transport. E-Bikes replaced in the German speaking part on workdays between 3 to 4.5 km. This means that a substantial part (86% of mileage) of the bike trips was replaced whereas only 28% (mileage) of the car trips were substituted by the E-Bike. On the weekend E-Bikes replaced mainly bike trips. E-Scooters replaced much more car trips than E-Bikes, for example 8.3 km on workdays in the German speaking part of Switzerland (63% of mileage of all car trips). As already mentioned, two-wheelers were used less often in the Italian speaking part .

Figure 11: Comparison stated-revealed (km), workdays, all households

	E-Bike IS	*E-Bike GS*	*E-Scooter IS*	*E-Scooter GS*	*4-wheeler IS*
Car	-1.6	-3.1	-3.5	-8.3	-28.7
Motorbike	not used	not used	-2.4	not used	-0.6
Foot, Bike	-1.4	-4.5	-1	-2	not used
Public Transport	not used	-3	-0.8	-3.5	not used

Figure 12: Comparison stated-revealed (km), weekend, all households

	E-Bike IS	*E-Bike GS*	*E-Scooter IS*	*E-Scooter GS*	*4-wheeler IS*
Car	-0.8	-0.8	2	-2.2	-20
Motorbike	not used	not used	-1.1	not used	-0.3
Foot, Bike	-1.3	-2.8	-0.2	-2.0	0
Public Transport	not used	-0.4	not used	-3.5	not used

4.3 Environmental Effects

In the framework of the „Large scale fleet test with LEVs in Mendrisio“ environmental effects of the LEV have been calculated, based on the mileage of the private motorised vehicles in the household.[25] In this account at hand the same method was applied.[26] Public transport and bikes were neglected since these data were unknown. Yet it is highly probable that this did not seriously distort the results because fuel consumption and emissions are to a high degree determine by car use. Emission factors and fuel consumption follow the „Handbuch Emissionsfaktoren“ (handbook of Emission Factors) of the “Swiss Agency for the Environ-

[25] ARGE Abay & Meier / Polyquest AG (2001) Verbrauchsmessungen im Alltag und Umweltauswirkungen, in: AssoVEL (Hrsg.), *VEL Mendrisio 1995-2001*, Mendrisio, (CD-ROM).

[26] Account of the emissions during the operation of the LEVs – without analysing the production of the LEV and the power generation.

ment. Forests and Landscape“ (SAEFL).[27] The energy use of the LEV was measured „in the field“ during the „Fleet test“.[28]

The introduction of two-wheelers in the household brought a reduction of fuel consumption and emissions of about 5% (see figure 13). The effects of four-wheelers were more meaningful: In the Italian speaking part emissions could be reduced by 30%, fuel consumption by 20%. In the GS this effects were much smaller maybe because of the lower level of car mobility.

Figure 13: Changes in energy use and emissions after the purchase of the LEV, all households

	Mileage of private motorised vehicles	*fuel consumption*	*CO_2-emissions*	*NO_x-emissions*	*PM10-emissions*
E-Bike GS	+2.9%	-4.9%	-5.6%	-5.6%	-5.3%
E-Scooter GS	+8.6%	-4.5%	-5.8%	-5.8%	-5.3%
E-Bike/E-Scooter IS	+6.6%	-4.5%	-4.3%	-4.3%	-3.8%
4-Wheelers IS*	+7.0%	-20.2%	-30.3%	-30.3%	-30.3%
4-Wheelers GS*	+28.0%	-6.2%	-14.4%	-14.4%	-14.4%

*3-Wheelers included.

5. Interpretation of Results

5.1 LEV use

In both regions of Switzerland LEVs were mainly additional vehicles. They covered a substantial part of daily mobility, primarily as commuter vehicles. People bought the LEV to

[27] UBA und BUWAL (1999), *Handbuch Emissionsfaktoren des Strassenverkehrs* (Version 1.2/Januar 1999), Bern.

[28] ARGE Abay & Meier / Polyquest AG (2001) Verbrauchsmessungen im Alltag und Umweltauswirkungen. In: AssoVEL (Hrsg.), *VEL Mendrisio 1995-2001*. Mendrisio, (CD-ROM).

handle their mobility more environmental friendly compared to the car and more flexible and faster compared to public transport and bikes. Obviously people did not want to *reduce* their mobility but to chose more freely the currently most convenient means of transport. This fits with the thesis of Wilke (2002) that postulates a declining importance of routines in mode choice. Following Rölle/Weber/Bamberg (2002) who analysed the role of residential change, LEVs may initiate changes in people's personal mobility concept.

5.2 Increased mobility because of LEV?

Ecologists have argued that LEVs could stimulate additional traffic. The results at the level of households do not confirm these concerns for both region and both two-wheelers an four-wheelers. In contrast, mileage of households without reported changes of external conditions slightly declined and the sample "all households" shows only a small increase of mileage. Besides, these data do not include - as already mentioned - public transport and bikes. Since LEVs (especially two-wheelers) replaced trips of these means of transport as well, the total decrease might have possibly been higher. These results qualify the thesis which postulates, that additional vehicles go along with more kilometres travelled. After the year's survey some household showed a considerable growth of kilometres travelled. It is striking that this growth very often couldn't be explained during the interviews.

5.3 Conclusions

Considering the effects on the households' mobility behaviour the results justify the promotion of LEV. In addition to the environmental effects, E-Bikes have positive effects on land use and health.

The promotion of LEVs should focus on heavily motorised households.

Important questions remain unanswered, though. For example the long-term effects could differ from the effects only one year after the purchase. Furthermore, the life cycle of the LEVs is only partially known. And last but not least the user groups covered by the study - innovators and early adopters in the terms of Rogers (1995) – may show a different behaviour than groups occurring later in the innovation process. Further research should answer these questions and consolidate the present data.

The politically most important question referring to the market potential of LEV was not in the focus of the study. It seems obvious though, that the political framework will determine this potential to a large degree.

6. References

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