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Light electric vehicles: substitution and future uses

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Abstract

Light electric vehicles may challenge established forms of transport in the near future. This paper looks at how different kinds of consumers assess the future uses of light electric vehicles. Such uses are further characterized by examining how they could replace the current uses of existing modes of transport such as cycling, cars and public transport. The paper approaches the take-up of light electric vehicles from the vantage point of technological niches which have the potential to transit to sociotechnical regimes (Schot and Geels, 2008; Geels, 2002). It considers insights from recent user studies on light electric transport and broadens their scope to include a wider range of vehicles. Data from a representative survey of 1030 Finns are used to analyse and characterize future uses of light electric vehicles. Currently, light electric vehicles remain technological niches, but consumers show interest in them, and the paper addresses the match between different kinds of consumers and these vehicles, building opportunities for large scale use.

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Keywords: Light electric vehicles, consumers, sociotechnical transition, technological niche, electric bicycle, electric moped, electric microcar, electric 3- and 4-wheelers, electric skateboard, Segway

1. Introduction

Rapid technological developments have made light electric vehicles, such as electric bicycles, 3- and 4-wheelers, skateboards and Segways, viable alternatives for conventional forms of transport, especially in cities (Figure 1). It is hoped that they will address challenges relating to transport, the environment and human health. Electric bicycles are already widely available, and their prices have approached those of quality bicycles and special models. China leads

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the market for electric bicycles, but many European markets are also rapidly developing. For instance, electric bicycles secured a 10% share of the bicycle market in Germany in 2013 (BIKEeurope, 2014). However, it is still unclear what kinds of established forms of transport they will replace and what new kinds of transport they will contribute to. This article examines the take-up of light electric vehicles in Finland. The Finnish market is developing similarly to other non-leading markets for light electric vehicles in industrial economies. It is estimated that electric bicycles account for 1% of the bicycle market, while the size of the markets for other light electric vehicles are reported in the production and sales figures of companies rather than as market shares. The Finnish climate poses a particular challenge to light electric vehicles, as winters are cold and icy, which emphasizes the need for warm clothing and good vehicle balance.

Picture 1. Electric bicycle. Photo: Meine Heimat [Chiemgau], CC BY-ND 2.0.

Picture 2. Electric four-wheeler. Photo: Les Chatfield, CC BY 2.0.

Picture 3. Segway. Photo: Chris Brown, CC BY 2.0.

Fig. 1. Examples of light electric vehicles.

This paper assesses the opportunities of light electric vehicles to enter the transport system against the background of sociotechnical change as proposed by Geels (2002). Geels' sociotechnical transition approach has been widely applied in studies on electric mobility when describing systematic change while accounting for markets and user preferences, techno-scientific knowledge, and industrial networks (see Geels, 2012; Genus and Coles, 2008; Nykvist and Whitmarsh, 2008; Hoogma et al., 2002). The approach emphasizes the existence of competing technologies, i.e. various types of light electric vehicles, and the uncertainty of their success in making the transition from technological niches to parts of an established sociotechnical regime (see Schot and Geels, 2008). In this respect, the approach challenges and complements focused user studies in which consumer interest towards a given vehicle, most notably the electric bicycle, is studied.

The paper examines how different kinds of consumers consider future uses of light electric vehicles. The following sections discuss how the sociotechnical transition approach places the development of light electric vehicles within the context of competition, assists in identifying issues for innovative success that require further research, and complements focused user studies on the vehicles. First, the sociotechnical transition approach is discussed with a particular emphasis on technological niches. Then, the results from earlier user studies on light electric vehicles are presented in order to highlight key issues for analysis. These are followed by a presentation of the methodology used in this paper and an analysis of the responses to a representative survey conducted in Finland in 2015 which investigated consumer interest in light electric vehicles for everyday transport and compared them to other forms of transport. The analysis also provides an opportunity to assess whether consumer attitudes to light electric vehicles conform with attitudes to electric bicycles.

2. Sociotechnical transition and user studies on light electric vehicles

The sociotechnical transition approach embraces a wide range of dimensions connected with the emergence of new products and services such as the use of light electric vehicles. The approach encompasses industrial networks and their strategic games, culture and symbolic meanings, infrastructure and technology (Geels, 2002). Technological niches can fail as innovations but receive, according to the approach, renewed opportunities to enter the sociotechnical regime. Techno-scientific knowledge, sectoral policy, markets and user practices are all central to sociotechnical regimes, indicating that the potential of light electric vehicles should not be studied in isolation from them. Similarly, developments in the slowly evolving sociotechnical landscape, such as economic growth, the price of oil, changes in cultural norms and values, and environmental problems also have an effect on the success of innovations.

The approach is ideally suited to the study of the market for light electric vehicles, as currently there are numerous producers of vehicles, no vehicles which have gained a dominant position on the market, and the market remains small in comparison to its potential. The sociotechnical transition approach is also apposite for bringing forth a wide range of issues such as the role of consumer practices, future expectations, social networks, learning, and city and traffic planning (Geels and Kemp, 2012).

Light electric vehicles still lack widespread user practices similar to those of regular bicycles, and many of the vehicles are still in the development phase, which makes it difficult to identify which types of light electric vehicles will become popular in the future. Therefore, light electric vehicles can be considered as technological niche products with the potential to become part of the sociotechnical regime. The history of cycling confirms that light transport is of great sociotechnical interest: it has been studied from the perspective of its liberating effect on transport for women (Bijker, 1995), in terms of the development of new types of bicycles and equipment (Bijker, 1995 on the safety bicycle; Robinson, 2007 on the benefits of use of helmets; von Hippel, 2005 on the mountain bike), and in relation to the desirability of appropriating wealthier car drivers as customers rather than cyclists (O'Connell, 1998). Recent policy interest has been directed at replacing car driving with light transport as a measure to reduce traffic congestion and adverse environmental effects (Finnish Transport Agency, 2015) and at attempts to overcome the administrative and social challenges posed by light transport.

The novelty of light electric vehicles is highlighted by the fact that relatively few studies have addressed them from a user perspective (Rose, 2012; Adey et al., 2014; Repo et al., 2015). Empirical user studies have primarily investigated electric bicycles and, in line with diffusion theory, user attitudes and early forms of use (see Rogers, 1995). Studies have focused on early adopters, who have been described as environmentally conscious and interested in new technology (Wolf and Seebauer, 2014). Environmental values, functional features such as speed, acceleration and effortless use over longer distances, as well as positive health effects, have encouraged consumers to take up electric cycling (Dill and Rose, 2012; Popovich et al., 2014).

Electric bicycles have been recognized to interest women, the elderly and the physically challenged (Dill and Rose, 2012). User needs and access to conventional forms of transport thus have a significant impact on the purchase and use of electric bicycles (Gojanovic et al., 2011). Studies also show that electric bicycles are used for both utilitarian and recreational purposes, although they are used more for work, shopping and running errands than for hobbies and leisure (Popovich et al., 2014).

It is particularly interesting to study which established forms of transport light electric vehicles could replace. In this respect, early studies report rather contradictory findings, which can explained by different transport cultures and established forms between countries. For instance, the Chinese, who are accustomed to light transport, substitute electric bicycles for walking, regular bicycling and bus transport, rather than for driving a car. By contrast, in the United States, renowned for its automobile culture, electric bicycles tend to replace car driving (Popovich et al., 2014).

Studies have also identified barriers to the diffusion of electric bicycles. High purchase prices constitute a key barrier, but also traffic safety is a concern alongside underdeveloped battery technology and distance ranges which are perceived as short. In a study conducted in the United States, the speed differences between regular and electric bicycles raised concern (Dill and Rose, 2012; Popovich et al., 2014), whereas in China the rapid take-up of electric bicycles has challenged traffic safety due to the lack of speed limits (Weinert et al., 2008).

In consumer studies, the electric vehicle has been typically considered a stable and rather mature type of vehicle, and attention has been given to the adopters and adoption of that vehicle. Thus, the focus has been on such issues as consumers' attitudes towards and incentives to use quite established vehicles (Lebeau et al., 2013; Sierzchula et al.,

2014). In the field of light electric traffic, consumer and user studies are few in number and focus on electric bicycles, although there are quite a large range of other vehicles, such as electric mopeds, electric microcars, electric 3- and 4-wheelers, electric skateboards, and the Segway.

From the perspective of the large-scale adoption of various kinds of light electric vehicles, the consumer studies cited above are limited in scope. The sociotechnical transition approach extends this scope, accentuating variety in terms of vehicles and practices of use, and prolonging the time span of adoption and diffusion.

The following sections of this paper investigate the prerequisites for the development of light electric vehicles into an established mode of transport. Attention is paid to how different kinds of consumers assess light electric vehicles. The paper also investigates the purposes for which they would use light electric vehicles and the established forms of transport that light electric vehicles would replace. This analysis is performed in accordance with the sociotechnical transition approach, with a particular focus on how technological niches can develop into established sociotechnical regimes (Schot and Geels, 2008; Geels, 2002). This approach accentuates the existence of alternative paths of development, the social context of development, and competition between technological niches.

3. Materials and methods

The study is based on the statistical analysis of responses to an internet survey representative of the Finnish population in terms of gender, age, place of residence and household size. The survey's 1030 respondents were selected from a pool of 40,000 Finns recruited by the Finnish market research company Taloustutkimus Oy. The target group of the survey were individuals aged 15–79. The survey questions were based on earlier focus group interviews designed to identify relevant consumer issues in light electric traffic (Repo et al., 2015). In addition, different types of light electric vehicles were described in the survey to enhance the validity of the received responses. Six types of light electric vehicles were studied in the survey: electric bicycles, mopeds, microcars, 3- and 4-wheelers, skateboards and the Segway. At the time of the survey, there was on-going public debate over the eligibility of the electric skateboard and the Segway as forms of road transport.

The following analysis is based on the survey data, which concern interest in light electric vehicles, the purpose of their use, and replacement of established modes of transport. The survey was structured so that the respondents first described how they used various means of transport in their everyday life. Then they were asked about their views on and experiences of light electric vehicles. Finally, the respondents were asked to provide their socio-demographic details, such as gender, age, type of household, place of residence, household annual income, car availability in the household, and distance to work, school or college. These factors had been identified as relevant to the study of light vehicles in earlier studies and in the focus group interviews conducted when preparing the survey (Repo et al., 2015).

The responses were analysed statistically through the use of analysis of variance, t-tests and cross tabulations. The significance of the relationships between variables was examined with the F-test for variance and the chi-square ($\chi 2$) test. The study adopted the common measure of statistical significance of $p<0.05$. The results can be generalized to the population of Finland in respect to gender, age, place of residence and household size, as the survey sample was weighted so as to represent the target group. The analysis focused on different types of consumers, the uses of light electric vehicles and the established forms of transport that light electric vehicles could replace. Familiarity with light electric vehicles and experiences of use was also addressed, as they form the prerequisites for future use. Statistical analyses were carried out on the electric bicycle, electric moped, electric microcar, electric 3- and 4-wheelers, electric skateboard and the Segway, which represent novel types of light electric vehicles.

4. Survey results

The results cover how consumers in Finland assess the opportunities and shortcomings of light electric vehicles as a means of everyday transport, particularly in cities. Familiarity with and experience of using these vehicles is first addressed in order to define the prerequisites for a sociotechnical transition in transport. The analysis then proceeds to address future uses of light electric vehicles and substitution between transport forms.

4.1 Interest in light electric vehicles

The results show that the concept of light electric vehicles was found interesting by half the respondents. The vehicles were familiar to almost all respondents, although only 14% had tried or used them. The electric bicycle was the most familiar vehicle, as it was known by almost all respondents (95%), and it had been more frequently used (8%) than the other vehicles. The Segway was almost as well known (92%), but its use had been less frequent (3%). 3- and 4-wheelers were familiar to fewer respondents (87%), and only a small number (1%) had used them. Much less familiar were the electric microcar and electric skateboard, which were unknown to two thirds of the respondents. Men had more experiences of using light electric vehicles than women (18% vs. 9%).

The results indicate that there are future opportunities for light electric vehicles. The vehicles were seen more as potential modes of future transport than as current forms of transport. Half the respondents were quite willing to use light electric vehicles in the future, while one fifth had no intention of acquiring or using them.

The electric bicycle and the Segway attracted most interest also in future use (Table 1). 62% of respondents stated that they were either going to continue using the electric bicycle, planned to purchase and use one or would like to try one in the future, and 43% had similar attitudes towards the Segway. With the exception of electric 3- and 4-wheelers, the respondents were more interested in trying out light electric vehicles than purchasing them.

Table 1. Interest in future use of light electric vehicles (% of respondents, N=1030).

Light electric vehicle	Using, will continue to use	Plan to purchase, use in the near future	Might purchase, use later	Would like to try to assess features	Do not want to use	Total
Electric bicycle	1	1	28	32	38	100
Segway	0	0,3	8	35	57	100
Electric 3- and 4-wheelers	0,1	0	13	7	80	100
Electric moped	0	0,1	6	13	81	100
Electric skateboard	0,2	0,1	2	15	83	100
Electric microcar	0,2	0	3	10	87	100

According to the respondents, the best motivators for purchasing and using light electric vehicles were increased opportunities for independent mobility (86%), the vehicles' ease of use (84%), affordability (78%), fun (71%) and environmental friendliness (71%). Barriers to purchase and use relate to the features of the vehicles, the Finnish climate, and the infrastructure for electric transport. The key barriers identified included expensive purchase prices (95%), problems in winter use (94%), the small number of charging points (87%), and limited dedicated paths and ways (79%).

Table 2 depicts the connection between respondents' sociodemographic background and the purchase and use of light electric vehicles. The variance analyses (F-test) and cross tabulations ($\chi 2$ test) showed that the respondents' gender, age, household type, income, and car availability had statistically significant effects on their interest in purchasing and using light electric vehicles.

There were, moreover, differences relating to the different kinds of vehicles. The purchase and use of the electric bicycle, i.e. the most popular vehicle, could be explained by the respondents' gender, age, household type and car availability. Men were more interested than women in testing and using the electric bicycle. Users were more frequently middle-aged, belonged to households without children, and had access to a car.

Table 2. Profile of users of light electric vehicles (N=1030).

	Gender	Age	Household type	Place of residence	Income	Car availability	Distance to work
Electric bicycle	0.000***	0.000***	0.040*	NS	NS	0.046*	NS
Electric moped	0.000***	NS	NS	NS	NS	NS	NS
Electric microcar	NS	0.012*	NS	NS	NS	NS	NS
Segway	0.009**	0.030*	NS	NS	0.002**	NS	NS
Electric skateboard	NS	0.005**	NS	NS	NS	NS	NS
Electric 3- and 4-wheelers	0.042*	0.000***	0.000***	NS	0,005**	NS	NS

*** - significant at 0.001 level, ** - significant at 0.01 level, * - significant at 0.05 level, NS - not significant at 0.05 level.

Most of the users of electric mopeds were men. The use of the electric microcar was connected to the respondent's age, with this form of transport gaining greatest favour among middle-aged and older respondents. Use of the Segway was explained by gender, age and income. The typical Segway user was male, middle-aged or slightly younger, and with a high income.

The electric skateboard interested more the young and the middle-aged. The profile of users of 3- and 4-wheelers included the elderly, women, respondents without children, and those in the middle income bracket.

4.2 Purposes of light electric vehicle use

The respondents identified many reasons for using light electric vehicles in future everyday life (Table 3). The electric bicycle, electric moped and electric microcar were described as vehicles of a general character. According to the respondents, they were suitable for transport to work, school and college, shopping and running errands, leisure activities, and supporting independent mobility. The Segway and the electric skateboard were seen mostly to belong in the domain of leisure activities, but they were also considered useful for shopping and running errands as well as for commuting to work, school and college. Electric 3- and 4-wheelers were mainly seen as vehicles that supported the independent mobility of the physically challenged and the elderly, thereby enabling activities such as shopping and running errands. Shopping and running errands constituted the most popular purposes for using light electric vehicles.

Table 3. Purposes of light electric vehicle use (% of respondents).

	Work, school and college	Shopping and running errands	Leisure activities	Supporting independent mobility
Electric bicycle (n=553)	53	68	47	30
Electric moped (n=196)	47	70	40	32
Electric microcar (n=134)	30	68	37	37
Segway (n=440)	23	44	61	14
Electric skateboard (n=165)	31	50	66	11
Electric 3- and 4-wheelers (n=201)	5	40	12	67

The connections between the purpose of light electric vehicles use and the background of the respondents were studied with variance analyses (F-test) and cross tabulations ($\chi 2$ test), which demonstrated that the purposes of use differed according to sociodemographic factors. The differences were particularly evident in work, school and college-related use. All the sociodemographic factors (gender, age, type of household, place of residence, income, car availability and distance to work, school or college) significantly explained differences in the purpose of electric bicycle use (Table 4). The use of the electric bicycle for work, school and college-related journeys was more popular among women, those under 35 years of age, single households and households with children, city-dwellers and those with an annual income under 40,000 euros. For such uses, the electric bicycle was most popular among those who without access to a car and those whose journeys were less than 10 kilometres.

The use of the electric moped for travelling to work, school and college was connected to the respondent's age, car availability and distance to work (Table 4). Such usage was considered more common by those under 35 years of age, those without access to a car, and for journeys between three and 30 kilometres. The use of the electric microcar was partly parallel to that of the moped, as it attracted interest among the under-35s, households with children and single households, those without access to a car, and for work, school and college journeys between three and 30 kilometres.

The use of the Segway and the electric skateboard for commuting to work, school and college was explained by the age of the respondent, the distance to be travelled, household type, and car availability. The Segway attracted attention among those aged 25-49 years, single households and households with children. The electric skateboard was of interest to the under-35s and those without access to a car. Both would be used for journeys less than 10 kilometres. Interest in 3- and 4-wheelers was so limited that statistical analyses for them were not conducted.

Table 4. Purposes of light electric vehicle use (sociodemographic factors).

		Gender	Age	Household type	Place of residence	Income	Car availability	Distance to work
Electric bicycle	Work:	0.022*	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	Shopping:	NS	NS	NS	NS	NS	NS	NS
	Leisure:	NS	NS	NS	0.013*	NS	0.000***	NS
	Support:	NS	0.000***	0.000***	NS	0.005**	NS	NS
Electric moped	Work:	NS	0.000***	NS	NS	NS	0.028*	0.000***
	Shopping:	NS	NS	NS	0.049*	0.015*	0.043*	NS
	Leisure:	NS	NS	NS	NS	NS	NS	NS
	Support:	NS	0.000***	NS	NS	NS	NS	NS
Electric microcar	Work:	NS	0.000***	0.000***	NS	NS	0.007**	0.000***
	Shopping:	NS	NS	NS	NS	NS	NS	NS
	Leisure:	NS	NS	NS	NS	NS	NS	NS
	Support:	NS	NS	NS	NS	NS	NS	NS
Segway	Work:	NS	0.000***	0.020*	NS	NS	NS	0.000***
	Shopping:	NS	NS	NS	NS	NS	NS	NS
	Leisure:	NS	NS	NS	NS	NS	NS	NS
	Support:	NS	0.000***	NS	NS	NS	NS	NS
Electric skateboard	Work:	NS	0.001***	NS	NS	NS	0.032*	0.000***
	Shopping:	NS	NS	NS	NS	NS	NS	NS
	Leisure:	NS	NS	NS	NS	NS	NS	NS
	Support:	NS	NS	NS	NS	NS	NS	NS
Electric 3- and 4-wheelers	Work:	NS	NS	NS	NS	NS	NS	NS
	Shopping:	NS	NS	NS	NS	NS	NS	NS
	Leisure:	NS	NS	NS	NS	NS	NS	NS
	Support:	NS	NS	NS	NS	NS	NS	NS

*** - significant at 0.001 level, ** - significant at 0.01 level, * - significant at 0.05 level, NS - not significant at 0.05 level.

The use of electric vehicles for shopping and running errands was distributed rather evenly across respondents. The only significant differences concerned the electric moped. To some degree, the use of the electric moped could be explained by the respondent's place of residence, income and access to a car. Users were more frequently city-dwellers, without access to a car, and their annual incomes were under 40,000 or more than 70,000 euros.

There were two statistically significant differences between intentions to use light electric vehicles for leisure activities. Use of the electric bicycle varied according to the respondent's access to a car and place of residence. The use of light electric vehicles for supporting independent mobility was connected to the respondent's age, household type and income. Respondents aged 50 and above, those living in households without children, and those with an

annual income between 40-70,000 euros were more interested in using the electric bicycle to support their independent mobility. The over-50s also were interested in using the electric moped and the Segway for this purpose.

4.3 Substitution for existing forms of transport

The survey results show that light electric vehicles were primarily considered to substitute for riding bicycles, walking and driving cars. To some extent, they also were considered to substitute for public transport and use of their non-electric counterparts. The electric bicycle and moped substituted for regular bicycles and cars while the electric microcar substituted for cars and public transport. The Segway, electric skateboard and 3- and 4-wheelers substituted for walking and cycling (Table 5).

Table 5. Forms of transport that light electric vehicles will replace in the future (% of respondents).

Substitute for	Bicycle	Car	Public transport	Moped, scooter	Walking
Electric bicycle (n=553)	81	38	32	9	29
Electric moped (n=196)	58	44	35	26	26
Electric microcar (n=134)	31	57	42	23	26
Segway (n=440)	45	15	15	8	69
Electric skateboard (n=165)	54	13	18	7	74
Electric 3- and 4-wheelers (n=201)	38	35	11	9	46

Table 6 shows the differences, based on variance analyses (F-test) and cross tabulations ($\chi 2$ test), in respondents' intentions to substitute light electric vehicles for established modes of transport. The respondents were rather united in which established forms of transport would be replaced by light electric vehicles. However, the background of the respondents partially explained the results, with gender, age, household type, place of residence, and income having statistically significant effects on some substitutions. The differences were also connected to the availability of a car and distance to work, school or college. The following sections review the most common substitutions for each type of light electric vehicle.

Statistically significant differences among respondents who would replace established modes of transport with electric cycling were observed according to gender, age, place of residence, car availability, and distance to work. There was no significant connection between the respondents' background and substitution of a regular bicycle with an electric bicycle. The substitution of an electric bicycle for a car was connected only to access to a car. Those currently using a car were more likely to express the intention of replacing the car with an electric bicycle.

Replacing public transport with an electric bicycle could be explained by several factors. Such substitution was more prevalent among women, those aged under 35 years, city-dwellers, those without access to a car and for journeys of between three and 30 kilometres.

Substitutions relating to the electric moped could be explained among the same factors and similarly as to the electric bicycle. Substitutions concerning the electric microcar were connected to respondents' age, household type, place of residence, car availability, and distance to work, school or college. Substituting a car with an electric microcar interested respondents aged 35 and above, households without children and those who currently had access to a car, while substituting public transport with an electric microcar interested city-dwellers, those without access to cars and those with journeys to work, school and college between three and 30 kilometres.

Differences in intentions to substitute regular modes of transport with light electric vehicles in general and the Segway in particular were best explained by age. Bicycling would be substituted with the Segway more frequently by the respondents aged 25-64 and car driving by those aged 35-64 and having access to a car. Walking would be substituted by women and respondents under 35 years of age. Public transport, in turn, would be substituted more frequently by city-dwellers and those with 3-30 kilometres distance to work, school or college. There were only small differences between respondents when studying the electric skateboard and 3- and 4-wheelers. The respondents aged

25-64 years would substitute public transport with the electric skateboard. Substituting a regular car with the electric 3- and 4-wheelers was connected to the respondent's access to a car, and substituting public transport to place of residence.

Table 6. Substituted forms of transport (sociodemographic factors).

		Gender	Age	Household type	Place of residence	Income	Car availability	Distance to work
Electric bicycle	Bicycle:	NS	NS	NS	NS	NS	NS	NS
	Car:	NS	NS	NS	NS	NS	0.000***	NS
	Pub. transport:	0.048*	0.000***	NS	0.000***	NS	0.000***	0.000***
	Moped:	0.018*	NS	NS	0.008**	NS	NS	NS
	Walking:	NS	NS	NS	NS	NS	NS	NS
Electric moped	Bicycle:	NS	NS	NS	NS	NS	NS	0.020*
	Car:	NS	NS	NS	NS	NS	0.000***	NS
	Pub. transport:	0.019*	0.012*	NS	0.000***	NS	0.000***	0.000***
	Moped:	NS	0.004**	NS	NS	NS	NS	NS
	Walking:	NS	NS	0.050*	NS	0.013*	0.000***	NS
Electric microcar	Bicycle:	NS	NS	0.014*	NS	NS	NS	NS
	Car:	NS	0.000***	0.050*	NS	NS	0.012*	NS
	Pub. transport:	NS	NS	NS	0.009**	NS	0.000***	0.000***
	Moped:	NS	0.002**	NS	NS	NS	NS	NS
	Walking:	NS	NS	NS	NS	NS	NS	NS
Segway	Bicycle:	NS	0.030*	NS	NS	NS	NS	NS
	Car:	NS	0.009**	NS	NS	NS	0.001***	NS
	Pub. transport:	NS	NS	NS	0.000***	NS	NS	0.004**
	Moped:	0.009**	NS	NS	NS	0.007**	NS	NS
	Walking:	0.036*	0.003**	NS	NS	NS	NS	NS
Electric skateboard	Bicycle:	NS	NS	NS	NS	NS	NS	NS
	Car:	NS	NS	NS	NS	NS	NS	NS
	Pub. transport:	NS	0.008**	NS	NS	NS	0.026*	NS
	Moped:	NS	NS	NS	NS	NS	NS	NS
	Walking:	NS	NS	NS	NS	NS	NS	NS
Electric 3- and 4-wheelers	Bicycle:	NS	NS	NS	NS	NS	NS	NS
	Car:	NS	NS	NS	NS	NS	0.000***	NS
	Pub. transport:	NS	NS	NS	0.040*	NS	NS	NS
	Moped:	NS	NS	NS	NS	NS	NS	NS
	Walking:	NS	NS	NS	NS	NS	NS	NS

*** - significant at 0.001 level, ** - significant at 0.01 level, * - significant at 0.05 level, NS - not significant at 0.05 level.

5. Discussion and conclusions

This paper approached light electric vehicles as technological niches with the potential to develop into established parts of sociotechnical regimes (Geels, 2002; Schot and Geels 2008). Attention was paid to which types of consumers were interested in light electric vehicles, the uses they considered appropriate for the vehicles and the established forms of transport that light electric vehicles would replace. Such issues are salient in circumstances where there are no dominant actors or interests in the market (see Bijker, 1995). Such circumstances also enable multiple paths of development and innovative solutions. The Segway is an example of a light electric vehicle which is so novel that it has not yet been recognized as a vehicle in many countries, which represents an obstacle to its wider use.

The paper presented the results of a representative survey of the Finnish population conducted to examine the opportunities and shortcomings of light electric vehicles as a technological niche. The responses indicated that each type of light electric vehicle has its own special character, and the vehicles were also considered to have distinct uses and users.

Consumers appear to carefully consider how light electric vehicles could substitute for regular vehicles, i.e. provide a competitive advantage that would enable them to make the transition from technological niches to sociotechnical regimes. Against this background, it is understandable that electric bicycles constitute a focal point for approaching light electric vehicles. They represent a well-known and improved version of the regular bicycle, provide the opportunity to travel longer distances, and are useful to those who have physical difficulties in using a regular bicycle. Electric bicycles are also readily available on the market. The results of this paper on the use of electric bicycles confirm and complement the results of previous studies, which have found that the public views electric bicycles as interesting and facilitative of new kinds of mobility (Wolf and Seebauer, 2014; Dill and Rose, 2012; Popovich et al., 2014). This paper, furthermore, looked in greater detail at different types of consumers and how electric bicycles could substitute for established forms of transport. Such substitution could be culturally embedded and therefore calls for further studies. Expensive purchase prices are a key barrier to adoption, but this article did not specifically examine acceptable price levels for light electric vehicles.

In addition, this paper considered a wide range of light electric vehicles. The results demonstrated that the electric microcar can be considered an inferior yet expensive version of regular or electric cars. However, it is an improvement for those who cannot use regular cars, which was reflected in the survey responses. Similarly, electric 3- and 4-wheelers appeared unfamiliar to consumers, but the Segway attracted interest.

Apart from consumer interest and demand, there is wider societal interest in the use of light electric vehicles, in particular concerning how light electric vehicles could substitute for cars and whether they would replace public transport, cycling or walking. The results of the survey indicate that consumers are interested in trying out light electric vehicles, but that they would probably use them to replace regular cycling and walking, which could cause commotion on pavements and cycle paths. In the longer term, this might change, as car drivers who are now interested in light electric vehicles will become even more so with the increasing regulation of car driving. The results of the present study show the need for future research on other markets and contexts of the use for light electric vehicles. The way in which light electric vehicles act as substitutes for established modes of transport, each other, and new alternatives, such as autonomous vehicles, may also change over time.

The results confirm that light electric vehicles are seen by consumers as technological niches (cf. Geels, 2002; Hoogma et al. 2002). With the possible exception of the electric bicycle, which is developing established user practices, light electric vehicles are still seeking wide and accepted uses. As the consumer responses in this study demonstrate, however, there are many opportunities and potential development paths for these technological niches to achieve established positions in sociotechnical regimes.

References

Adey, P., Bissell, D., Hannam, K., Merriman, P., Sheller, M., Eds., 2014. *The Routledge Handbook of Mobilities*. New York: Routledge.

BIKEurope, 2014. All Signs Are Green Thanks To E-Bikes. http://www.bike-eu.com/sales-trends/nieuws/2014/12/all-signs-are-green-thanks-to-e-bikes-10110110. 20.12.2014. Retrieved 22.5.2015.

Dill, J., Rose G., 2012. E-bicycles and Transportation Policy: Insights from Early Adopters, Transportation Research Record, 2314, 1-6.

Finnish Transport Agency, 2015. Sähköavusteisten polkupyörien tiekartta. Kulkumuodon mahdollisuudet kestävän liikennejärjestelmän edistämisessä (Road map for pedelecs. The potential of this transport mode to promote a sustainable transport system). Tutkimuksia ja selvityksiä 10/2015. Helsinki: Liikennevirasto.

Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study, Research Policy, 31(8-9), 1257-1274.

Geels, F.W., 2012. Socio-technical analysis of low-carbon transition: introducing the multi-level perspective into transport studies, Journal of Transport Geography 24, 471-482.

Geels, F.W., Kemp, R., Dudley, G., Lyons, G., Eds., 2012. *Automobility in Transition. A Socio-Technical Analysis of Sustainable Transport.* London, Routledge.

Genus, A., Coles, A.-M., 2008. Rethinking the multi-level perspective of technological transitions. Research Policy, 37, 1436-1445.

Gojanovic, B., Welker, J., Iglesias, K., Daucourt, C., Gremion, G., 2011. Electric bicycles as a new active transportation modality to promote health. Medicine and science in sports and exercise, 43(11), 2204-2210.

Hoogma, R., Kemp, R., Schot, J., Truffer, B., 2002. *Experimenting for Sustainable Transport. The Approach of Strategic Niche Management*. London: Spon Press.

Lebeau, K., van Mierlo, J., Lebeau, P., Mairesse, O., Macharis, C., 2013. Consumer attitudes towards battery electric vehicles: a large-scale survey, International Journal of Electric and Hybrid Vehicles, 5(1), 28-41.

Nykvist, B., Whitmarsh, L., 2008. A multi-level analysis of sustainable mobility transitions: Niche development in the UK and Sweden, Technological Forecasting and Social Change, 75, 1373-1387.

O'Connell, S., 1998. *The Car and British Society: Class, Gender and Motoring 1896-1939.* Manchester: Manchester University Press.

Popovich, N., Gordon, E., Shao, Z., Xing, Y., Wang, Y., Handy, S., 2014. Experiences of electric bicycle users in the Sacramento, California area, Travel Behaviour and Society, 1, 37-44.

Repo, P., Hyvönen, K., Lammi, M., 2015. Sähköinen liikkuminen murroksessa. Kuluttajat, sosiotekninen muutos ja tulevaisuuden kevyet kulkuneuvot (Electric transport in transformation. Consumers, sociotechnical transition and the light electric vehicles of the future), Kulutustutkimus.Nyt, 9(1), 30-48.

Robinson, D.L., 2007. Bicycle Helmet Legislation: Can We Reach a Consensus? Accident Analysis and Prevention, 39(19), 86-93.

Rogers, E.M., 1995. *Diffusion of Innovations.* Fourth Edition. New York: New Press.

Rose, G., 2012. E-bikes and urban transportation: emerging issues and unresolved questions, Transportation, 39, 81-96.

Schot, J., Geels, F.W., 2008. Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy, Technology Analysis and Strategic Management, 20(5), 537-554

Sierzchula, W., Bakker, S., Maat, K., van Wee, B., 2014. The influence of financial incentives and other socio-economic factors on electric vehicle adoption, Energy Policy 68, 183-194.

Weinert, J., Ogden, J., Sperling, D., Burke, A., 2008. The future of electric two-wheelers and electric vehicles in China, Energy Policy, 36(7), 2544-2555.

Wolf, A., Seebauer, S., 2014. Technology adoption of electric bicycles: A survey among early adopters. Transportation Research Part A: Policy and Practice, 69, 196-211.

von Hippel, E., 2005. *Democratizing Innovation*. Cambridge, MA: MIT Press.