

Environmental Evaluation and Effectiveness of Electric-assist Bicycle for a Local Transportation

Miguel TORREGROSA MIRA, Naoki MARUYAMA, Motohide OKAMOTO, and Masafumi HIROTA

*Division of Mechanical Engineering, Graduate School of Engineering, Mie University
1577 Kurimamachiya-cho, Tsu 514-8507, Japan*

Life cycle environmental impact of an electric-assist bicycle has been discussed, and the effectiveness of such bicycle is compared with existing transportation from the viewpoints of carbon dioxide and carbon dioxide equivalent emissions. In life cycle environmental evaluation, in-vehicle fuel cell power generator is applied as an energy source for the electric-assist bicycle as well as commercial purchased electricity. Its transportation with scooter, passenger car and light truck are chosen for comparison. Accordingly, the environmental impact affecting factors of each type of transportation device are shown. As a result, the electric-assist bicycle is found to be effective for short-distance transport of as in a factory or a local transportation.

Miguel TORREGROSA MIRA, Research student, Div. of Mechanical Engineering.

Naoki MARUYAMA, Associate Professor, Div. of Mechanical Engineering.

Motohide OKAMOTO, Guest Associate Professor, Div. of Mechanical Engineering.

Masafumi HIROTA, Professor, Div. of Mechanical Engineering.

INDEX

Purpose of the investigation	4
Diagnosis	5
Hypothesis	6
Methodology	7
Global factors of mobility	9
Factors involved in the environmental evaluation	
Political	11
Economics	13
Current	
Future	
Penetration	
Obstacles	
Offer and Trends	
Technological	26
Electric-assist Bicycle	
Antecedent	
Alternative	
Lithium ion battery	
Fuel cell	
Membrane	
Social	
User groups	32
Car drivers	
Commuters	
Parents and Shoppers	
Professional groups	
65+ and Health Problems	
Tourists	
Short distance passenger mobility	40
Highlights	
Why travel?	
Spend travelling	
Environmental	46
Legal	48
Development	51
Evaluation	
Advantage	
Conclusions	59
Acknowledgement	
References	

Purpose of the investigation

One of the challenges of developed societies in mobility is evolve to economic models of low-carbon and energy-efficient. It is the challenge of sustainability. Therefore, sustainable mobility means guarantee that our transport systems respond to economic needs, social and environmental, and minimizing adverse impacts.

Also, the functionality and organization of most of the various mobility systems depend on a high percentage of transportation. It is absolutely necessary to adopt strategies, without sacrificing performance and urban and interurban organization, to address the problems today so strongly manifested. Mobility strategies must address all the variables that go with it, this is the solution must be comprehensive and coherent in all terms assuming the complexity that entail.

Urban and intercity systems have associated different rules and speed that influence in mobility, forming a complex mobility demand, in terms of destinations, timetables and service characteristics. Social needs are complex and essential to measure the environment impact that is caused by humans. One general approach does not always correspond to the demographic variety, which can lead to substantial differences expected in an initial approach. Anticipate human behaviour resolve future errors, because contextualize the reality.

Evaluate the social factor form quantify allows facilitate the necessary change in the current model of mobility, making it more efficient and sustainable, thereby contributing to the reduction of their impacts, such as the reduction of greenhouse gases and other pollutants, contributing to the fight against climate change.

This document intended to be a study, whose implementation makes possible progress towards a sustainable mobility model.

Diagnosis

Demographic phenomena, technological innovations, implementation of new production processes, changes in the rules of settlement and business location, changing habits, appearance of new consumer behaviours and valuation of natural resources, etc.. Behind this dynamic process, which inevitably brings with mobility needs, also a continually evolving.

This study addresses the challenge of meeting these changing demands, providing the necessary information within the technical and economic of the society allow. Clearly, the existence of an offer permanently adjusted to social demands is complex, dynamic and be subject to conflicting forces, whose resultant is required to calculate.

The transport model has begun to change with the introduction of new concepts that support more sustainable mobility such as priority measures to integrate environmental objectives into proper planning. The achieve of a quality transport system and sustainable alternatives, is a declared objective and shared by the majority of countries, cities and metropolitan areas. As a response supply has increased and developed systems of higher quality due to technological improvements. However, the preventive assessment avoid the impacts presence of both global and local.

Hypothesis

The conversion to a low carbon society is proposed due to greater aggravation of global environmental problems such as global warming caused by carbon emissions. During the past years, a low CO₂ emission power system has been attracted a great deal of attention for transportation. Accordingly, the electric-assist bicycle is one of the low carbon emission vehicles from the viewpoint of life cycle environmental impact. The bicycle can be possibly accommodated for a greater in human activity, and the electric-assist tricycle can also carry goods on its cart at the back. Electricity for the electric-assist bicycle can be supplied by several sources such as photovoltaic power, wind power and fuel cell power as well as commercial purchased electricity. However, the life cycle environmental impacts of an electric-assist bicycle have not been examined yet. Here, the life cycle environmental impact assessment of the electric-assist bicycle is examined from the viewpoints of CO₂ and CO₂ equivalent emissions, and the advantages and disadvantages of its introduction are shown.

Methodology

To predict the future states is based at present trends in retrospection. It is required to measure changes in the present to reach the expected future state. The comprehension of possible scenarios helps to prepare with more flexibility to companies and organizations. Involves, the present research, the development of innovation, the market and the consumer behaviour to anticipate competition. Using qualitative and quantitative methods to approximate the shape of the future. If 15% to 25% of the population integrates an innovation, project, belief or action in your daily life then becomes a dominant trend. The trend persists long term and great range, affecting many society groups, grows slowly and with a deep base. On the contrary, fashion operates in short term, temporary interest, only affects a specific social group, and spreads quickly in this group.

Environmental scanning

The study and interpretation of the political, economic, social and technological trends affecting the market, in this case the short distance passenger mobility. Environmental assessment at the macro level to comprising industry, market, company and competitors. The micro level corresponding to company, suppliers, customers and competitors included in industry.

The next factors are need for the environmental assessment: events, trends, issues and expectations of the different interested parties. The problems in this case environmental and energy are the precursor of change or evolution. The trend break exist by change in society values and technological innovation.

PESTEL analysis describes the macro environment or external factors are identified and examined. PEST stands for political, economic, social and technological, adding two more factors, the environmental and legal factor.

- **Political** factors are how and to what extent a government intervenes in the economy. Specifically, political factors include areas such as tax policy, labour law, environmental law, commerce restrictions, tariff, and political stability. Political factors may also include goods and services the government wants to provide. The governments have great influence on health, education and infrastructure of a nation.
- **Economic** factors include economic growth, interest rates, exchange rates and the inflation rate. These factors have major impacts on how businesses operate and make decisions. For example, interest rates affect a firm's cost of capital and therefore to what extent a business grows and expands. Exchange rates affect the costs of exporting goods and the supply and price of imported goods in an economy
- **Social** factors include the cultural aspects and include health consciousness, population growth rate, age distribution, career attitudes and emphasis on safety. Trends in social factors affect the demand for a company's products and how that company operates. For example, an aging population may imply a smaller and less-willing workforce (thus increasing the cost of labour). Furthermore, companies may change various management strategies to adapt to these social trends (such as recruiting older workers).
- **Technological** factors include technological aspects such as R&D activity, automation, technology incentives and the rate of technological change. They can determine barriers to entry, minimum efficient production level and influence outsourcing decisions. Furthermore, technological shifts can affect costs, quality, and lead to innovation.

- **Environmental** factors include ecological and environmental aspects such as weather, climate, and climate change, which may especially affect industries such as tourism, farming, and insurance. Furthermore, growing awareness of the potential impacts of climate change is affecting how companies operate and the products they offer, both creating new markets and diminishing or destroying existing ones.
- **Legal** factors include discrimination law, consumer law, antitrust law, employment law, and health and safety law. These factors can affect how a company operates, its costs, and the demand for its products.

The factors can be classified as opportunities and threats in a SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats).

Global factors of mobility

Political factors:

- The Kyoto Protocol is a protocol to the United Nations Framework Convention on Climate Change (UNFCCC or FCCC), aimed at fighting global warming. The UNFCCC is an international environmental treaty with the goal of achieving the "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

Economic factors:

- The energy consumed by the transport sector represents more than 40% of the total energy remains one of the main causes of increased emissions of greenhouse gases (GHG).
- Time wasted in traffic jams and its economic impact in the productive sector.
- Economic consequence of road accidents is too high.

Social factors:

- Increased number and distance of motorized travel in metropolitan areas, derived from recent urbanization trends and the availability of industrial land.
- The accidents and casualties caused by urban traffic accidents. The number of traffic accidents with victims on urban roads in Spain amounted 2007th 50,688, resulting in 62,733 injuries and 741 dead¹.
- High geographical concentration in southern European countries and in coastal areas requiring the oversized infrastructure and generates considerable pressures in the territory.
- Occupation of urban space for the movement infrastructure and parking of vehicles. Urban space occupied by the use of cars and motorized transport in general represents percentages above 50%² in new urban developments.
- Decreased socializing character and communicator of public space.
- Loss of autonomy in the movement of specific social groups (children, elderly and disabled).

Technological factors:

Low integration between different modes of transport, with limitations in intermodal connections.

Environmental factors:

- The energy consumed by the transport sector represents more than 40% of the total energy is primarily responsible for the increased emissions of greenhouse gases (GHG).
- Deterioration of air quality, especially in urban areas, the pollutants more concern are nitrogen dioxide (NO₂) and particle, both PM₁₀ and 2.5.
- Health deterioration of the population due to noise traffic (estimated to affect 26.7% of households), the sedentary produced by new social habits, and the deleterious effects associated with traffic pollution.
- Increasing fragmentation of natural habitats and seminatural caused by the increase of the density of the network infrastructure, threat to biodiversity.

¹ Series Statistics on accidents and casualties - Traffic Department. Ministry of Interior. Spanish Government.

² Urban Ecology Agency of Barcelona

Legal factors:

- European Union directive 2002/24/EC exempts vehicles with the following definition from type approval: "Cycles with pedal assistance which are equipped with an auxiliary electric motor having a maximum continuous rated power of 0.25kW, of which the output is progressively reduced and finally cut off as the vehicle reaches a speed of 25km/h (16mph) or if the cyclist stops pedaling." This is the de facto definition of an electrically assisted pedal cycle in the EU. As with all EU directives, individual member countries of the EU are left to implement the requirements in national legislation. European product safety standard EN 15194 was published in 2009. The aim of EN 15194 is "to provide a standard for the assessment of electrically powered cycles of a type which are excluded from type approval by Directive 2002/24/EC".

Factors involved in the environmental evaluation

Political factors

Some local authorities and member states are trying to stimulate the use of bicycles in general and of electric-assist bicycles in particular by means of fiscal incentives. A few examples:

Many years ago, Holland introduced a law allowing employers to give their employees a bike, tax-free, up to an amount of € 749. The Dutch trade association for bicycle dealers is lobbying for an increase of this tax-free amount so that it can also easily cover electric-assist bicycles. In 2008, 240,000 so-called company bikes were sold, i.e. almost 1 out of 5 new bikes, at an average price of € 836. Holland has 18 million bicycles for 16 million people. The bicycle accounts for 26% of all trips.

In Belgium, the law allows employers to pay employees, who cycle to work, a tax-free fee of currently € 0.20 per cycled kilometre. Paying the fee is a favour, not a legal obligation. Research by the Belgian mobility department has shown that if a company pays the fee, cycling increases considerably. The number of cyclists rises from 6.3% to 9.5%, that is +50%.³ Furthermore, employers can give a bike and electric-assist bicycle to their employees as a benefit in kind. Following a recent Parliamentary decision, these company bikes are now also tax-free. What's more, in contrast to Holland where there is a limit of € 750, in Belgium there is no limit to the value of the company bike and the employer is also allowed to compensate his employee for the parking and maintenance costs of the bike.

In 2005, the UK government launched the "Cycle to Work" tax incentive scheme.⁴ Employers can lend bicycles and electric-assist bicycles to their staff as a tax-free benefit on condition that the vehicles are mainly used to go to and from work or for work-related purposes. The employee pays back the loan with a salary sacrifice, allowing him to benefit from tax and national insurance relief. At the end of the lending period he 'buys' the bike for a nominal sum.

In 2009, the Italian Ministry of Environment set up a subsidy scheme for the purchase of bicycles or electric two-wheelers. The total budget of € 19 million resulted in the sales of an extra 127,000 bicycles/electric-assist bicycles.⁵

"Austria's klima: aktiv programme" is aimed at reducing greenhouse gas emissions with 13% between 2008 and 2012 compared with 1990. As part of that programme, Austria cofinances the purchase of electric-assist bicycle fleets with a maximum of 10 vehicles. The initiative is reserved to companies, local, regional and national authorities, tourist organisations and tourist companies and NGO's. The subsidy amounts to € 200 per vehicle or € 400 if green electricity is used. To promote the programme, the environment minister climbed the Großglockner, Austria's highest mountain by electric-assist bicycle. Several Austrian regions and local councils have set up incentives for private individuals who buy an electric two-wheeler. Salzburg has the highest subsidy, up to € 400 plus € 100 for green electricity. Oberösterreich offers € 300 plus € 150 and Steiermark € 250.⁶

3 Federale Overheidsdienst Mobiliteit en Vervoer, 2005, "Diagnostiek Woon-Werkverkeer van 30 juni

4 <http://www.dft.gov.uk/pgr/sustainable/cycling/cycletoworkguidance/>

5 <http://www.bike-eu.com/news/3647/italians-sell-57-000-bikes-in-5-days-with-incentive-scheme.html>

6 http://www.escooterstore.at/819_Foerderungen_fuer_Elektrofahrraeder.html

In 2009, the Paris Council has voted to extend the existing subsidy on the purchase of electric scooters to electric bicycles.⁷ This decision complies with the city's strategy for improvement of mobility, public health, and the fight against air pollution and noise. The subsidy amounts to 25% of the purchase price with a maximum of € 400. It applies to all Parisians, whilst the duration of neither the measure nor the budget is limited.

At European level, there is no coherent integrated programme aimed at stimulating electric two-wheelers in general and electric-assist bicycles in particular. In November 2008, the President of the European Commission has announced the European Green Cars Initiative as one of the three Public Private Partnerships of the European Economic Recovery Plan. The objective of the initiative is to support R&D on technologies and infrastructures that are essential for achieving breakthroughs in the use of renewable and non-polluting energy sources, safety and traffic fluidity. Beyond providing loans through the European Investment Bank, the PPP European Green Cars Initiative is making available a total of one billion EUR for R&D through joint funding programmes of the European Commission, the industry and the member states. These financial support measures will be supplemented by demand-side measures, involving regulatory action by Member States and the EU, such as the reduction of car registration taxes on low CO2 cars to stimulate car purchase by citizens.

Despite its name the Green Cars Initiative is not only for passenger cars. Under the Green Cars Initiative, the topics include research on trucks, internal combustion engines, biomethane use, and logistics. However a main focus is on the electrification of mobility and road transport. Nevertheless, the Green Cars Initiative does not include two-wheelers. In June 2009 the European Commission held an Expert Workshop seeking to understand the landscape of ongoing initiatives at national levels in Europe related to development of fully electric vehicles and the required infrastructure.⁸ At this meeting, Politic stressed the need to consider all modes of transport when talking about electrification. So far this advice has not been followed.

The Directorate-General for Energy and Transport will support a large European "electro mobility" demonstration project on electric vehicles and related infrastructure with a total budget of around € 50 million as part of the Green Car Initiative. This does not include electric two-wheelers.⁹

Under point 4.4 we indicate another missed opportunity as two-wheelers were not included in Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles.

In 2009, ETRA, together with the industry associations COLIBI and COLIPED have made an appeal to the Commission for a European strategy on tax incentives for cycling. In 2002, the European Commission presented a new strategy on the taxation of passenger cars in the European Union. The Commission analysed existing passenger car taxation systems and explored ways to remove the tax obstacles to free movement of passenger cars within the Internal Market. The 3 organisations said it was now time for a European analysis of cycling prohibitive taxation systems as an impetus for a new strategy on tax incentives for cycling in the European Union. The European Commission has not responded.¹⁰

7 <http://www.bike-eu.com/news/3646/paris-grants-euro-400-subsidy-on-e-bike.html>

8 European Commission, 2009, "Report on a European Commission Workshop: European Commissions' and Member States' R&D Programmes for the Electric Vehicle", Draft Version 1.0 / 15 November 2009.

9 http://ec.europa.eu/transport/urban/vehicles/road/electric_en.htm

10 <http://www.etra-eu.com/newsitem.asp?page=2&type=1&cat=4&id=4433406>

Economics Factors

Current Market

There are no exact statistics available for the production, sales, import and export of electric bicycles in the European Union. As for EU sales however, there are various estimates.

Bike Europe, the international trade journal for the European bicycle and scooter market, published the following in their April 2009 issue: “For the entire European Union with its current 27 member states, 2008 sales are estimated by some industry associations at 300,000 units, which seems too low considering that in Holland and Germany alone last years sales stood at about a quarter of a million units. For 2009 the industry associations are expecting sales to grow to about 400,000 units in Europe. This number again seems to be an underestimation given that in Europe’s main markets, Germany and the Netherlands, public interest in e-Bikes is at high level.”

The “Electric Bikes Worldwide Reports – 2010 Update”¹¹ estimates European sales in 2009 at 750,000 and has a prognosis of 1,000,000 vehicles in 2010. In any case, the European Union is now the second largest market in the world after China. The very high sales volume in China is due to the fact that a large number of cities have legally banned petrol engine mopeds and scooters. People had no other choice than to opt for electric bicycles. In China, the type that can be propelled by the motor itself largely dominates the market.

It is important to note that since 2007, growth in the EU is vigorous. Today, the European market of electric bicycles consists almost exclusively of electric assist bicycles. As for individual member states, the following data have been published.

Austria:

Pedelec sales have only started in 2009. The take-off was partly linked to the entry into the market of the Austrian bicycle manufacturer KTM.

Belgium:

There are no statistics available but the most important suppliers all confirm the success of the electric bicycle. Since 2007, Sparta, which is one of the most popular brands in Belgium reports growth of 10 to 15% a year, with a +15% prognosis for 2009. With that, sales of electric bikes are reported to increase more than other types of bikes.

Denmark

Sales in 2009 were estimated at 8,000 units.

France:

Sales in 2008 were at 15,800 units, which is a 50% improvement of the 2007 result.

Germany:

In 2008, an estimated 100,000 electric bicycles were sold, which is 2.5% of total sales volume. Growth is considerable: +62.5% in 2007, +54% in 2008 and a forecast +20% in 2009.

Italy:

Sales in 2008 are estimated at 10,000, whereas for 2009 they were expected to increase to 30,000.

¹¹ Benjamin Ed, Jamerson Frank, 2010, “Worldwide Electric Bike Reports, 2010 Update to 2009 Edition”.

Sales may well be further encouraged as a result of the cycling incentive scheme.

The Netherlands:

In 2008, almost 140,000 electric bikes were sold at an average retail price of € 1,900. Thus electric bicycles have generated 1/3 of the total revenue from sales of new bikes in Holland. In the first half of 2009, sales grew further by 49% to 105,000. Average price was just over 2,000, whilst electric bikes achieved a 12% share in the total bicycle sales.

UK:

In 2009, the leading electric cycle manufacturers and distributors in the UK have formed the British Electric Bicycle Association (BEBA)¹² to provide membership services for manufacturers, distributors and dealers. According to BEBA UK electric bicycle sales hit an all-time record of over 15,000 units sold in 2009. The total value of the market was around £13 million in 2008 with sales of £25 million predicted for 2009 and a further 50% growth predicted by manufacturers for 2010.

At the 2009 Eurobike-show in Friedrichshafen¹³, which is the most important international show for the bicycle industry, a total of 82 electric bicycle manufacturers exhibited. Of these, some 30 companies started off in the conventional bicycle business, whereas more than 50 companies were newcomers in the electric cycle industry. The companies were not only originating from the EU but also from the Far East and from America. Next to them, 9 battery producers were also present in Friedrichshafen.

Unfortunately it is not possible to provide reliable information as to turnover, production, import, export, nor the total number of people employed in the production of electric cycles and related components and accessories. The only possible estimate is the following. Suppose the 2009 EU sales are 400,000, as indicated in Bike Europe, at let's say an average sales price of € 1,500, then this results in a European wide revenue of almost € 600 million.

In any case, the success of electric assist bicycles in the Netherlands clearly shows in the statistics of EU bicycle production. In 2008, for the very first time the Dutch value of bicycle production outran the German value. It was sent up as a result of the high value of electric assist bicycles. Compared with 2007, the Dutch value rose by 20% to € 577 million in 2008, whereas German value was € 340 million.

Future Market

It is very difficult to predict the future market of electric assist bicycles in the European Union. Following Everett Rogers' theory on diffusion of innovation,¹⁴ the innovators constitute 2.5% of all consumers adopting the innovation, the early adopters 13.5%. Dutch population in 2009 was 16.5 million and each one of them owns at least one bicycle. Consequently, the group of innovators would be just over 400,000 people, whereas in the past few years more than 400,000 electric assist bicycles have been sold. As a result, it is now the group of early adopters who are in the process of buying electric assist bicycles and if their assessment of the product is positive, the famous tipping point, at which the majority rapidly adopts the innovation, is imminent. Several industry experts have stated that they expect electric assist bicycles in the Netherlands to acquire a market share of 25 to 30% by 2015. If the majority effectively accepts electric assist bicycles, that prognosis may well come true.

12 <http://www.beba-online.co.uk>

13 <http://www.eurobike-show.de/>

14 Rogers Everett, 1995, "Diffusion of innovations (4th edition)", The Free Press. New York.

The question is however: how about electric assist bicycles in other EU member states. Jack Oortwijn, Editor in Chief of the European trade paper Bike Europe predicts the following: “2009 was the year of the electric bicycle. 2010 will be even more so. In those countries (Netherlands and Switzerland) where e-bikes are a trend, their popularity continues to grow. Other countries will follow in 2010, with Germany first. With that in mind, one thing is already certain: 2010 will be a better year than 2009.”¹⁵

Belgium and Germany are in the stage of innovators trying out electric assist bicycles, whereas in Denmark, France and the UK, electric assist bicycles are in their very early stages. In quite a number of member states, notably in Eastern Europe, electric assist bicycles are still virtually non-existent.

According to Rogers, the innovation-decision is made through a cost-benefit analysis where the major obstacle is uncertainty. People will adopt an innovation if they believe that it may yield some relative advantage to the idea it supersedes.

The Dutch example shows that growth of the electric assist bicycle market is to a large extent driven by commuters who use the electric assist bicycle because it is cheaper, faster and healthier than the car. Their cost-benefit analysis is positive and they believe traveling by electric assist bicycle offers advantages over traveling by car. The cost of car usage is increasing everywhere in the EU, whereas the problems of congestion, pollution and deteriorating public health exist in all member states. This creates a real chance for the diffusion of electric assist bicycles throughout Europe.

Extra Energy¹⁶ founder Hannes Neupert expects electric assist bicycle sales in Europe to round the cape of 1 million in 2010 and two million in 2012.

Below is a prognosis published in the 2010 update to the 2009 edition of the Electric Bikes Worldwide Reports. These numbers include all types of two- and three-wheel cycles with an electric motor:

	2007	2008	2009	2010	2011	2012
China	21,000,000	22,000,000	21,000,000	22,000,000	23,000,000	25,000,000
India	85,000	20,000	7,500	10,000	15,000	17,500
Japan	300,000	300,000	300,000	325,000	350,000	350,000
EU	250,000	500,000	750,000	1,000,000	1,350,000	2,200,000
Taiwan	10,000	10,000	11,000	12,000	14,000	15,000
SE Asia	200,000	500,000	400,000	600,000	800,000	1,000,000
USA	120,000	170,000	150,000	300,000	400,000	500,000
Total	21,965,000	23,500,000	22,618,500	24,247,000	25,929,000	29,082,500

According to Frank Jamerson Ph.D, and Ed Benjamin, authors of the Reports, electric assist bicycle sales in Europe have been obstructed by the unavailability of funds to finance production. Electric assist bicycle manufacturers had to provide funds to support component manufacturers six months ahead of the vehicle production. However, they did not have funds available for such a long period and therefore ordered less than what the market needed. This hampered sales. Now, large European

¹⁵ Bike Europe, December 2009, p.2

¹⁶ <http://extraenergy.org>

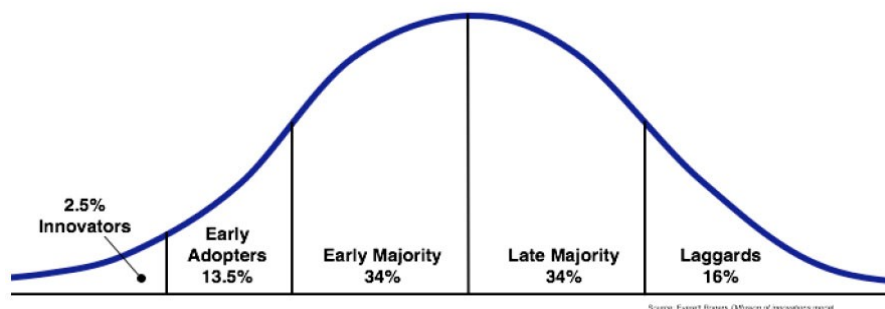
companies such as Bosch and possibly Schaeffler and Hella are preparing to enter the electric bicycle business. Their entry should contribute to eliminating the financial bottleneck and to stepping up the production of high quality European electric assist bicycles.

In the article “The Silent Revolution”, product developer Han Goes¹⁷ predicts “that clean, silent electrified two- wheelers will cause the biggest ever revolution in the bike industry”. However, he warns the bike industry. Today, most manufacturers are ‘electrifying’ existing bicycle concepts: Dutch city bikes, folding bikes, cargo bikes, ... Goes questions this approach: “The big question is whether this is really what the consumer is looking for, and whether bicycle companies and their product managers should try to better understand the real consumer needs for convenience, comfort, fun, speed in a modern package away from the traditional and archaic concept of the bicycle.” He pleads for a shift from horizontal product differentiation (= apply the same concept to different groups) to vertical product differentiation (= apply the same functionality i.e. electric mobility to different concepts). He reports that some companies among which Giant, JD Components, Ultra Motor, E-Solex and Elmoto have chosen that path and consumers have shown great interest for their products. Goes warns the bike industry that if they do not opt for vertical product differentiation, they will soon be faced by huge competition from the car industry.

Market Penetration

In “Diffusion of Innovation”, Everett Rogers defines diffusion as “the process by which an innovation is communicated through certain channels over time among the members of a social system”. Furthermore, he identifies 5 steps in the adoption process:

- knowledge: the individual becomes aware of the innovation
- persuasion: the individual becomes interested in the innovation and actively seeks information
- decision: the individual prepares a decision on adopting or rejecting the innovation
- implementation: the individual effectively uses the innovation
- confirmation: the individual assesses his information and takes a final decision



With that, Rogers distinguishes 5 adopter categories: innovators, early adopters (who have the highest degree of opinion leadership), early majority, late majority and laggards. When opinion leaders adopt an innovation, diffusion reaches the tipping point and the majority follows with rapid adoption of the innovation.

From this theory, Rogers concludes that there are two major ways to encourage the spread of an innovation:

- 1) mass media have a powerful effect as a result of spreading knowledge of innovation to a large audience at short notice;
- 2) A powerful way to push diffusion is to affect opinion leader attitudes. They are more trusted and

¹⁷ Goes Han, 2009, “The Silent Revolution”, Eurobike Show Dailies September 2009.

have a greater influence on doing away with resistance or apathy.

To eliminate lack of awareness, the use of mass media is the most effective. Persuasion of opinion leader is the best way to change attitudes about an innovation.

Today, raising awareness on electric assist bicycles through mass media is happening: CNN, BBC, The New York Times, The Frankfurter Allgemeine,... a lot of major television stations and newspapers have reported on the trend of electric bicycles. Sometimes, celebrities are involved to attract media attention. End of 2009, the Chinese Minister of Technology Wang Gang presented US Secretary of Energy Steven Chu with an electric bike for President Obama and one for himself.¹⁸ Another example involving celebrities is the “Spot the E-bike” action, which Rotterdam is about to launch. If people see a celebrity on a electric assist bicycle, they are encouraged to take a photograph and send it in for publication on the dedicated website. With that they can win a prize.

Another successful tactic to get the press is to invite journalists to try out electric assist bicycles with a view to writing a report. Furthermore, there are an infinite number of events offering opportunities to spotlight electric bicycles. At European level, Mobility Week, Green Week, EU Sustainable Energy Week, ... are just a few examples of such events. Many events at local, regional or national level offer similar opportunities to raise awareness actively by organising vehicle tests, or passively, by making electric assist bicycles available at events where participants have to cover distances, for instance from public transport locations to the event location or between exhibition/congress locations, ...

Convincing people to ride a electric assist bicycle is a determining factor in the diffusion process that should not be underestimated. This can and is being done in many different ways. Extra Energy was a pioneer in this process. The organisation has been setting up test tracks for electric cycles since 1992. They started at the most important international bike exhibitions with a view to convincing the industry first and, from there on, gradually expanded their initiatives with a view to informing and persuading the general public. ETRA,¹⁹ the European trade association for bicycle dealers, regularly organises test rides for European politicians and European civil servants in order to persuade them to take electric bicycles into account in the development of policies. ETRA has used for instance TREN Day, Mobility Week and Green Week for this purpose.²⁰ In the Netherlands, the organisation elektrischefietsen.com holds an annual demonstration day.²¹ In 2010, visitors have the opportunity to try out almost 30 different brands.

Dealers, manufacturers and importers play a crucial role in informing people on electric bicycles and persuading them of the advantages of the innovation. Many brands as well as dealers are active and sometimes very inspired in this field. In the Netherlands, the Dutch dealer Ruud Worm has been specialising in electric bikes for 10 years. In the margin of his company, he has set up elektrischefietsen.com, a comprehensive and objective Internet site aimed at informing people on electric bicycles. Furthermore, he organises the above mentioned national demonstration day. Finally, he offers a fully organised weekend in a B&B close to his shop, enabling people to extensively try out different electric assist bicycles. In the Czech Republic, ekolo.cz²² “helps open-minded individuals and companies change their city transportation habits.” Their aim is to provide intensive information and training to increase the usage of electric two-wheelers in Prague and other

18 http://www.chinadaily.com.cn/m/tianjin/e/2009-11/27/content_9063895.htm

19 <http://www.etra-eu.com/>

20 <http://www.etra-eu.com/newsitem.asp?page=2&type=3&cat=4&id=9166377>

<http://www.etra-eu.com/newsitem.asp?page=3&type=3&cat=4&id=1282161>

<http://www.etra-eu.com/newsitem.asp?page=5&type=3&cat=4&id=1464961>

21 <http://www.elektrischefietsen.com/Nationale-E-Bike-Opstapdag-2010/Nationale-E-Bike-Opstapdag-2010.html>

22 <http://ekolo.cz/>

large cities. The first ekolo.cz showroom was opened in May 2008 in Prague. They do not only sell electric bicycles but also offer hire-purchase schemes and short term rent. For companies, they have developed a special programme similar to car fleet management, Fleet Bike. They are also preparing a special GPS application for city bikers.

In Austria, KTM has set up an alliance with Opel offering a so-called ecoPaket.²³ Buying certain car models before a set date was rewarded with an ecoPaket, consisting of a discount card for public transport, a Garmin GPS and a € 100 voucher for a KTM bicycle. In celebration of Opel's 111th anniversary, KTM produced the Opel ecoBike "edition 111" limited to 111 pieces.

The Dutch brand Sparta has established the "Ion Club"²⁴ (named after the brand name of their electric assist bicycles). Members receive regular updates on their vehicle, advice on how to use and maintain it, information on new charging points, interesting cycle routes, etc. Furthermore they receive special offers and discounts for day trips or weekends, special offers for Ion accessories and they can consult Ion coaches. Anybody interested in Sparta's pedelecs can use a form on the manufacturers' website to book a test-ride on-line.

It is not clear yet, to which extent electric assist bicycles are/will be used to replace other means of transport. Some parties concerned fear electric assist bicycle use will to a large extent replace the use of conventional bicycles. In order to stimulate a changeover from other less sustainable means of transport, it is very important to have electric assist bicycle demonstrations outside the conventional cycling and/or mobility framework. As an example: in the Post-Expo 2010 in Copenhagen, there will be among other things a Zero Emission Vehicle Zone where also electric bicycles will be demonstrated.²⁵ Any other events focusing on sustainability, lifestyle, health, etc. are excellent opportunities to show the potential of electric assist bicycles.

Finally, electric assist bicycle rental schemes as well as electric assist bicycle tours for tourists may also be considered as a type of demonstration initiative. It provides people with an opportunity to become aware of and to get acquainted with the vehicles, which marks the first step (knowledge) in Rogers' adoption process.

As Rogers explains, a powerful way to push diffusion is by affecting opinion leaders attitudes. This requires a more profound and fundamental approach than showing, demonstrating and testing. To affect opinion leaders' attitudes one needs to prove that the innovation offers advantages not just for individuals but also for a larger group. Perhaps, if one can prove that the innovation is useful as part of a bigger plan, for instance combating climate change or improving the quality of life in urban areas, opinion leaders will be even more disposed to adopt and promote the innovation. A very significant example of such a bigger plan so far is Germany's programme "Modellregionen Elektromobilität in Deutschland"²⁶ (model regions electro-mobility in Germany) launched in 2009. With this programme, the German Transport Ministry supports 8 regions with a total of € 115 million until the end of 2011. Further support till 2020 is anticipated. The programme is aimed at accelerating the introduction of electric vehicles with a view to making Germany leader in the electric mobility market. Electric bicycles were included in the call for proposals. Of the 8 selected regions, 4 have planned activities involving electric assist bicycles. Berlin-Potsdam will put into service a fleet through electric assist bicycle sharing (see point 5.3). Rhein-Main will integrate electric assist bicycles in the existing mobility chains. Rhein-Ruhr will add electric assist bicycles to existing fleets. Oldenburg-Bremen will set up a Personal Mobility Center to guarantee the introduction of electric mobility including electric bicycles. The programme is part of the National

23 <http://www.opel.at/page.asp?id=2009122712082894IM7>

24 <http://www.ionclub.nl>

25 http://www.postexpo.com/zero_emission.php

26 <http://www.bmvbs.de/artikel-,302.1092406/Modellregionen-Elektromobilita.htm>

Electromobility Development Plan aimed at speeding up research and development in battery electric vehicles and their market preparation and introduction in Germany. The German Federal Government is looking to have one million electric vehicles on the road by 2020.

In 2009, Rotterdam has started a electric assist bicycle project as part of an integrated plan to improve air quality and accessibility.²⁷ The municipal services are using 25 electric assist bicycles as service vehicles. The 15 municipal bike parking are being equipped with battery charging points. The local council lends out 25 electric assist bicycles, free of charge for one month, to companies that wish to stimulate sustainable means of transport for commuting. Employees can book these electric assist bicycles on-line and try them out for one week. The commuter is expected to answer a few questions before and after the test to evaluate his experience as well as the bike. Rotterdam has carried out a first evaluation of this project. The general conclusion is: *“The potential of the E-bike is high among people who now travel by car, especially under car users with a commuter trip between the 9 and 19 kilometre. 60% think the E-bike is a transport mean by which they can fulfil their commuter trip and 40% of the car users are planning to buy an electric bike in the future. The people who commute normally by car rated the experience with the tested E-bike high and the product almost always met their expectations. However, the willingness to pay the price for an E-bike is a drawback.”*²⁸

The show piece among electric assist bicycle projects is New Ride in Switzerland, which was introduced in 2002 to support the introduction of electric bicycles and scooters.²⁹ It is part of Suisse Energie, a government programme to promote energy efficiency and renewable energy. In close cooperation with municipalities, manufacturers, importers and dealers, New Ride offers a wide range of promotional activities and services: road shows, public relations, a website, product information, dealer training, dealer certification with New Ride logo, participation in regional exhibitions, ...

In 2008 for instance, New Ride organised, with the collaboration of 40 municipalities, 140 dealers and 10 electric bike brands, a total of 161 road-show days. Most of these were organised in the framework of a larger event related to mobility and/or health. New Ride has experienced that road-shows embedded in larger exhibitions attract more visitors. New Ride counted some 7,000 test-rides and 24,300 visitors, whereas 1,700 test vouchers were distributed. With these vouchers, consumers can go to any New Ride dealer of their choice for a free test ride. New Ride had 2,100 electric assist bicycles available for these events. Since the start of the programme, the content of conversations has clearly changed. Originally, visitors mainly asked for explanations on the functioning of the vehicle. In 2008, conversations were a lot more detailed and complex. Consumers mainly asked questions about the differences between the vehicles. New Ride's press work resulted in more than 1,000 articles. The website attracted almost 50,000 unique visitors, who downloaded 371,000 pages.³⁰ Sales of electric bikes in Switzerland have finally taken off. At the start of the programme, in 2002, sales were only at 1,000 vehicles. In 2008, sales reached 13,000 units, compared with 7,000 in 2007, which is an increase of almost 86%.

27 <http://www.rotterdamelektrisch.nl>

28 van der Eijk Wim, 2009, *“A research on the potential of the electric bike”*, Master Thesis, Erasmus School of Economics, Erasmus University Rotterdam.

29 <http://www.newride.ch/>

30 http://www.newride.ch/Downloads/JB_2008.pdf

Obstacles to Market Penetration

Electric assist bicycle sales are still obstructed by a number of factors at the level of the consumers, the business as well as the authorities.

From research, it appears that dissatisfaction among electric assist bicycle users with their vehicles is related to: range, performance, weight, price and servicing and repair costs.

As for range, a 2008 Swiss study³¹ over 3 years shows that in that period battery capacity has more than doubled. As a result, even for cyclists who require a high level of assistance, battery capacity largely exceeds their real needs. The study has also established a clear relationship between quality/price and performance of the vehicle.

Manufacturers and dealers have an important role to play in dealing with this issue. The products and their range need to be diversified following the different user categories. Customers should be questioned about their intended use so that dealers can advise them on the most appropriate type of electric assist bicycle. Finally, customers need to be optimally informed not only on the actual range of their vehicle, but also on how to manage their energy use and charging batteries.

As for performance, current European legislation limits the motor output of v to 0.25 kW. ETRA has submitted a proposal to the European Commission because the limit proves to be insufficient, for instance in hilly and mountainous areas, for people suffering from obesity, for three-wheelers developed for physically impaired people, for vehicles developed to transport cargo,...³² For cycles used in these conditions, the increase of power will have a positive effect on the safety because it will provide the cyclists far more reliability. Since the cyclist can rely on a cycle that in all conditions will perform at the required level, he will also enjoy more safety and comfort (see further details in the fact sheet).

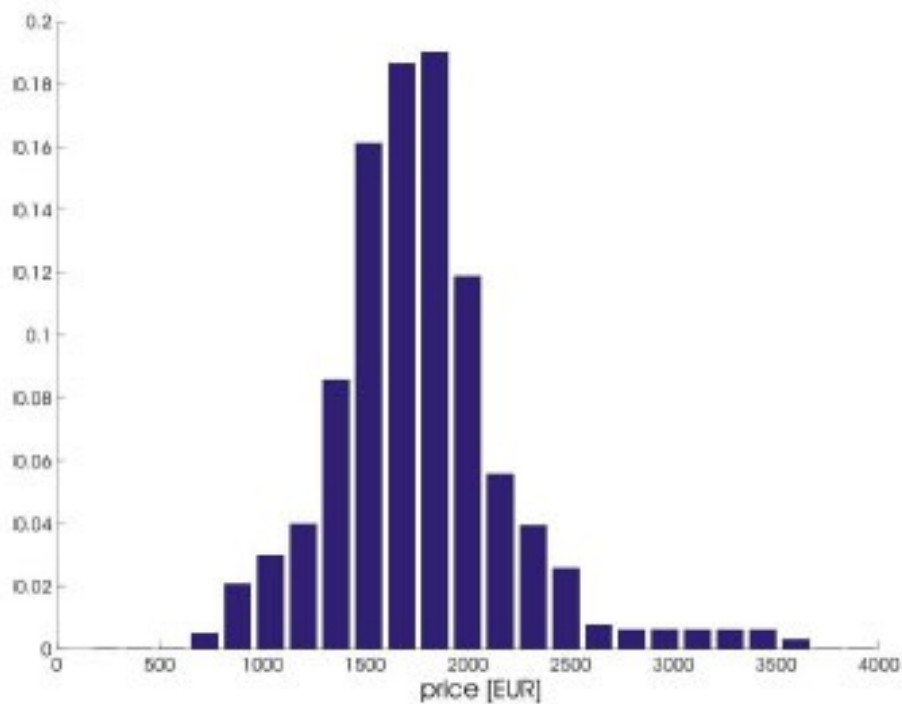
As for price, growing sales will increase production volumes, which in turn are likely to push prices down. Nevertheless, the above-mentioned Swiss study has clearly shown that the performance of the electric assist bicycle is linked to its price/quality. Here too, manufacturers and dealers are of paramount importance. They need to inform consumers on the characteristics of the vehicles as well as on the related price/quality ratio.

Many dealers and consumers still consider electric assist bicycles as an expensive “variation on the theme bicycle”, a view which often results in a negative cost-benefit analysis and consequently rejection of the innovation. For the study “The Pedelec Market in Flanders”,³³ 102 bicycle dealers filled in a questionnaire, whilst the researchers also analysed the websites of an additional 110 bicycles shops. 85% of the responding dealers were offering electric assist bicycles or power kits. 33% of the dealers had one single brand, 51% offered at least 2 different brands. However, only 38% of the visited websites were mentioning electric assist bicycles. The researchers concluded: *“This is much less than what would be expected from the results of responding dealers. Whether the 85% is too much because dealers who do not offer pedelecs did not take trouble to answer the inquiry, whether the dealers find it unnecessary to make publicity for these products on their websites. This may mean that most dealers are not actively promoting the pedelec. Their main concern is the ordinary human powered bicycle. (...)Although most dealers are won for the electrical assistance, they are not actively promoting the pedelec.”*

31 van der Eijk Wim, 2009, “A research on the potential of the electric bike”, Master Thesis, Erasmus School of Economics, Erasmus University Rotterdam.

32 <http://www.etra-eu.com/newsitem.asp?type=3&id=7933772>

33 Cappelle Jan, Lataire Philippe, Timmermans Jean-Marc, Van Mierlo Joeri, 2007, “The Pedelec Market in Flanders”.



The distribution of offered electric assist bicycle prices in Flanders

If electric assist bicycles are for instance marketed as a cheap, efficient, comfortable, healthy and clean alternative for private car usage, the perception of price may well completely change. If the choice is between a second car and a electric assist bicycle, the cost-benefit analysis will undoubtedly be positive.

Conventional bicycle manufacturers who entered the electric assist bicycle market logically used their existing distribution network of bicycle dealers. Electric assist bicycle manufacturers who were previously not involved in the production of conventional bicycles are more likely to use other/new distribution networks. Today, new types of companies effectively arise: mobility centres, electric vehicle shops, eco-mobility shops, ... They do not profile themselves as vendors of specific vehicles, but as suppliers of cleaner, better, more sustainable ... mobility solutions. The slogan on the homepage of the Spanish shop "Transporte del Futuro"³⁴ is "The car is no longer the best solution to travel through town". Such an approach immediately puts the price of the vehicles in a completely different perspective. As for servicing and repair costs, this factor is also largely related to perception and information. Dealers need to select suppliers who provide them with a complete offer of support. This includes training, service manuals, speciality tool and a sound warranty policy.

Furthermore, dealers need to inform their customers about their servicing and repair offer when they sell the electric assist bicycle. This allows the customer to monitor the functioning of his vehicle and to anticipate servicing, repairs and costs involved. Electric assist bicycles with integrated software offer additional opportunities for improving servicing and repair. The software provides exact information on the use of the vehicle. As a result, on the basis of travelled distance, dealers can determine exactly when the electric assist bicycle is due for servicing. Furthermore, the dealer can adapt the performance of the vehicle to the specific use of the customer. Finally, the software also functions as an anti-theft device. Informing the customer of the details and the quality level of the servicing provided, will certainly contribute to customer satisfaction.

As for weight, battery and motor have become considerably lighter in the past few years. Today,

³⁴ <http://www.transportedelfuturo.com/>

they add around 7.5 kg to the bicycles. This is not so much an obstacle to ride the vehicle but rather to handle it, for instance to carry it on stairs, lift it on a train or a bicycle rack on a car, ... The extra weight cannot be eliminated. Dealers should try to anticipate weight related problems and advise a electric assist bicycle with a removable battery.

The electric bicycle industry consists of only a few large companies and many small and even micro companies. The activities of a large number of companies are still in an R&D phase, whereas companies with effective production still have relatively high R&D costs. In the wake of the economic crisis banks have been reluctant to lend to new business ventures thus making start-up of new enterprises more difficult. Furthermore, it proves to be difficult, especially for small companies, to participate in government programmes aimed at promoting R&D, technological innovation, sustainability, ... Information on these programmes does not reach the companies or they do not have sufficient staff and/or know-how to deal with applications.

Furthermore, there is too often a lack of knowledge of and interest in electric assist bicycles among authorities who develop programmes to stimulate business activities. They do not know or underestimate the potential effects of electric assist bicycle usage on mobility, environment and public health. Furthermore, they focus on electric four-wheelers only because they believe their economic weight in terms of employment and sales is far more important than electric two wheelers. They may also believe that public opinion is rather sensitive to the promotion of electric cars and vans than electric bicycles. Finally, because the electric bicycle industry mainly consists of small companies, many of which are in a start-up phase, their lobby is currently not strong enough to influence authorities in a structural way.

A telling illustration of this is the fact that in the framework of the European Economic Recovery Plan, the European Commission has launched the European Green Cars Initiative.³⁵ The Commission's Research website states: "As the car industry is a major employer, any major disturbance to the industry risks affecting the economic and social fabric of Europe. This is why the European Commission made the car industry a key focus of its recovery package, presented in November 2008. At the same time, today's environmental imperatives mean that we need to encourage all road transport stakeholders to move towards more sustainable transport. The European Green Cars Initiative responds to both these needs. It provides financial support to research into the green technologies that will propel our cars, trucks and buses in the near future – spending on research today to correctly meet the demands of tomorrow."³⁶ Despite the proven demand for electric bicycles, the Commission totally disregards this vehicle in the European Green Cars Initiative.

The lack of attention on behalf of the authorities results in legislation that overlooks electric two-wheelers and thus stunts the growth of the market. Two examples to illustrate this situation. Whilst a growing number of local, regional and national authorities allocate funds to the co-financing of electric assist bicycles, the vehicles are subject to the standard VAT rate of minimum 15%, which is in some cases (for instance Scandinavia) as high as 25%. Numerous appeals on the European Commission and the member states for the application of the reduced rate have fallen on deaf ears. It does not seem logical to submit environmentally friendly vehicles to the same fiscal regime as polluting means of transport. In April 2009, European Parliament and Council have adopted Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles.³⁷ As a result, authorities have to comply with a number of rules aimed at guaranteeing the purchase of clean and energy-efficient vehicles. The Directive does not cover two-wheelers and is therefore a

35 <http://www.green-cars-initiative.eu/>

36 http://ec.europa.eu/research/transport/info/green_cars_initiative_en.html

37 <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:120:0005:0012:en:pdf>

missed opportunity to make authorities aware of and interested in electric two-wheelers. Consequently, they can continue to issue tenders for combustion engine mopeds and motorcycles which through their technical requirements actually exclude electric two wheelers, as is the case today.

Offer and Trends

The very first consumer groups to become interested in electric bicycles were elderly and physically impaired people. Their preference was a classic, inconspicuous vehicle that looked as much as possible like a conventional bicycle and preferably had a low step-through frame. As a result, most of the electric bicycle manufacturers who first entered the market originated from conventional bicycle production and focused on integrating motor and battery in existing bicycle design, in many cases classic women's bikes.

That is for instance the case for the Accell Group, today one of the market leaders of electric assist bicycles. Other conventional bicycle producers who are currently playing a role in the electric bicycle market are among others Biria, Diamant, Epple, Gazelle, Giant, Heinz Kettler, Helkama, Kalkhoff, Pantherwerke, Riese & Müller, Schwinn, Trek,...

In the last few years, the market is gaining momentum. On the one hand, new consumer groups become interested in electric bicycles and on the other hand, technical developments result in new products, which are appealing to these new groups. Furthermore, more and more European cities start to discourage private car usage and encourage more sustainable means of urban transport. The electric bicycle is an excellent alternative for car trips, whether these trips are for commuting, professional reasons, shopping, delivering goods, transporting children, tourism, leisure,...

As a result, new manufacturers enter the market, manufacturers who were previously not involved in the production of conventional bicycles and who are developing electric cycles for specific purposes and the corresponding user groups. Among them are Bion-X, Clean Mobile, Currie, OHM Cycles, Ultra Motor, Watt World.

One of the "oldest examples" of such a new entry is Flyer, a Swiss company that started to produce electric bicycles in 2001 and now has a prominent position in the market. They have traditional city models but also a tandem, a folding bike, a carbon bike, a sports series and a very compact city bike. They continue to broaden their offer, but for the EU they are restricted as a result of current legislation.

Another example of a "new entry" is Karbon Kinetics a UK based company founded by someone who previously worked for McLaren Cars. The company has developed the world's lightest production electric bicycle, which does no longer look like a conventional bicycle and which is aimed at 25 to 45 year old city professionals and their families. JD Components is a Taiwanese component manufacturer who has developed a pedal assisted bicycle with a very unique design and a lithium-polymer battery. Main Street Pedicabs is producing electric cycles in pedicab, truck, and delivery van configurations.

Finally there are companies that, before entering the electric bicycle market were addressing a niche market with special products, and now add an electric version to their offer. Dahon, specialises in folding bicycles and has now introduced a first electric folder. HP Velotechnik is a specialist recumbent manufacturer who also develops electric recumbents. Hase has launched an electric version of its Pino tandem, which is a combination of a conventional and a recumbent bike. Utopia

specialises in trekking bikes for cycling tourists. They have designed the eSupport, an electric kit to equip their existing range with electric pedal assistance.

Clean Mobile specialises in power-trains for cargo and load transport to 300 kg in combination with fuel cells (e.g. postal delivery) and off-road vehicles (mountain bike). Consequently, today there is an abundant range of models and designs available. Cargo bikes, recumbent bikes, folding bikes, mountain bikes, trekking bikes, ... all become available with electric pedal assistance.

A growing number of these vehicles have a unique appearance, which is a long way off the classical bicycle concept. What's more, manufacturers are becoming increasingly aware of the need to adapt their specifications to the specific use they are intended for. For instance, the requirements of a commuter using his bike for a daily sporty ride to and from work of, say, 15 km are completely different from the requirements of a postman who daily pushes a heavy load for several hours. The difference will not only pertain to the technical characteristics of the bicycle, but also to the performance of the electric assistance. The range and the output of the battery for instance will be far more important to the postman than to the commuter.

Another important development is that electric power is not only used to assist the cyclist with pedalling but also to charge other appliances. The Biologic Recharge by Dahon and the E-werk by Busch & Müller allow for the recuperation of power from a hub dynamo. This power can be used to charge cycling computers, mobiles, GPS, Ipods, etc. The Copenhagen Wheel has an electric motor that recuperates kinetic energy generated through braking and stores it in a battery. The cyclist can use the energy whenever he requires a little push in the back. By means of a series of sensors and a Bluetooth connection with the cyclist's telephone, the Wheel can monitor the speed, distance and direction of the cyclist. The system can gather information on pollution and show you the healthiest route. It also has a "smart" lock. If there is an attempt to steal the bicycles, the owner receives a warning by sms.



Gruber Assist is a very small and lightweight drive assist that supplies a boost on demand. It was originally designed to help mountain bikers in difficult climbs. As the Copenhagen Wheel shows, the concept of sporadic boosts may well be useful in various circumstances and for different types of cyclists.

Many people ask questions about, and are attracted to, the idea of an electric bike that can regenerate, or recharge itself. The idea behind this is that since an electric motor can be easily used as an electric generator, then using the electric motor in a "regenerating" mode could recharge the batteries either on down hills, or by the rider's pedalling effort.

In theory, this is possible. But in reality, there are a number of factors that diminish the usefulness of this concept. First, there are efficiency losses in the motor, the wiring, the controller, and particularly in the ability of the battery to accept a charge (most batteries simply cannot accept as much energy as the regenerating motor can create on a long downhill). That means that only a small

percentage of the energy created by the down hill run, or the rider's effort will make it back into the battery as useful energy that can propel the bike.

The motor must be able to be run by the mechanical effort of the wheel turning, which means that usually only a direct drive motor can be used. Also, the controller and battery management system must be configured for regenerating. So there is some extra cost, and some limits to what equipment can be used.

The amount of energy recovered by even the most efficient systems, under ideal conditions, amounts to only a few meters of extra range per trip, at best. Finally, to recharge the battery by pedalling is an arduous effort for all but the strongest of riders. Not really a practical idea. Carrying a charger and using it on the way is much more practical. Or pedalling more while on the bike. Even mild effort while pedalling will greatly extend range by decreasing the demand on the battery.

Technological factors

Electric-assist Bicycle

The electric bike also commonly described with the following terms: e-bicycle or bike with pedal assistance. In a parallel hybrid motorized bicycle, invented by Hosea W. Libbey in 1897, human and motor inputs are mechanically coupled either in the bottom bracket, the rear or the front wheel, whereas in a (mechanical) series hybrid cycle, the human and motor inputs are coupled through differential gearing. In an (electronic) series hybrid cycle, the evaluated, human power is converted into electricity and is fed directly into the motor and mostly additional electricity is supplied from a battery. This latest model developed in the late 1990s with torque sensors and power controls was patented by Takada Yutky in Japan. The speed sensor with the power regulator offers help only when the rider performs the action of pedaling.

Up to now the electric bicycles marketed use rechargeable batteries. Some of the cheaper electric bicycles used voluminous lead-acid batteries. While the new models used NiCd, NiMH or Li-ion batteries, the Li-ion give more lightweight and higher density of energy charge. Lead-acid and Cadmium are prohibited in the European market to be highly polluting. There are also experiments with electric double-layer capacitor and fuel cells.

Antecedent



The PHB is a hydrogen bicycle prototype, power-assisted by an electric motor that gets its electricity from a fuel cell. It is manufactured by Pearl (SPHPST.Co), unveiled at the 9th *China International Exhibition on Gas Technology, Equipment and Applications* in 2007. It uses a proton-exchange membrane fuel cell to generate about 200 Watts. It can reach approximately 25 km/h and, on a full tank may ride a distance of 60 to 100 kilometres. As stated by the manufacturer, those who already have a bike don't need to change the original frame structure, the fuel cell can be directly integrated into the original bicycle.

Alternative



Presented at Dec. 15, at the Copenhagen Conference on Climate Change, MIT researchers will debut the Copenhagen Wheel — a revolutionary new bicycle wheel that boosts power.

Toward this end, the Wheel can store energy every time the rider puts on the brakes, and then give that power back to provide a boost when riding uphill or to add a burst of speed in traffic.

The Wheel uses a technology similar to the KERS (Kinetic Energy Recovery System), which has radically changed Formula One racing over the past couple of years. When you brake, your kinetic energy is recuperated by an electric motor and then stored by batteries within the wheel, so that you can have it back to you when you need it. The bike wheel contains all you need so that no sensors or additional electronics need to be added to the frame and an existing bike can be easily retrofitted.

The initial prototypes of the Copenhagen Wheel were developed along with company Ducati Energy and the Italian Ministry of the Environment.

Conclusion:

This prototype is a serious competitor. In the absence of actual data with which to assess effectively. Its simplicity of use for the user, because avoid reloading and economic cost of this. In section ecological, produce their own clean energy of the kinetic braking, means disappearance of the environmental impact in the use phase and decrease in the life cycle. It is necessary to know performance and specifications, or better to obtain the necessary data directly with a real model to add in this study. As interesting alternative.

Lithium ion battery

The electric or electric accumulator battery is essentially based on a process called reversible reduction-oxidation, a process in which one component is oxidized losing electrons and the other component is reduced (gains electrons). Whose components do not result consumed or lost, merely change their oxidation state and that in turn can return to its original state in the right circumstances. A device that takes polarization achievable limits, and generally consists of two electrodes of the same or of different material, immersed in an electrolyte.

The lithium ion battery, also called Li-Ion battery is a device designed for storage of electrical energy which uses as the electrolyte, a lithium salt ions that procures required for reversible electrochemical reaction that takes place between the cathode and the anode. Lithium batteries were first proposed by MS Whittingham, used titanium sulfide (II) and lithium metal as electrodes. The cathodes containing polyanions (eg, sulfates), producing a voltage exceeding the oxides due to the inductive effect of the polyanion was shown by Arumugam Manthiram Goodenough and 1989. In 1991, Sony and Asahi Kasei released the first commercial Li-ion battery. The lithium ion batteries (Li-ion) currently use a graphite anode and a cobalt oxide cathode, trifilina (LiFePO₄) or manganese oxide.

Advantages:

- A high energy density: accumulate much greater load per unit weight and volume.
- Light weight: With the same charge stored, are lighter and take up less volume than Ni-MH and much less than Ni-Cd and Lead.
- Large discharge capacity. Some Li-Ion-calls "Lipo" Polymer Lithium-ion (lithium ion polymer). On the market that can be downloaded completely in less than two minutes.
- Shortly thickness: Presented in rectangular plates, with less than 5 mm thick. This makes them particularly attractive for integration into portable devices that should be low thickness.
- High voltage per cell: Each battery provides 3.7 volts, the same as three Ni-MH or Ni-Cd (1.2 V each).
- Have no memory effect.
- Linear discharge: Throughout the discharge, the battery voltage varies little, thereby avoiding the necessity of regulating circuits. This is an advantage because it very easy to know the stores charge in the battery.
- Long life batteries for electric vehicles professionals. Some manufacturers show data from more than 3,000 charge/discharge capacity at a pressure of 20% to C/3.
- Easy to know the store load. Simply measure, at rest, the voltage of the battery. The stored energy is a function of the measured voltage.
- Very low self discharge rate: When we keep a battery will discharge progressively but not use it. In the case of Ni-MH batteries, this "self-discharge" can mean more than 20% per month. For Li-Ion is less than 6% in the same period. Many of them, after six months at rest, can retain 80% of their charge.

Disadvantages:

- Average length: depends on the amount of charge stored, regardless of use. They have a lifespan of about three years or more if stored with 40% of its maximum load (actually, any battery, regardless of technology, if stored unloaded deteriorates. Enough to recall the sulfation process happened in the old zinc-carbon batteries when stored at fully discharged).
- Support a limited number of charges: between 300 and 1000, less than a nickel cadmium and equal than Ni-MH, so start to be considered in the category of consumables.
- Can overheat until explode: flammable materials are made which makes them prone to explosions or fire, for this is necessary to provide the electronic circuits for control the temperature at all times.
- Worse cold working capacity: offer underperformed the Ni-Cd or Ni-MH at low temperatures, reducing its length until 25%.
- Contains heavy metals and chemical compounds, many of which are harmful for the environment.

Fuel cell

Another energy source on experimentation process is the fuel cell, also called cell or fuel cell is an electrochemical device converting energy similar to battery, but differs from the latter in that it is designed to allow continuous replenishment of reagents consumed, that is produces electricity from an external source of fuel and oxygen as opposed to the limited storage capacity of energy possessed a battery. In addition, electrodes in a battery react and change according to how it is charged or discharged, whereas in a fuel cell electrodes are catalytic. If it is a hydrogen cell, the reagents used in a typical fuel cell are hydrogen in the anode side and oxygen on the cathode side. Is obtained because in a proton exchange membrane cell (or polymer electrolyte) hydrogen/oxygen in a fuel cell (PEMFC: proton exchange membrane fuel cell), a polymer membrane conducting proton (electrolyte), separates anode side from the cathode side.

On the anode side, the hydrogen in contact with anode catalyst, dissociates into protons and electrons. The protons are transferred through the membrane to the cathode, but electrons are forced to travel through an external circuit (energy producing) as the membrane is electrically insulated. In the catalyst of the cathode, oxygen molecules react with electrons (conducted through the external circuit) and protons to form water. The only residue is water vapour or liquid water. Humidifying the membrane is important for the protons to pass through it, because the proton conductivity of the polymer membranes used in this type of batteries depends on the humidity of the membrane. Therefore, it is usual humidify gases prior to entry into the battery.

The cell voltage depends on the charging current. The voltage in open circuit is 1.2 volts, to create sufficient voltage combining, the cells are grouped in series or in parallel, series produces a higher voltage and parallel produces a more current "Fuel Cell Stack".

Addition to electricity, fuel cells produce water and heat, depending on the fuel source, very small amounts of nitrogen dioxide and other emissions. The energy efficiency of a fuel cell is generally between 40-60%, or up to 85% effective if the residual heat is captured for use.

In this type of fuel cell, the membrane must be hydrated, requiring water that evaporates at precisely the same speed as produced. If the water evaporates too quickly, dry the membrane, the electrical resistance through it increases, if finally is consumed the water creates a short circuit, where the hydrogen and oxygen directly combine and the heat generated, damage the fuel cell. If the water evaporates slowly, the electrodes is flooded, preventing that reagents pass the catalyst and the reaction stops. Methods for water management in the cell is being developed as electro-osmotic pumps, are concentrated on flow control. As in a combustion engine, a constant reaction between the reagent and the oxygen is necessary to maintain the efficiently operating inside fuel cell.

The same temperature must be maintained throughout the cell in order to prevent destruction of the cell through thermal loading. This is particularly challenging as the $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ reaction is highly exothermic, so a large quantity of heat is generated within the fuel cell.

Difference with battery:

Proton exchange membrane fuel cell

Proton exchange membrane fuel cells, also known as polymer electrolyte membrane (PEM) fuel cells (PEMFC), are cell type developed for fuel transportation applications and portable stations due to its compactness. Its distinctive features with respect to the other membranes are its low temperature and pressure ranges (50°C to 100°C), typically 80°C, and especially because the electrolyte membrane is a polymer.

To function, the membrane must carry out the exchange of hydrogen ions (protons), but not of electrons because this would have the effect of short circuit in the fuel cell. The membrane must also prevent gas to pass Through it, a problem known as gas crossing. Furthermore, the membrane

should be resistant to the reducing environment at the cathode as well as the harsh oxidative environment at the anode.

The platinum catalyst on the membrane is easily poisoned by carbon monoxide (no more than one part per million is generally acceptable) and the membrane is sensitive to metal ions can be introduced by corrosion of metallic bipolar plates, metal components system or contaminants in the fuel oxidant.

The pure hydrogen gas is not economical to produce in mass by electrolysis or other method. Instead, hydrogen gas is produced by steam reforming light hydrocarbons, a process which produces a mixture of gasses that also contains CO (1–3%), CO₂ (19–25%), and N₂ (25%). Even tens of parts per million of CO can poison a pure platinum catalyst.

The practical efficiency of a PEM's is in the range of 40–60% using the Higher Heating Value of hydrogen (HHV). Main factors that create losses are:

- Activation losses
- Ohmic losses
- Mass transport losses

Social

This guideline deals with electric-assist bicycles which are equipped with an auxiliary electric motor having a maximum continuous rated power of 0.25 kW, of which the output is progressively reduced and finally cut off as the vehicle reaches a speed of 25 km/h, or sooner, if the cyclist stops pedalling only.

Potential user groups

To date, there is little research into the background of the existing consumer for electric-assist bicycles. The available studies show that the majority of electric-assist bicycle users can be classified in two main groups: 65+ people and commuters. Nevertheless, the average age of electric-assist bicycle buyers is decreasing. This is likely to be the result of a growing number of commuters using electric-assist bicycles and/or new target groups discovering this new means of transport.

The Dutch report “Rapport Elektrisch Fietsen – Marktonderzoek en verkenning toekomstmogelijkheden” (Electric Cycling: market research and exploration of prospects) was published in June 2008³⁸. It was based on 1,448 questionnaires. At that time, 3% of the Dutch population owned a electric-assist bicycle, yet over 40% of the Dutch people indicated (possible) interest in the product.

Those who used electric-assist bicycles cycled faster, more often and over longer distances. Consequently, they made less use of the conventional bike and of the car.

At the time of the research, the respondents thought that electric-assist bicycles were mainly fit for elderly and physically impaired people, whereas they found electric-assist bicycles less suitable for other target groups such as commuters or parents with young children.

Reason for using a electric-assist bicycle	Users	Interested
Conventional cycling is (too) difficult	66%	12%
Conventional cycling may become too difficult	NA	65%
To make cycling with headwind easier	52%	36%
To be able to cycle over longer distances without (much) extra effort	46%	33%
To make it easier to climb hills	29%	19%
I am not very sporty but I would like to have (some) more exercise	17%	NA
To cycle faster (less travel time) without (much) extra effort	11%	13%
As an alternative for less environmentally-friendly means of transport	10%	20%
To get to work without sweating	8%	7%
Other reasons	4%	1%
No opinion	NA	8%

Remarkably enough, one out of 5 respondents were interested in electric-assist bicycles for environmental reasons.

³⁸ Hendriksen Ingrid, Engbers Luuk, Schrijver Jeroen, van Gijlswijk Rene, Weltevreden Jesse (BOVAG), Wilting Jaap (BOVAG), 2008, “Rapport Elektrisch Fietsen – Marktonderzoek en verkenning toekomstmogelijkheden”.

The respondents in the Belgian study “De elektrische fiets als duurzame mobiliteit in steden” (the electric bicycle as sustainable mobility in cities)³⁹ had a quite different view on the potential users of electric-assist bicycles. They were asked who, they thought, was the most typical electric-assist bicycle user:

Most typical electric-assist bicycle user	
Commuters	61.4%
Elderly people	32.5%
Less sporty people who want to exercise more	24.9%
People who live in a hilly area	12.7%
Everybody	11.7%
Physically impaired people	10.7%
Sporty people	6.6%
Shoppers	5.6%
People who want to cycle without too much effort	4.6%
Employees in suits	3.6%
People who live in a flat area	3.6%
Long distance cyclists	1.5%
Students and daredevils	1.5%

In 2009, the bicycle and car accessory retail chain Halfords carried out an on-line survey,⁴⁰ which received over 500 responses. 37% of the respondents would consider buying a electric-assist bicycle to cycle more easily, whilst 28% was interested because it might help them to get fitter. To the question which characterisation applies best to electric-assist bicycles, 60% indicated “comfortable”, 59% “easy” whereas 36% opted for “modern”. According to Halfords, the average age of electric-assist bicycle buyers was at that time around 50.

Since a few years, the Swiss Canton Basel-Stadt grants subsidies to electric-assist bicycle purchasers, provided that they add a complete questionnaire to the subsidy request. Between 2003 and 2008 they received 634 completed questionnaires. This has allowed the Canton to draw up a profile of the average electric-assist bicycle user, which was published in October 2008.⁴¹

Electric-assist bicycle users in the Canton Basel-Stadt were on average 49 years old. There was an equal distribution between men and women, but in the age group 20 to 39 women had a greater share, whereas among 65+ men were over-represented. Their level of employment was very high, unemployed electric-assist bicycle users were underrepresented. Both their gross income and their education level were above average. They lived in bigger households than the rest of the Basel population.

Nevertheless, over the research period the following changes have been observed among

39 Capelle Jan, Lataire Philippe, Magetto Gaston, Timmermans Marc, “De elektrische fiets als duurzame mobiliteit in steden”, Vrije Universiteit Brussel.

40 <http://www.tweewieler.nl/nieuws/1591/e-bike-krijgt-steeds-jonger-koperspubliek.html>

41 Schwegler Urs, et al., 2003, “Auswirkungen elektrischer Zweiräder auf das Mobilitätsverhalten. Schlussbericht des Schweizer Projekts im Rahmen von: Electric Two-Wheelers On Urban Roads (E-TOUR, Eu-Rahmenprogramm)“, University of Bern.

Basel electric-assist bicycle users:

- increasing share of female buyers
- increasing average age
- decreasing level of employment
- decreasing level of education and gross income
- whereas in 2003, 98% of the buyers had a car driver's license, in 2008 that was 82%

Conclusion: the demographic mix of people who buy a electric-assist bicycle is broadening.

Since a number of years, sales of electric-assist bicycles in the EU are steadily increasing. Whereas the numerical growth of the electric-assist bicycle market is apparent, it is much more difficult to prove the growing popularity of the vehicle among different sections of the population. Available research clearly shows a significant interest among elderly, physically impaired and commuters. Although this means of transport is very suited for many other target groups, they have not yet been mapped in any research. Study of relevant literature allows for the distinction of the following target groups.

1 Car drivers:



According to the European Commission's Statistical Pocketbook 2001 "EU Energy and Transport in Figures", every European makes circa 3 trips per day of which about half are up to 3 km. Moreover, about half of all car trips are 6 km or shorter. These figures clearly demonstrate that the potential for substituting car trips by cycling is huge.

The electric bike is particularly appropriate for convincing die-hard car drivers to leave their vehicle aside for short distances because it overcomes a number of "popular" objections against cycling. As shown in the table above, interest in electric-assist bicycles springs to a large extent from the fact that cycling is made easier and more comfortable.

All research so far shows electric-assist bicycles are used as an additional means of transport without however generating additional traffic. The Swiss study "Elektro-Zweiräder – Auswirkungen auf das Mobilitätsverhalten" (Electric Two-Wheelers – Effects on Mobility) shows that the use of electric-assist bicycles resulted in 5.2% less car kilometres. What's more, the study has found that electric-assist bicycles incite people to think about routines in their transport behaviour.

Therefore, it concludes with the following recommendations: "The use of LEVs should be encouraged. (...) LEVs question the traditional approach to mobility. LEV encouragement should

particularly focus on heavily motorised households.”^{42,43}

A 2008 special Eurobarometer on attitudes towards the environment⁴⁴ shows that European citizens attach great value to the environment and are increasingly aware of the role that the environment plays in their lives. Asked about the actions they take for environmental reasons, 28% indicate choosing an environmentally friendly way of traveling (foot, bicycle, public transport). In Finland, Sweden, the Netherlands, Denmark, Slovakia and Hungary, this percentage is more than 40%. Of the EU-27 respondents, 17% indicate less car usage as an action for the environment. In Luxembourg, Finland, France, Belgium, Germany and the Netherlands more than 1 out of 4 respondents mention this action. A 2007 Flash Eurobarometer on European transport policy⁴⁵ shows that 56% of the EU-27 respondents tried to save fuel by walking or cycling more.

In conclusion, the growing concern for the environment and the rising cost of car usage clearly creates opportunities to convince car drivers of swapping their car for an electric bike for certain trips.

2 Commuters:



Commuters opt for the car rather than for the bike as soon as they have to travel more than 7 kilometres. The average speed of an electric bike is 24 km/h, compared with 17 km/h on a traditional bike. Since electric bikes make rides easier (no transpiration) and quicker, commuter

42 Schwegler Urs, et al., 2003, “Auswirkungen elektrischer Zweiräder auf das Mobilitätsverhalten. Schlussbericht des Schweizer Projekts im Rahmen von: Electric Two-Wheelers On Urban Roads (E-TOUR, Eu-Rahmenprogramm)“, University of Bern.

43 LEV = light electric vehicle – the study concerns electric two, three and four-wheelers, e-bikes in this instance means any bicycle equipped with an auxiliary electric motor.

44 European Commission, Directorate General Environment, 2008, “Attitudes of European citizens towards the environment”, Special Eurobarometer 295.

45 European Commission, Directorate General Energy and Transport, 2007, “Attitudes on issues related to EU Transport Policy - Analytical report”, Flash Eurobarometer 206b.

trips up to 15 km one way are within reach. Employers can incite their employees to use a electric-assist bicycle for commuting, for instance by participating in existing tax incentive schemes such as allowances for commuting by bike or company bikes, by including electric-assist bicycles in mobility plans or by leasing electric-assist bicycles. In 2009, Riese und Müller⁴⁶ was the first manufacturer to offer a leasing scheme for their electric-assist bicycles. Furthermore, there are companies specialised in leasing electric bikes, such as Electric Bikes Fleet⁴⁷ (UK) or Electric Bikes Lease⁴⁸ (NL).

Electric-assist bicycles are accessible for all types of commuters. They make cycling easy, regardless of fitness level or physical condition. They enable riders to tackle hills and headwinds without minimal effort. A electric-assist bicycle can easily reach an average speed of 20 km/h, which is significantly more than the average speed of cars or public transport in city traffic. They can zip to work without needing a shower on arrival. The use of a electric-assist bicycle will improve their physical condition, which in turn results in fewer sick leaves.

3 Parents and Shoppers:



Motivated also by the price of fuel and the lack of space in cities with high population density. The electric-assist bicycle solve the problem of carrying weight, whether it concerns a child in a seat on the carrier, bags, a trailer,... Including bikes and cargo bikes were installed an electric assist kit that help people ride their bike more and use cars less. As external factors have led to consumers to find alternatives on the market. Manufacturers begin to develop specific electric-assist for this purpose, for instance carrier cycles with pedal assistance or electric cargo bikes.⁴⁹

46 <http://www.r-m.de/produkte/leasing/>

47 <http://www.electricbikesfleet.co.uk/>

48 <http://www.eb-lease.nl/>

49 Giddings Morgan, "*A Quiet Revolution in Bicycles: Recapturing a Role as Utilitarian People-Movers (Part I)*", published on www.chrismartenson.com

4 Professional groups, Emergency services and Civil servants:



Home delivery is becoming fashionable again. Grocers, bakers, butchers, fishmongers, ... redevelop this service to the customer in an attempt to distinguish themselves from their competitors and to improve their customer relations. Whereas in earlier days, they would have used a moped, today a electric-assist bicycle will prove to be just as fast and effective whilst being clean and quiet. This in turn will have a positive contribution to the social responsibility of the company. In the meantime, the pizza-boys and all other food home delivery services are abandoning mopeds for the benefit of electric-assist bicycles.

Lawyers, bankers, real estate agents, doctors and couriers are also putting electric-assist bicycles in use to make their professional trips faster, more reliable and enjoyable. During the Copenhagen Climate Conference 2009, the Avenue Hotel made electric-assist bicycles available to their guests with a view to helping them “greening” their stay. This is only one of a growing number of hotels that have a fleet of electric-assist bicycles available for their customer, which mainly exists of business people. The electric-assist bicycles allow them to get to their meetings on time. With that, new companies are emerging that offer electric-assist bicycle fleets not only to hotels but also to companies, tourist businesses, local councils.

The very first ambulance electric-assist bicycle was shown at the Dutch national electric-assist bicycle test day in 2008⁵⁰. Since, several models have been introduced and purchased. They are very robust bicycles equipped with cases that hold life support equipment. They are put into action in two different situations. During large events such as concerts, fairs, sports events, the ambulance electric-assist bicycle is used for first aid. Large companies where first-aiders sometimes have to walk a considerable distance to reach the injured also show interest in this vehicle.

Alternatively, they are used in urban areas where either car usage is hindered or where traffic is extremely dense. A electric-assist bicycle ambulance provides speed and access so that acute first-aid can be given, even if in expectation of a four-wheeled ambulance to take the patient to hospital.

Police officers patrolling by bike are becoming a very familiar sight in more and more European

⁵⁰ <http://fietsen.web-log.nl/fietsen/2008/05/wereldprimeur-e.html>

cities. The bicycles are easy to manoeuvre, quiet and allow for a fast pursuit irrespective of the terrain or traffic. More importantly, bicycles contribute to their image and they are considered more approachable than their colleagues in cars.

Quite a number of voluntary firemen use a bicycle when they receive an emergency call because this is the fastest means of transport to their station. Moreover, firemen involved in prevention also use two wheels to call on visit.

There are specific electric-assist bicycles on the market for police forces as well as for firemen. They make their job easier and they speed up their interventions.

Many postal services in the EU already have electric-assist bicycle on the road, among which in Germany, UK, Finland, the Netherlands, Denmark, France, Italy and Austria. In 2009, the Belgian “De Post” has come to an agreement with WWF on 35% less CO² missions by 2010. Consequently, De Post is now testing electric-assist bicycle with a view to replacing their current fleet of mopeds.⁵¹

The Eco-Management Audit Scheme (EMAS) working group of the European Parliament has decided to supplement the service bicycle fleet with one electric-assist bicycle in Brussels and Luxembourg as a test.

Of course, electric-assist bicycle for services need to be specifically designed for their heavy duties. Several companies have such models in their range. These extra strong electric-assist bicycles are equipped with special features such as racks and bags to carry, a special stand and a stabiliser to prevent the front wheel from tilting during standstills.

7 People with 65+ and Health Problems:



In 2008, 17.1% of the population in the EU-27 was aged 65+, that is 84.6 million people (source: Eurostat). Many of them become less mobile as they age. As a result of failing strength and a deteriorating condition, they are no longer capable of cycling. Electric-assist bicycles allow this age group to remain mobile and fitter for a longer time. Also, there are models available, which are

⁵¹ <http://www.wwf.be/NL/?inc=news&newsid=728&pageid=news>

specifically designed for this group, for instance electric-assist bicycles with a step-through frame and electric three wheelers.

The Dutch report “Electric Cycling: market research and exploration of prospects” shows that 89% of the 65+ people who own a electric-assist bicycle, use it for recreational trips, 68% for shopping and 47% for visiting. This shows that electric-assist bicycles are effectively used as a means to safeguard their mobility and to maintain their independence and their social inclusion.

The Swiss study « Evaluation d’impact sur la santé Promotion du vélo à assistance électrique »⁵² (Evaluation of the impact on health of the promotion of electric-assist bicycles) concludes that electric-assist bicycle use helps to prevent cardiovascular diseases, hypertension, diabetes type II and colon cancer. As a result, electric-assist bicycle use helps to reduce the general cost of the health system. Apart from the preventative function of electric-assist bicycle use, the vehicles are also extremely well suited to allow people suffering from chronic diseases to continue to exercise or to rehabilitate. This is the case for patients with multiple sclerosis, cancer, obesity, cardiovascular diseases, etc.

9 Tourists



Cycling tourism in Europe is becoming increasingly popular. The Dutch polders, the Loire region or the cycling path along the Danube are suited for the overall majority of cyclists. The Alps, Abruzzo or the Dolomites however are reserved to the very well trained cyclists or to those who enjoy electric-assist bicycle.

Little by little tourist businesses in hilly or mountainous regions discover the potential of electric-assist bicycles to achieve sustainable tourism. They put electric-assist bicycles up for rent, develop specific cycling routes and create spots where cyclists can charge their batteries. The Swiss manufacturer of the Flyer electric bicycles has developed the Movelo programme,⁵³ fully organised electric bike holidays in Germany, Austria and Mallorca.

In 2009, the first edition of “La Montée Electrique”⁵⁴ (the electric ascent), more specifically of Alpe d’Huez took place. The organisers all are fanatic supporters of environmentally-friendly transport. Their event is aimed at making the electric bicycle better known as a clean vehicle that is accessible to everybody.

⁵² Cantoreggi Nicola, Diallo Thierno, 2006, “*Evaluation d’impact sur la santé Promotion du vélo à assistance électrique (VAE)*“, République et canton de Genève, Département de l’économie et de la santé, Direction générale de la santé.

⁵³ <http://www.movelo.com/elektrofahrrad/>

⁵⁴ <http://www.la-montee-electrique.com/>

City trips by electric-assist bicycle are bound to prosper. The organisation “Paris Charms & Secrets”⁵⁵ is probably one of the trailblazers paving the way for many more electric city tours in Europe to come.

The importance of tourism use of electric-assist bicycles for their acceptance as a utilitarian means of transport should not be underestimated. Many people have their very first electric-assist bicycle experience during their holidays. Once they have been introduced to the vehicle and “felt” it, an interest may start to grow. Furthermore, tourism makes electric-assist bicycles visible.

Short distance passenger mobility in Europe

Highlights

Passenger mobility statistics are presently not covered by the European Statistical System. However, in a number of European countries, short and long distance passenger mobility surveys exist. These surveys are designed for national purposes and there are presently no agreed standards for conducting comparable and reliable surveys.

The national travel surveys collect information from a sample of population contacted by phone or mail and asked to answer a certain number of questions focusing on their travelling behaviour during a fixed period prior to the moment when each respondent answers the mobility questions. It is possible to make some analyses for those countries where data exist (BE, DK, DE, ES, FR, LV, NL, AT, PT, FI, SE, UK, NO and CH), although the methodological differences between countries’ surveys do not allow a full comparison of the results obtained.

Table 1: Main characteristics of short distance passenger mobility

Country	Year	Population covered - age	Average number of trips / person / day	Average travel distance (km) / person / day	Average total travel time (min) / person / day
BE	1999	> = 6	3.0	:	:
DK	2001	10 - 84	2.3	30.1	40.7
DE	2002	> = 10	3.5	38.5	79.2
ES*	2000	All	1.9	:	46.0
FR	1993-1994	> = 6	2.9	35.3	58.2
LV	2003	> = 6	1.9	8.7	13.0
NL	1998	All	3.4	33.6	66.1
AT	1995	> = 6	3.0	28.1	68.8
FI	1998-1999	> = 6	2.9	45.8	84.3
SE	2001	6 - 84	2.8	44.2	:
UK	1999-2001	All	2.8	29.9	59.2
NO	2001	> = 13	3.1	37.0	62.0
CH	2000	> = 6	3.6	47.6	88.8

*: For ES, the data correspond to an average working day. The figures for an average weekend day are 1.3 trips and 39 minutes per person per day.

Source: National travel surveys

In order to assess the main characteristics of short distance mobility, the average number of trips per person per day, the average travel distance per person per day and the average total travel time per person per day are relevant indicators that are generally gathered. Despite the heterogeneity of short-distance passenger mobility statistics, these indicators have the same order of magnitude for the available countries. When focusing on the main transport modes used to travel, it appears, unsurprisingly, that people mostly use passenger cars for their trips, with the exception of Latvia, where nonmotorised private transport (cycling and especially walking) and public transport are equally resorted to. With regard to trip purposes, trips devoted to work or school are the most frequent.

Nevertheless, travel information can also be drawn from the knowledge of people’s daily activities, linking mobility behaviour with the use of time and resources. When studying Harmonised

⁵⁵ <http://www.parischarmssecrets.com/>

European Time Use data, which is an alternative source of information based on a different methodology, it appears that among people aged 20 to 74, men spend more time on daily travel than women and that the amount of time spent travelling decreases gradually with age.

National Travel Surveys: a heterogeneous source of information

Passenger mobility statistics are presently not covered by the European Statistical System. However, measurement of passenger travel behaviour is becoming more and more important for the Community and national transport policies, as well as for environmental policies. Information is needed on the average number of journeys taken by households or persons, on distances travelled, on differences in passenger mobility between age groups and household types, on the transport modes or combinations of modes used and on the travelling purposes. In a number of Member States short and long distance passenger mobility surveys exist. These surveys are designed for national purposes and there are presently no agreed standards for conducting comparable and reliable surveys at an EU level.

In this context a survey on long distance mobility within the 5th Transport R&D Framework Programme (Dateline project) was started, managed by the Directorate General for Energy and Transport of the European Commission. This project started in 2001 and one of the results is a database which is comparable for all Member States and produces results at a European level, based on a uniform methodology. Since June 2003 this database is available free of charge on the DATELINE Web Site: <http://cgi.fg.uni-mb.si/elmis/>. The Dateline project surveys all journeys exceeding 100 km in a straight line. A journey is defined in this project as a series of trips starting and ending at home or a temporary location. Journeys that include a destination more than 100 km away from the reference location (normally home) are long-distance journeys. The 100 km limit is a generally accepted standard to distinguish long and short distance mobility. As regards short distance or daily mobility, this kind of general survey design applied in all Member States does not exist. Nevertheless, a Passenger Transport Statistics Working Group was set up by Eurostat to support the development of Community passenger transport statistics. Its objectives were to give expert support to Eurostat in methodological and technical questions and to support it in the establishment of a first passenger mobility database covering the Member States. The database should include meta-information

on existing sources of information and a network of expertise, modal passenger transport statistical data as well as passenger mobility statistical data of Member States and EFTA countries collected under common and harmonised definitions. In practice, the database has been limited to an ad hoc collection of data and metadata files in different standard formats.

All available information related to the latest national surveys is listed in Table 2. As shown in this table, this kind of survey is performed in a limited number of countries.

According to the available information, it is obvious that the statistics of national travel surveys are not easily comparable in their current form. The information collected and the definitions used are not exactly the same in all the countries and the figures are not obtained in the same way. As an example, trips abroad, trips undertaken off public roads or even walking trips with duration inferior to ten minutes can be, according to the country, included or not in its travel survey. Also, a trip distance can be assessed either according to the true distance covered by the traveller or in a straight line between the origin and the destination of the trip. To further illustrate the disparities between countries, different methods to make the sample representative of the whole population and to correct or minimise the effects of non-response have been used. Furthermore, the heterogeneity of reference years and data collection periods in the different national surveys makes this lack of comparability even more difficult. Older data from some countries such as France (1994) and

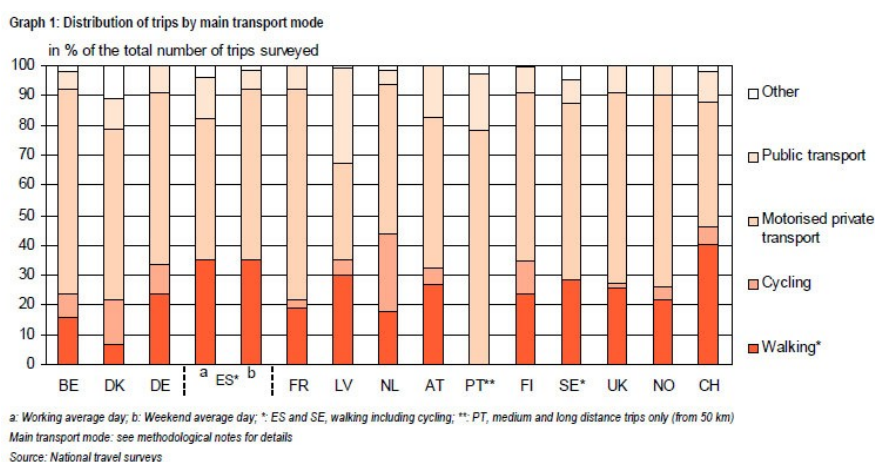
Austria (1995) can not be properly compared to more recent data from other countries. Finally, the indicators judged most relevant to establish passenger mobility statistics are not the same for all countries. Despite the heterogeneity of the available data, it is nevertheless possible to make some analyses for those countries where data exist. However, all these methodological differences between countries' surveys have to be borne in mind when analysing the figures presented in this publication.

Table 1 shows the main characteristics of daily passenger mobility for thirteen countries. In the case of Portugal, although a medium and long distance mobility survey has been done, the same kind of information was not available. These results come from the raw data provided by the countries and concern all daily trips, disregarding the distances travelled. Most of the countries (BE, ES, FR, NL, AT, FI, SE, UK, NO and CH) are also interested in the results of long-distance mobility, but the related trips are surveyed separately: long-distance trips are, as defined above, trips of at least 100 km distance, except for Belgium (at least 200 km), Austria (at least 50 km) and the United Kingdom (at least 80 km). From Table 1, it can be seen that the indicators have the same order of magnitude for the available countries. The average number of trips per person per day goes from 1.9 in Spain (in an average working day) and Latvia to 3.6 in Switzerland. As regards the average travel distance and travelling time per person per day, in Latvia (8.7 km and 13 min) they are clearly lower than in other European countries, while Switzerland presents the highest figures (47.6 km and 88.8 min).

Why and how do people travel?

This section gives some further details on the reasons why people travel and which transport modes are mostly used. Portugal is included in the different analyses, even if the results for this country do not correspond to short-distance mobility but to medium and long-distance trips longer than 50 km.

In a passengers' mobility study the modes of travel are obviously classified, but it is first necessary to determine which is the main mode used during a trip or journey, i.e. the mode used for the longest part of the trip or journey. One way to group the modes of transport is to consider the three following categories: non-motorised private transport (i.e. walking and cycling), motorised private transport (i.e. passenger car – as driver or passenger –, moped and motorcycle) and public transport (i.e. bus/coach, rail, air and water).



According to Graph 1, motorised private transport and more particularly passenger car is by far the most used transport mode. It represents more than two thirds of all trips in Belgium, France and Portugal, even though for Portugal the high share of trips made by car can also be explained by the

fact that only trips of at least 50 km were registered. Nevertheless, the high predominance of car can be seen in all the countries, except in Latvia where non-motorised private transport, accounting for 35% of all the trips, is the most used

mode, just ahead of motorised private transport and public transport, which represent almost the same proportions (around 32%). The Netherlands and Switzerland, with about 45%, registered the highest proportions of trips undertaken with non-motorised private transport, whilst in Denmark and France this transport mode accounted for 22% of all trips. In Switzerland trips made walking represent 40%, which is clearly greater than in other countries. Latvia, which displays the second highest percentage of walking trips, just reaches 30%. Danish people are those who walk the least, this mode accounting for only 7% of all their trips. In Netherlands it is cycling (26% of all trips) that contributes most to the importance of nonmotorised private transport ahead of walking (18% of all trips). Denmark, despite its low share of nonmotorised private transport, follows the Netherlands as regards the use of cycling, with 15% of all trips. France and the United Kingdom are the countries which use this mode least, with 3% and 2% respectively of their total trips. Finally public transport accounts for less than one fifth of trips in all countries except Latvia.

Table 3: Distribution of trips by main purpose

<i>in percent</i>	BE	DK	DE	ES*	FR	LV	NL
Escort	13.9	-	-	8.3	-	3.6	-
Work/school	27.2	29.2	26.0	53.1	33.9	49.9	26.3
Shopping/personal business	28.0	29.2	40.6	8.2	32.7	22.8	23.3
Leisure	30.3	29.2	33.3	18.6	33.3	15.2	32.7
Other	0.5	12.5	-	11.8	-	8.5	17.7
Total	100	100	100	100	100	100	100

<i>in percent</i>	AT	PT	FI	SE	UK	NO	CH
Escort	-	-	-	-	12.6	13.0	4.8
Work/school	47.3	44.2	29.6	31.9	25.3	22.0	35.5
Shopping/personal business	21.3	7.2	21.3	21.2	31.3	25.0	19.1
Leisure	29.0	44.6	49.1	34.0	26.5	30.0	39.5
Other	2.4	4.0	-	12.9	4.3	10.0	1.0
Total	100	100	100	100	100	100	100

* For ES, the figures of the table correspond to a working average day. The figures for a weekend average day are 4.0%, 9.5%, 9.3%, 63.1% and 14.1% for escort, work/school, shopping/personal business, leisure and other respectively.

Main trip purpose: see methodological notes for details.

Source: National travel surveys

Looking at the purposes of trips, those devoted to work or school are the most frequent. They range from 22% of all the trips in Norway to half of the trips in Spain (in a working average day) and Latvia (see Table 3). In the other countries they account for around 30% of all trips. Leisure activities are the second most important purpose for travel. Leisure trips account for around 30% in all countries except in Spain (19% in a working average day, though this kind of trip reaches 63% in a weekend average day), Latvia (15%), Portugal (45%), Finland (49%) and Switzerland (40%). The proportion of trips related to shopping or personal business varies greatly across the different countries, from 7% in Portugal to 41% in Germany. Escorting people, which is a reported purpose in six countries (BE, ES, LV, UK, NO and CH), always accounts for less than 14%.

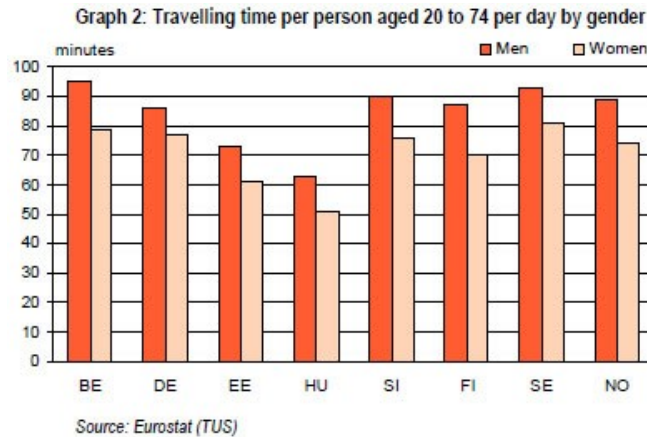
Harmonised European Time Use Surveys: how long do people spend travelling?

The National Travel Surveys collect information from a sample of population contacted by phone or mail. The sampled persons are asked to answer a certain number of questions focusing on their travelling behaviour during a fixed period prior to the moment when each respondent answers the mobility questions. Nevertheless some countries, like the United Kingdom, use a different method and ask the surveyed population to complete a travel diary for a fixed number of days (see Table 2 for details). In fact, conceptually, travel corresponds to only one of many possible activities that can be carried out during a day. Hence, travel information can be drawn from the knowledge of people's daily activities. Moreover, analyses based on activities can link mobility

behaviours with the use of time and resources.

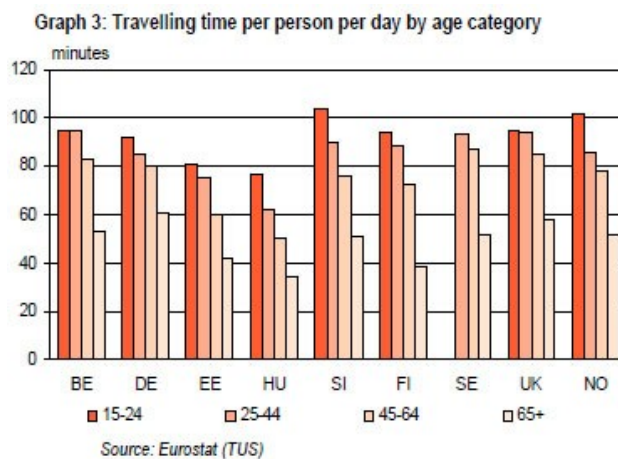
This explains the interest in considering Harmonised European Time Use Surveys in order to extract information on daily trips.

Time Use data are an alternative source of information based on a methodology different to that used in the framework of travel surveys. Thus, the results presented for the 10 countries covered by the Time.



Use surveys are not comparable with those presented in the previous sections.

According to available information related to mobility behaviours, people aged 20 to 74 spend, on average, between one hour and 90 minutes per day travelling. In Estonia and Hungary people spend least time travelling. According to the country, men spend between 63 and 95 minutes on daily travel (see Graph 2). In all the surveyed countries, women spend less time on travel than men. On average, men travel 13 minutes more than women do per day.



The amount of time spent travelling is highest among young people and decreases gradually with age (see Graph 3 on the previous page). Retirement means a clear drop in travel time. Mobility difficulties increase with age, which might also explain this drop. This trend is similar among women and men, even though the reduction appears slightly clearer for women.

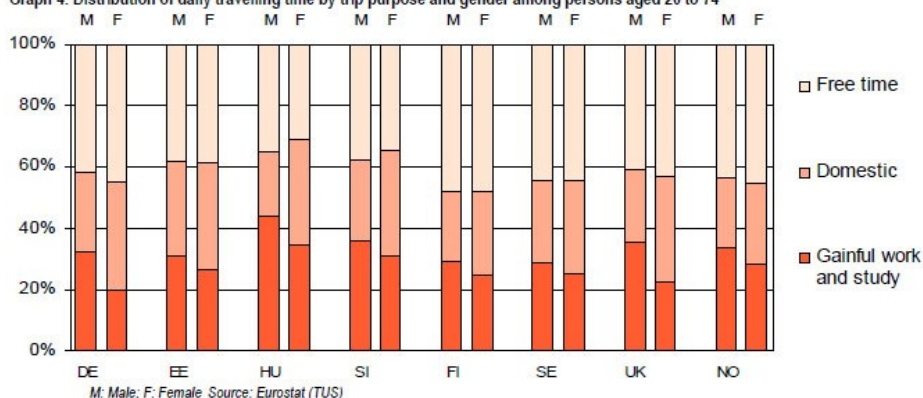
Table 4: Time spent on daily travel by gender and by mode of travel among persons aged 20 to 74

	BE	DE	EE	HU	SI	FI	SE	UK	NO
Total	Minutes per day								
Car, motorcycle	58	54	21	14	44	49	52	53	56
Public transport	9	12	16	16	6	13	13	12	11
On foot or bicycle	18	18	27	25	29	14	19	18	14
Unspecified mode	2	1	3	1	4	2	3	5	3
Travel total	87	81	67	57	83	78	87	87	81
Men	Minutes per day								
Car, motorcycle	65	60	30	21	52	61	60	57	63
Public transport	10	12	14	16	4	12	14	12	12
On foot or bicycle	18	16	25	24	28	11	16	16	14
Unspecified mode	2	1	4	1	5	2	4	6	4
Travel total	95	86	73	63	90	87	93	90	89
Women	Minutes per day								
Car, motorcycle	52	48	13	9	36	38	44	49	48
Public transport	8	12	17	16	7	13	12	12	11
On foot or bicycle	17	19	28	26	30	17	22	18	15
Unspecified mode	3	1	3	0	4	2	3	5	2
Travel total	79	77	61	51	76	70	81	85	74

Source: Eurostat (TUS)

Regarding the modes of travel used, the car represents more than half of total travel time in all the countries except Estonia and Hungary, where it represents less than one third of travel time (see Table 4). In the latter countries people travel on foot or bicycle and use public transport more than elsewhere. Slovenes also spend much time on foot or bicycle whilst public transport represents only 7.2% of their total travel time, which is the lowest share amongst the available countries. In all countries, men travel by car more than women do, whether the amount of time spent or the share of total travel time is considered. Women and men spend however almost the same amount of time on public transport and on foot or bicycle, although these means of transport both represent a higher share of their total travel time for women than for men.

Graph 4: Distribution of daily travelling time by trip purpose and gender among persons aged 20 to 74



M: Male; F: Female Source: Eurostat (TUS)

With regard to trip purposes, from nearly one third in Hungary to almost half of total travel time in Finland is linked to free time activities (see Graph 4). Gainful work and study as well as domestic activities justify the remaining time spent travelling, both kinds of activities globally accounting for similar proportions in all the countries (from some 25% to some 40%). Thus, the largest differences between countries in time spent on daily travel can be observed in trips connected with leisure activities. However, comparing women and men, differences in the share of travel time related to leisure activities are minimal, even though men tend to spend more time on leisure trips than women. The essential dissimilarity between men and women is that travel connected to gainful work and study accounts for a larger part of total travel time for men than for women, while women's trips intended for domestic tasks are more time consuming than for men's.

Environmental factors

According to the EEA report “Climate for a transport change”⁵⁶, total EU-27 CO₂ emissions between 1990 and 2005 would have fallen by 14% instead of 7.9% if transport sector emissions had respected the same reduction trends as society as a whole.

As far as CO₂ emissions are concerned, according to New Ride, every electric bicycle on the road results in 900km less car kilometres per year.⁵⁷ The European Union has a stated objective to reduce CO₂ emissions from new passenger cars to an average of 120grams per kilometre by 2012.⁵⁸ Consequently, if this objective is to be achieved, every electric bicycle that avoids the above-mentioned 900km car kilometres should yield a reduction of 108kg CO₂ per year. Following these calculations, the 140,000 electric bicycles sold in 2008 in The Netherlands may have resulted in 15,120 tons less CO₂, whereas the estimated 400,000 to 500,000 electric bicycles sold in the EU may have resulted in 43,200 to 54,000 tons less CO₂.

Based on the same assumption as above, i.e. 1 electric assist bicycle avoids 900km of car usage, the estimated half a million electric assist bicycles sold in the EU in 2008 prevented the use of 38.25 million litres of petrol, which equals € 42.75 million. It also saved 337.50 kWh electricity, which equals € 55.96 million. That results in a total saving of almost € 100 million.

According to Eurostat, the price of household electricity in the first semester of 2009 was € 16.58 per 100 kWh for the EU-27.⁵⁹ Thus to recharge a 200 watt-hour electric assist bicycle battery would cost only € 0.033. A electric assist bicycle might travel 60km with one charge so the cost per km would only be € 0.00055. For a combustion engine four-wheel vehicle, fuel cost per km would be around € 0.095. Thus, the electric assist bicycle is 172 times less costly for fuel than a combustion engine four-wheel vehicle. As for the electricity needed to charge the batteries, much depends on the type of power plant supplying the energy. The table below states CO₂ emissions per type of energy source:

Energy source	CO ₂ - Emissions (gram/kWh)
Wind	9 - 25
Water	8 - 33
Sun (PV system)	50 - 60
Nuclear energy	3,5 - 100
Biomass	0 - 540
Gas	350 - 450
Coal	850 - 1000

*Source: www.milieucentraal.nl⁶⁰

In the case of a 200 watt-hours battery, producing the energy to charge the battery will lead to 0 CO₂ in the best case (biomass) and 0.17 to 0.2 kg in the worst case (coal). As a result, if the charge

56 European Environment Agency, 2008, “Climate for a transport change - TERM 2007: indicators tracking transport and environment in the European Union”, Report No 1/2008.

57 Schneider Bernhard, “Energieeffizienz lohnt sich – für die Umwelt und fürs Portemonnaie”, New Ride

58 http://ec.europa.eu/environment/air/transport/co2/co2_home.htm

59 http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-QA-09-048/EN/KS-QA-09-048-EN.PDF

60 <http://cgi.milieucentraal.nl/pagina.aspx?onderwerp=Duurzame%20energiebronnen>

allows for 60km range, this vehicle will in the best case cause no CO² emission at all, whereas in the worst case it will cause over a 100 km trip 0.333 kg of CO². For comparison, a car with a CO² emission of 0.12kg per kilometre will emit 12kg of CO² over 100km.

The last but not the least environmental advantage of electric assist bicycles is that they produce hardly any noise.

Legal factor

Electric bicycle and/or LEV (Light Electric Vehicle of weight less than or equal to 400 kg) is a term, which covers two different concepts of vehicles with an auxiliary electric motor. On the one hand, there are cycles equipped with an auxiliary motor that cannot be exclusively propelled by that motor. Only when the cyclist pedals, does the motor assist. For these vehicles types the term “electric assist bicycle” is more commonly applied. On the other hand, there are cycles equipped with an auxiliary electric motor that can be exclusively propelled by that motor. The cyclist is not necessarily required to pedal. These vehicles are generally called Ebikes.

Electric assist bicycles and E-bikes are not always two-wheeled. There are vehicles with 3 or 4 wheels. Legal definitions always have the term “cycles” in order to cover all vehicles, irrespective of their number of wheels.

European legislation stipulates that only electric assist bicycles “which are equipped with an auxiliary electric motor having a maximum continuous rated power of 0.25 kW, of which the output is progressively reduced and finally cut off as the vehicle reaches a speed of 25 km/h, or sooner, if the cyclist stops pedalling”⁶¹ are classified as bicycles. For these vehicle types, the European standard EN 15194 (EPAC – Electrically Power Assisted Cycles) has been implemented.

E-bikes and electric assist bicycles of which the motor output exceeds 0.25 KW and/or the motor assists beyond 25 km/h are classified as mopeds. They have to comply with the type-approval legislation as laid down in Directive 2002/24/EC and all accompanying Directives. Full details on all legislation governing electric assist bicycles and E-bikes are in the fact sheet “Legal Framework”.

This policy guideline deals with electric assist bicycles which are equipped with an auxiliary electric motor having a maximum continuous rated power of 0.25 kW, of which the output is progressively reduced and finally cut off as the vehicle reaches a speed of 25 km/h, or sooner, if the cyclist stops pedalling only. The term electric bicycle is a generic name for all bicycles equipped with a motor, i.e. both electric assist bicycles and E-bikes.

Legal status in other countries:

In China electric bikes currently come under the same classification as bicycles and hence don't require a driver's license to operate. Previously it was required that users registered their bike in order to be recovered if stolen, although this has recently been abolished. Due to a recent rise in electric-bicycle-related accidents, caused mostly by inexperienced riders who ride on the wrong side of the road, run red lights, don't use headlights at night etc., the Chinese government plans to change the legal status of illegal bicycles so that vehicles with an unladen weight of 20 kg (44 lb) or more and a top speed of 30 km/h (19 mph) or more will require a motorcycle license to operate, while vehicles lighter than 20 kg (44 lb) and slower than 30 km/h can be ridden unlicensed. In the southern Chinese cities of Guangzhou, Dongguan and Shenzhen, electric bicycles, like all motorcycles, are banned from certain downtown districts. There are also bans in place in small areas of Shanghai, Hangzhou and Beijing. Bans of scooter style electric bikes (SSEB) were however cancelled and in Shenzhen electric bicycles may be seen on the streets nowadays (2010–11).

⁶¹Directive 2002/24/EC of the European Parliament and of the Council of 18 March 2002 relating to the type-approval of two or three-wheel motor vehicles and repealing Council Directive 92/61/EEC, article 1(h).

In Australia the electric bicycle is defined by the Australian Vehicle Standards as a bicycle that has an auxiliary motor with a maximum power output not exceeding 200 W without consideration for speed limits or pedal sensors. Each state is responsible for deciding how to treat such a vehicle and currently all states agree that such a vehicle does not require licensing or registration. Various groups are lobbying for an increase in this low limit to encourage more widespread use of electric bicycles to assist in mobility, health benefits and to reduce congestion, pollution and road danger. Some states have their own rules such as no riding under electric power on bike paths and through built up areas so riders should view the state laws regarding their use. There is no licence and no registration required for electric bicycle usage. The law is not heavily policed due to difficulty determining if the electric power is in operation at the time and ambiguity about the methods of testing motor output. In fact, in NSW the legislation relies on sketches of different vehicles as a guide for compliance! It is currently still legal to pedal a 1000W electric bicycle if not employing power. Many people often purchase higher powered electric conversion kits and convert their own regular bicycle into an electric bicycle as this is the only option available for people with low pedalling abilities or very hilly areas if they wish to use an electric bike.

A high proportion of electric bicycles in Australia come from a variety of inexperienced importers importing generic 200 W electric bikes from China with both lead acid and lithium ion battery options, as many of the larger brands have steered clear of the Australian market due to its ambiguous legislation and internationally low power limit. However this is starting to change with international brands such as eZeebike and Gazelle being imported by Glow Worm Bicycles and Gazelle Australia respectively.

The legal requirements for selling is to have the components tested by an engineer and to ensure the battery charger has Australian electrical approval.

Eight provinces of Canada allow electric power assisted bicycles. A three-year trial in Ontario ended October 2009. In seven of the eight provinces, e-bikes are limited to 500 W output, and cannot travel faster than 32 km/h (20 mph) on motor power alone on level ground. In Alberta the limits are 750 W and 35 km/h (22 mph). Age restrictions vary in Canada. All require an approved helmet. Regulations may or may not require an interlock to prevent use of power when the rider is not pedaling. Some versions (e.g., if capable of operating without pedaling) of e-bikes require drivers' licenses in some provinces and have age restrictions. Vehicle licenses and liability insurance are not required. Generally they are considered vehicles (like motorcycles and pedal cycles), so are subject to the same rules of the road as regular bicycles. In some cases regulatory requirements have been complicated by lobbying in respect of the Segway HT.

Bicycles assisted by a gasoline motor or other fuel are regulated differently than ebikes. These are classified as motor cycles regardless of the power output of the motor and maximum attainable speed.

In Israel, persons above 14 years old are allowed to use electric assisted bicycle with power of up to 250W and speed limit of 25 km/hour. The bicycle must satisfy the European Standard EN15914 and be approved by the Standards Institution of Israel. No license or insurance is required. Other motorized bicycles are considered as motorcycles and should be licensed and insured as such.

In New Zealand an electric bicycle is considered to be a 'Power-assisted cycle'. A power-assisted cycle is a cycle that has a motor of up to 300 watts. The law treats these as ordinary cycles rather than motorcycles. This means that it is not necessary to register or license them.

In the United Kingdom electric bicycles are classed as standard bicycles providing the motor's maximum continuous rated power output does not exceed 250 W, and cuts out once the bike reaches 15.5 mph (24.9 km/h). It must also be under 40 kg (88 lb). This means the rider does not require a

license to use them, however riders must be of at least 14 years of age.

Federal law in the United States states that an electric bicycle must have a top speed when powered solely by the motor under 20 mph (32 km/h) and a motor which produces less than 750 W (1.01 hp). They are not considered motor vehicles by the federal government and are subject to the same consumer safety laws as unassisted bicycles. Their legality on public roads is under state jurisdiction, and varies. See the main Electric bicycle laws article for details on the law in individual states.

In addition to federal electric bicycle laws, the state of Illinois added that the operator be at least 16 years of age. A license and registration is not required.

New York State law bans motor-assisted bicycles from state roads and city streets, though the ban is not currently enforced and a bill is under consideration to allow electric bikes with a top speed of 20 mph (32 km/h) and less than 1,000 watts of power.

Development

Environmental Evaluation of Electric-assist Bicycle and Tricycle

Electric-assist Bicycle and Tricycle

The electric-assist bicycle and tricycle in this study are shown in Fig. 1. The tricycle is a three-wheel type with a rear basket for carrying of a small lightweight materials. The electricity is charged to a lithium-ion battery carried on the electric-assist bicycle. A PEFC generator is also employed in this system as well as commercial purchased electricity. The PEFC generator is installed to the bicycle in substitution for the in-vehicle lithium-ion secondary battery.

The basic specifications of each apparatus for evaluation are shown in Table 1. The power assist systems of both bicycle and tricycle are same. The capacity of PEFC stack is 300 W and the output of this generator is approximately 250 W.



(a) Electric-assist bicycle with fuel cell generator

(b) Electric-assist tricycle

(c) Fuel cell generator

Figure 1. Electric-assist bicycle and fuel cell generator.

Table 1. System specifications.

Electric-assist bicycle	Type	Panasonic BE-ENE633
	Motor output	0.25 kW
	Mass (Weight)	27.7 kg
Electric-assist tricycle	Secondary battery	25.2 V, 12 Ah (Li-ion)
	Type	Panasonic BE-ENR833
	Motor output	0.25 kW
Fuel cell generator	Mass	32.2 kg
	Secondary battery	25.2 V, 12 Ah (Li-ion)
	Type	PEFC H-300 (Horizon Fuel Cell Technologies Pte. Ltd.)
	Fuel	H ₂ (Hydrogen storing metal alloy)
	Mass	10 kg
	Output	System: 250 W (25V, 10A) PEFC: 300 W (43.2V, 7A)

Boundary Condition of Environmental Evaluation and Estimation of Environmental Impact

Actually, there are 6 kinds of greenhouse gases for environmental evaluation. Among them, CO₂, CH₄, N₂O and SF₆ are estimated for the environmental impact in this evaluation. These environmental impacts are converted to CO₂ emission using GWP (Global Warming Potential). This value is defined as the CO₂ equivalent emission, CO₂ eq, in this paper. The boundary condition of environmental evaluation is set from material supply to recycle/disposal stages. Figure 2 shows the

boundary condition of environmental evaluation for the electric-assist bicycle.

For the evaluation of raw material extraction stage, the bicycle and tricycle are disassembled into each part. Figure 3 shows the demolition photos of the bicycle and tricycle. The bicycle and tricycle are disintegrated for 53 and 55 parts, respectively. The quality of the material of each part is distinguished. Then, each mass of them is measured using the electric balance. SimaPro 7.2 and ecoinvent 2.2 are applied for the background inventory collection for the estimation of greenhouse gas emissions of electric-assist bicycles in this research^[2].

For the production stage, it is difficult to obtain the energy consumption for each manufacturing process such as bending, milling, drilling, welding, and etc. Therefore, the energy consumption for each part is not included in this estimation. However, the environmental impact of some assembled part such as Li-ion battery, motor, and etc, include the impact of production stage of it using SimaPro 7.2 and ecoinvent 2.2.

For the use stage, the greenhouse gas emissions are estimated from power consumption while the bicycle is running. The operating conditions are set for several running speeds, gear ratios and running modes. Then, the power consumption is experimentally obtained using wattmeter. The averaged electricity consumptions of the use stage of the bicycles are estimated based on the experimental results, as shown in Table 2. The weight of rider is 55 kg. The inventory for electricity consumption is estimated for two kinds of electricity sources in this study. The greenhouse gas emissions for the unit electric energy of the in-vehicle fuel cell generator are estimated using SimaPro 7.2 and ecoinvent 2.2. These emissions are estimated from overall greenhouse gas emissions during the life cycle, and the emissions are divided by overall generated electric energy during its lifetime. The service life distance of the electric-assist bicycle in this study is set to 10,000 km.

The bicycle operated by fuel cell generator consumes higher energy compare to energy consumed commercial purchased energy supply. For the tricycle, similar tendency can be perceived among these results. However, maximum energy consumption of power mode of fuel cell generator is lower than bicycle using purchased electricity supply. It may be considered that the energy consumption exceed the maximum output capacity of fuel cell generator in this situation.

Table 3 shows the greenhouse gas emissions estimated in use stage. The CO₂ and CO₂ equivalent emissions evaluated for energy consumption of bicycle and tricycle with in-vehicle fuel cell generator are quite small compared to the mention value from commercial purchased electricity supply. However, total emissions of bicycle and tricycle with in-vehicle fuel cell generator are quite large compared to system using commercial purchased electricity supply, because the emissions from manufacture the equipment is large.

The greenhouse gas emissions for the recycle/disposal stage are estimated using a common used recycling ratio of materials^[3,4]. The background inventory is drawn from SimaPro 7.2 and ecoinvent 2.2. Table 4 shows the examples of the recycling ratio of materials and CO₂ equivalent emissions for the recycle/disposal stage. The environmental impact in recycling is estimated by a negative value, because the recycling of materials generally reduces the environmental impact.

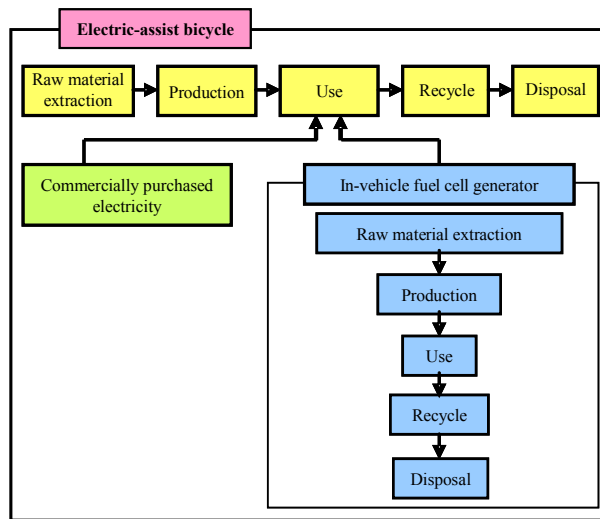


Figure 2. System boundary of environmental evaluation.



(a) Electric-assist bicycle

(b) Electric-assist tricycle

Figure 3. Demolished parts of the bicycle and tricycle.

Table 2. Energy consumption of bicycle and tricycle in use.

Vehicle	Energy supplied	Running mode	Averaged electricity consumption (Wh/km)
Bicycle	Purchased electricity (with Li-ion battery)	Power	5.4
		Automatic	4.1
		Economy	3.9
	Fuel cell generator	Power	6.8
		Automatic	5.1
		Economy	3.8
Tricycle	Purchased electricity (with Li-ion battery)	Power	8.2
		Automatic	5.5
	Fuel cell generator	Power	7.4
		Automatic	6.0

Table 3. Greenhouse gas emission in use for service life.
(Service life distance: 10,000 km)

Vehicle	Energy supplied	Running mode	Emission from energy consumption (kg-CO ₂ eq)	Emission from power source system (kg-CO ₂ eq)	Total (kg-CO ₂ eq)
Bicycle	Purchased electricity (with Li-ion battery)	Power	29	11	40
		Automatic	22	8.5	30
		Economy	21	8.1	29
	Fuel cell generator	Power	0.93	150	151
		Automatic	0.82	110	111
		Economy	0.81	82	83
Tricycle	Purchased electricity (with Li-ion battery)	Power	41	16	57
		Automatic	30	12	42
	Fuel cell generator	Power	1.2	160	161
		Automatic	1.3	130	131

Table 4. Example of greenhouse gas emission in recycle/disposal stage^[3, 4].

(a) Bicycle

No.	Parts name	Material	Weight [kg]	Recycle rate	Recycle (kg-CO ₂ eq)	Disposal (kg-CO ₂ eq)
B1	Frame	Iron	3.88	38	-2.44	0.017
B2	Front fork	Iron	0.80	38	-0.50	0.003
B3	Basket	ABS	0.70	73	-0.32	0.444
:	:	:	:	:	:	:

(b) Tricycle

No.	Parts name	Material	Weight [kg]	Recycle rate	Recycle (kg-CO ₂ eq)	Disposal (kg-CO ₂ eq)
T1	Frame	Iron	9.58	38	-6.04	0.042
T2	Handle	Aluminum	0.38	55	-1.59	0.004
T3	Front tire	Synthetic rubber	0.40	0	0	1.256
:	:	:	:	:	:	:

The life cycle environmental impact is estimated by combining each value throughout the life cycle. The greenhouse gas emission is converted to CO₂ equivalent emission using GWP. Table 5 and Fig. 4 show the environmental impact of the electric-assist bicycle throughout the life cycle. The electricity is supplied by two kinds of power source. The service life distance is put at 10,000 km.

The total environmental impact estimated from purchased electricity has lower environmental impact as shown in Table 5 and Fig. 4. Moreover, it is found that the impact of material supply and use stages have larger values compared to other stages. The reason is that the environmental impacts caused by a lithium-ion secondary battery and fuel cell generator have large impact. In order to overcome these problems, it is desirable to use low environmental impact materials.

Table 5 CO₂ emissions of electric-assist bicycle.

(a) CO₂ emission
(Service life distance: 10,000 km)

Vehicle	Energy supplied	Running mode	Raw material extraction and Production stages (kg-CO ₂)	Use stage (kg-CO ₂)	Recycle stage (kg-CO ₂)	Disposal stage (kg-CO ₂)	Total (kg-CO ₂)
Bicycle	Purchased electricity (with Li-ion battery)	Power	76	38	-13	9.4	110
		Automatic		29			101
		Economy		28			100
	Fuel cell generator	Power		140			212
		Automatic		100			172
		Economy		78			150
Tricycle	Purchased electricity (with Li-ion battery)	Power	91	54	-22	10	133
		Automatic		40			119
	Fuel cell generator	Power		150			229
		Automatic		120			199

(b) CO₂ equivalent emission
(Service life distance: 10,000 km)

Vehicle	Energy supplied	Running mode	Raw material extraction and Production stages (kg-CO ₂ eq)	Use stage (kg-CO ₂ eq)	Recycle stage (kg-CO ₂ eq)	Disposal stage (kg-CO ₂ eq)	Total (kg-CO ₂ eq)
Bicycle	Purchased electricity (with Li-ion battery)	Power	82	40	-14	9.4	117
		Automatic		30			107
		Economy		29			106
	Fuel cell generator	Power		151			228
		Automatic		111			188
		Economy		83			160
Tricycle	Purchased electricity (with Li-ion battery)	Power	98	57	-25	10	140
		Automatic		42			125
	Fuel cell generator	Power		161			244
		Automatic		131			213

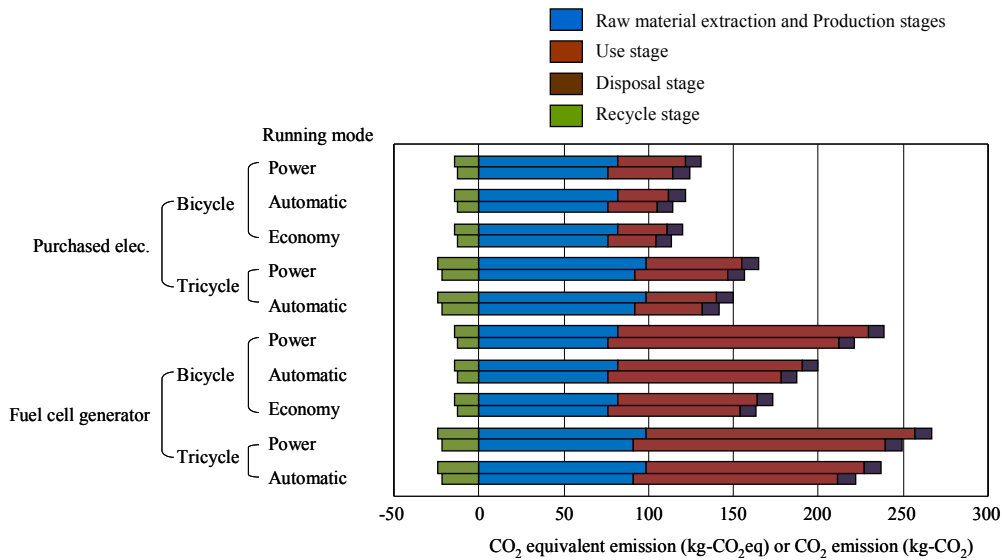


Figure 4. CO₂ emissions of electric-assist bicycle. (upper: CO₂ eq emission, lower: CO₂ emission)

Advantage of Introduction of Electric-assist Bicycle

Comparison with Other Traffic Devices

The advantage of introduction of the electric-assist bicycle can be evaluated by comparing the environmental impact with some other mean of transport. It is assumed that the transportation distance is not lengthy in a factory or local transportation. A light truck, passenger car and scooter are chosen here for comparison with the electric-assist bicycle. Table 6 and Fig. 5 show an evaluation condition of a different means of travel and environmental impacts of each transportation device for a service life distance. The environmental impacts of other traffic devices are estimated for life cycle, which are material supply, production, use and recycle/disposal stages. The CO₂, CH₄, N₂O and SF₆ emissions of life cycle are estimated using SimaPro 7.2 and ecoinvent 2.2. Then, these impacts are converted to CO₂ equivalent emission using GWP. The environmental impact for a light truck is estimated by the inventory for a 3.5-ton capacity truck.

The environmental impacts estimated for a passenger car and light truck have large values compared to other traffic devices, because of their long service life distance and weight of them. Therefore, it is important to evaluate the impact for a unit work of each traffic device.

Table 6 Evaluation condition of vehicles and CO₂ emissions.

(a) Evaluation condition

Vehicle	Energy supply	Weight (kg)	Fuel	Fuel consumption	Service life distance (km)	Number of passenger(person)
Electric-assist bicycle (power mode)	Purchased electricity	27.7	Elec.	5.4 Wh/km	10,000	1
	Fuel cell generator		H ₂	6.8 Wh/km		
Electric-assist tricycle (power mode)	Purchased electricity	32.2	Elec.	8.2 Wh/km		
	Fuel cell generator		H ₂	7.4 Wh/km		
Two wheel scooter (50cc)	Engine	81	Gasoline	30 km/liter	20,000	1
Three wheel scooter (50cc)				26 km/liter		
Passenger car		1,000		12 km/liter	100,000	5
Light truck		710		15 km/liter	100,000	2

(b) CO₂ emission

Vehicle	Energy supply	Raw material extraction and Production stages	Use stage	Recycle stage	Disposal stage	Total
Electric-assist bicycle (power mode)	Purchased electricity	76	38	-13	9.4	110
	Fuel cell generator		140			212
Electric-assist tricycle (power mode)	Purchased electricity	91	54	-22	10	133
	Fuel cell generator		150			229
Two wheel scooter (50cc)	Engine	310	1,700		68	2,100
Three wheel scooter (50cc)		420	2,100		94	2,600
Passenger car		3,900	22,000		410	26,300
Light truck		1,300	17,000		280	18,600

(c) CO₂ equivalent emission

Vehicle	Energy supply	Raw material extraction and Production stages	Use stage	Recycle stage	Disposal stage	Total
Electric-assist bicycle (power mode)	Purchased electricity	82	40	-14	9.4	117
	Fuel cell generator		151			228
Electric-assist tricycle (power mode)	Purchased electricity	98	57	-25	10	140
	Fuel cell generator		161			244
Two wheel scooter (50cc)	Engine	330	1,800		68	2,200
Three wheel scooter (50cc)		450	2,200		94	2,700
Passenger car		4,100	23,000		410	27,500
Light truck		1,400	18,000		280	19,700

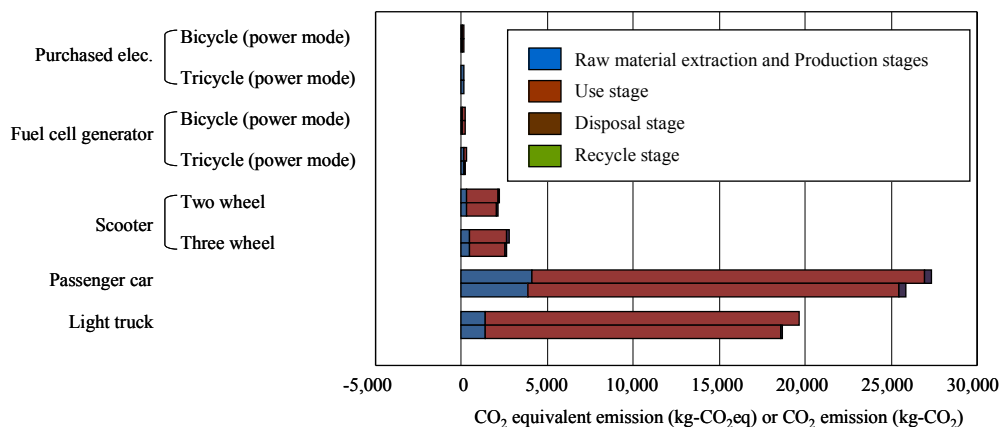


Figure 5. CO₂ emissions of each vehicle for a service life distance. (upper: CO₂ eq emission, lower: CO₂ emission)

Environmental Impact for Unit Work

In order to evaluate the environmental impacts for several different traffic devices, it is very important to define the boundary conditions because the function and service life distance are quite different for each traffic device. Hence, the environmental impact is estimated for unit work.

The environmental impact for unit work is estimated by the ratio of the life cycle impact divided by the number of passenger and service life distance. The relationship of unit impact is shown in Table

7 and Fig. 6. These show an optimum method to move with low environmental impact. The difference between these impacts estimated for CO₂ and CO₂ equivalent emissions are quite small. Therefore, only CO₂ equivalent emission is shown in Fig. 7. Each unit impact of electric-assist bicycle shows lower values. Then, the impact from passenger car follows because the car can carry many people at a time. However, in an actual situation, a passenger car carries only 1 to 2 people. Therefore, the estimated impact for passenger car may become large. If one hopes to carry some materials by one of these devices, the results maybe changed even if the results from two-wheel electric-assist bicycle have lowest impact in this estimation. The function of these traffic devices should be considered in order to show an actual special quality.

Table 7. Evaluation condition of vehicles for unit work.

Energy supply	Vehicle	CO ₂ emission (kg-CO ₂ /(capita·km))	CO ₂ equivalent emission (kg-CO ₂ eq/(capita·km))
Purchased electricity (with Li-ion battery)	Electric-assist bicycle (power mode)	0.011	0.012
	Electric-assist tricycle (power mode)	0.013	0.014
Fuel cell generator	Electric-assist bicycle (power mode)	0.021	0.023
	Electric-assist tricycle (power mode)	0.023	0.025
Two wheel scooter (50cc)		0.11	0.11
Three wheel scooter (50cc)		0.14	0.14
Passenger car		0.052	0.054
Light truck		0.098	0.10

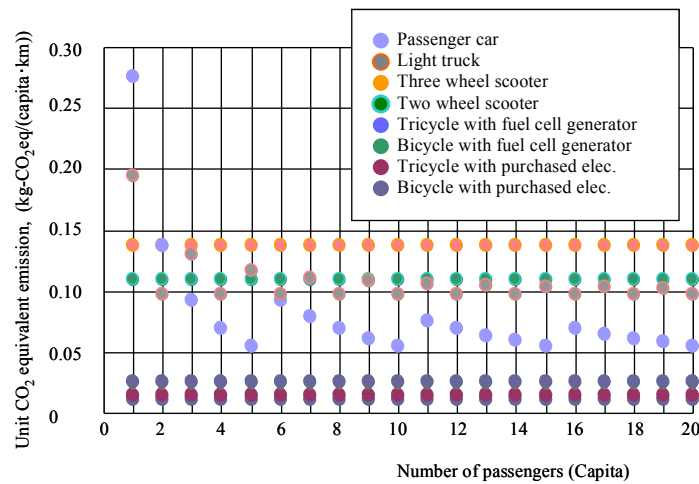


Figure 6. CO₂ eq emission of each vehicle for unit work.

Conclusion

The life cycle environmental impact of the electric-assist bicycle is estimated, and the impact is compared with such of other traffic devices. Then, the advantages and disadvantages of an electric-assist bicycle are evaluated from the viewpoint of environmental impact.

In the life cycle environmental evaluation of the electric-assist bicycle, the power sources are chosen here as in-vehicle fuel cell system and commercially purchased electricity. A light truck, passenger car and scooter are chosen here for comparison. As a result, the life cycle environmental impact estimated for the electric-assist bicycle shows a minimum value. In the present study, the principal factors of environmental impacts for each traffic model are shown. Moreover, the impact of material supply and production of the electric-assist bicycle compose the greater portion of the life cycle impact. Therefore, it is important to use low environmental impact materials for the bicycle.

As a result, the advantages of introduction of electric-assist bicycle for a local transportation are shown, even if the life cycle impact heavily depends on the evaluation condition such as service life distance and the number of passengers.

Acknowledgement

This research has been supported by JKA (Japan Keirin and Auto race Foundation).

References

- N. Maruyama, M. Tamada, etc, (2011), Environmental Evaluation and Effectiveness of Lightweight Electric-Assist Tricycle with Next-Generation Batteries, Proc. of 9th International Energy Conversion Engineering Conference 2010, CD-ROM, San Diego, USA.
- Pre consultants, SimaPro 7.2 and ecoinvent 2.2, The Netherlands.
- Yearbook of iron and steel statistic 1993, The Japan ferrous raw materials association.
- Yearbook of minerals and non-ferrous metals statistic 1991, Ministry of Economy, Trade and Industry, Japan.