Mobility management report, including mobility as a service

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Executive Summary

The idea of electric vehicles and electric propulsion in mobility is to reduce the environmental impact of traffic. The idea of mobility management is to guide citizens to use mobility modes that have less environmental impacts and to reduce the mobility.

Mobility management is often seen as an action pointed to citizens. In case of electric mobility, the choice is not always at the user of mobility. Car dependence is the result of urban planning and there is no real freedom for everybody to choose to use car or public transport.

One hinder for electric mobility is the availability of electric vehicles. The supply is still very limited, after years of the first modern EVs are launched. And the few available models are just traditional cars where the combustion engine is replaced with electric motor and battery. EVs do not use the whole potential of electric propulsion technology, which also limits the available properties and usability.

Energy consumption to move a human being depends on the weight of the vehicle. Rail vehicles benefits of the low rolling resistance, but rail nets cannot cover all locations. To reduce energy consumption requires to develop and shift towards lighter vehicles than the current 1.5 tons car.

The experienced mobility behavior shows that urban structure can be divided to urban zones for which a certain mobility mode is typical. The three main zone types are walking, public transport and car zones. Mobility management starts from planning the urban structure to one of these zones.

Another discovery is that aside the economical growth the number of trips made has grown and the growth is made by using car. And the growth is at the trips for shopping and leisure. This growth is also under the control of authorities as planners of the functional urban structure. So to influence trip generation also requires mobility management actions towards authorities in planning phase.

For more sustainable future, mobility management has to be understood more widely than as a task to get people to use desirable mobility modes and practices in existing urban structure and traffic system. mobility management has to cover urban and traffic planning. In this context, the role of electric mobility and EV technology is to benefit the electric propulsion technology in developing new vehicle concepts.

Also the possibilities of reducing the need for human mobility by alternatives for human mobility has to be discussed. It is impossible to replace human travelling if the purpose of the trip is an entertainment at the destination. But in many cases leisure time activities can be replaced with actions not requiring travelling. Like e-shopping and running errands using internet services.

Mobility services may and can reduce human mobility or make more sustainable mobility possible. One important reason for the growth of human mobility has been to replace delivery with human travelling to centralized shopping in malls and hypermarkets. Delivery services to homes and to local shops reduce the need to travel. Car sharing and rental services reduce the need to own a car and let benefit of travelling chains. When a plug-in rented or shared EV is available at both ends of a long trip, there is no need to use an unlimited range combustion engine car for this trip.

To fulfill the EU targets for green house gas emissions shifting to electric mobility and strong mobility management actions are necessary. All the actions discussed are required.

The main focus in this work has been the greater Helsinki region. Mobility research needs to be widened nationwide to cover the regions with less public transport than in Helsinki region. Development of Urban Zone concept for urban and traffic planning is still in process. As the concept is based on the current mobility modes, it has to be developed to take into account the future vehicles and their mobility modes.

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List of Acronyms and Abbreviations

°C	Degrees Celsius
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
CO_2-eq	CO_2-equivalent green house gas emission
CV	Combustion Engine Vehicle
€	Euro Currency
E-REV	Electric Range Extender Vehicle
EU	European union
EV	Electric Vehicle
g	Grams
g/s	Grams per Second
GDP	Gross Domestic Product
GHG	Green House Gas
HEV	Hybrid Electric Vehicle
HKL	Helsinki City Transport
HSL	Helsinki Region Transport
HVAC	Heath, Ventilation and Air Conditioning
ICE	Internal Combustion Engine
kgs	Kilograms
km	Kilo Meter
kW	Kilo Watt
kWh	Kilo Watt Hour
L	Litre
L-EV	Light Electric Vehicle
Li-Ion	Lithium Ion
LPG	Liquefied Petroleum Gas
m^2	Square Meter
m^3	Cubic Meter
MJ	Mega Joule
Mkg	Millions of Kilograms
MW	Mega Watt
P-EV	Plug-in Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
prs/sqm	Persons per Square Meter
RE-EV	Range Extender Electric Vehicle
TWh	Tera Watt Hour
VAT	Value Added Tax
W/K	Watts per Kelvin

1. Introduction

1.1. Scope

Electric mobility is often considered as a solution for negative environmental impact caused by traffic. This idea is usually based on the fact, that combustion engine emissions are remarkable environmental load and as an EV does not have those emissions, it solves the problem. In this series of SIMBe reports we have shown that local emissions of a single car are not the only environmental impact of traffic and the removal of local emissions with EV technology is not fast enough and not possible completely. In long term, up to year 2050, EV technology may and can have a significant role in reducing green house gas emissions. But still there remain a need to reduce energy consumption in traffic (Alku & Kosonen 2012).

There are two main ways to reduce the energy consumption of the traffic: to increase the energy efficiency of mobility and to reduce the need for mobility. Mobility management has impacts for both of these.

Using mobility management people can be directed to use less energy intensive mobility modes. Those are practically all the other modes than a legacy car having a tare weight of 1.5 tonnes. For the most this is a question of the choices made at traffic system level. Is public transport available in high enough service level to be used instead of a private car and does the traffic network include cycling and pedestrian roads and pathways? But this is also a question of vehicle technology. A bicycle or a motorized two wheeler offers quite a weak service compared to a car or public transport. Electric mobility has a potential to offer non-existing vehicle concepts between current two wheelers and cars or public transport.

To reduce the need of mobility is usually considered as a question of urban planning and urban structure, including the functionality structure. The trend of 1900’s was towards car based structure. For the first a car was considered as a solution of the unhealthy of the city. The functionalists of the 1930’s, Le Corbusier in front of those, thought that cars free the urban structure from the bindings of habitation and industry. Car based traffic system allows to separate areas for housing and industry so that the old fashioned densely built city structure can be replaced with a sprawled structure where housing is placed in the middle of a pure nature.

The planners of 1930’s did not have the experience we have today. They were not able to estimate the negative impacts of the traffic as they pointed to the negative impacts of the dense cities and polluting industry of their time. Today we know, that the dense city structure was not the unhealthy problem, but the undeveloped municipal engineering and infrastructure was. But what comes to the dense cities, while we have removed the negative circumstances with water and waste service and district heating, we have imported the emissions and noise of cars with the problem of space required both for parking and using the car. We have also taken most part of the city space out from people and given it to cars. Unlike in the past, streets are no more extension of the courtyard. And not even the sidewalks are safe places to let children stay there unattended.

The potential of electric mobility in urban structure is both in space and in other environmental impacts. The lack of local emissions removes or reduces the need for protective structures and distances to reduce the impacts. Vehicles smaller than cars do not require as much space as cars. Electric propulsion in lighter vehicles than cars expands the usability and range of vehicles like bicycles or makes tricycles available for other persons than those in good enough condition to be able to use them. This increases the overall accessibility of urban space and gives more freedom in planning the locations of urban services.

This report is a kind of a future study of the potential of electric propulsion in vehicle technology as a part of traffic system, urban structure and as a tool of mobility management. The focus is for long term. This is because as seen in the preceding report (Alku & Kosonen 2012), the change from fuel based propulsion technology to electric propulsion cannot happen within less than 15 to 20 years. But also, that is the time span in which there may happen some development in urban structure to adopt new mobility behavior.

1.2. Industrial and administrative challenges

The full benefit of electric propulsion is not only to replace combustion engine with an electric motor and battery pack. The main challenge for car industry is to go through an evolution from combustion engine and mechanical drive train manufacturing to battery, power electronics and electric motor manufacturing. Then the design approach may change to wider scale of vehicles and specially down from average current 1.5 tonnes car.

Another challenge for car industry is to adapt the after sales markets from servicing cars and selling spare parts to services supporting electric propulsion that does not require regular maintenance like combustion engine technology. These topics are widely discussed in other SIMBe work packages together with the role of new players in traffic markets, like electricity producers and distributers and organizations to manage vehicle charging.

Third challenge is in developing the urban structure in a wide scale. The development towards car based structure has been simple as it has been market driven. To switch from walking and public and delivery transport use to cars has meant growing consumer markets and reduction in cost structure of various economical activities when actions like commodity delivery are transferred to the customers using their cars. To switch to car use has offered new and growing business opportunities in car sales and after sales, gasoline sales, road building industry and housing industry. For commerce business and all kind of consumer services cars has offered a way to increase companies profitability by centralization to large units and to give up from delivery.

To reduce car dependency may not be self driven same way as to switch towards car use. For example as the grocery business sees large shopping malls as a best form of their business, they are not interested in returning to local services and smaller units. If the consumers on the other hand think that the prices of the commodities must remain same independent of where they are on sale, consumers actually do not give any value for that they do not need to pay and to use time for own travelling.

If travelling is seen as a demand for a service that may be fulfilled with alternative choices from a walk, public transport, delivery transport or using a car to a taxi service, one challenge is that the prices of all these alternatives are not easily comparable or not comparable at all. This is because of the structure of the paying of each of these is different. For a taxi or a shared car the customer pays all the expenses at the time. For a car the customer pays actually nothing each time the car is used. Depending on the usage of the car, even the gasoline is a fixed cost that is paid only weekly or monthly.

And finally, administration that is responsible for the city planning has a significant role. The use of cars is made possible by planning, building and paying a road and street network capable to carry the number of cars. Much of the shape of the recently built areas is a consequence of the space and facilities reserved for car traffic. This space has a value in reducing the land use efficiency and increasing the public infrastructure cost. This cost is paid from general tax incomes, so it is not collected from those who benefit from it or use it.

But same basics apply to the new modes of mobility that may come possible with electric propulsion technology. They cannot be benefitted if the urban structure does not support them. This starts from charging infrastructure, but it is clear that current traffic network is not suitable for remarkable growth of cycling, tricycles or other light vehicles. This applies also to the maintenance of the traffic network. If we assume that cycling might be weather proof like cars and public transport by itself, year-round cycling is not possible if cycle paths are not kept in condition.

The responsibility of the administration lies also in the economy of shopping and services. If large centralization is allowed in city plans, it makes the profitability of local services impossible. Also, if required traffic network is built free of charge for large shopping malls, there is nothing to limit the traffic volume. But the delivery work and cost is transferred away from commerce business.

Traffic network is a natural monopoly and therefore under authorities control. This means also, that the development in traffic systems is under control of authorities. The challenge of the authorities is to make the vehicle development possible in the traffic network solutions and in urban structure.

1.3. Objectives

In this work we will find out the potential of electric propulsion in saving energy in mobility, to reduce the need of mobility and allocate mobility to mobility modes that less energy intensive. All these aspects are studied during the mobility behavior and the trip generation statistics. The studies are coupled to urban structure.

Vehicle technology is not bound to current known technologies. Instead the mobility is seen as a service which will indicate needs for the technical solution of travelling. There may not need to be a suitable solution available yet, instead the results of the study may result specifications for some new solution to be developed.

The main focus is in the mobility of human beings. But as there are certain cases in which delivery or data transfer are alternatives for a travelling of a human being, these alternatives are taken into account.

This report is much like a summary of the work done in SIMBe work package #3. This report refers to the previous reports of this work package and results presented in those reports.

2. Overview of energy consumption and mobility needs

2.1. Energy consumption of moving one human being

The energy requirement of transportation was discussed in the first report of this SIMBe work package (Alku & Kosonen 2011a). The benefit of electric propulsion was clearly proven. Regenerative braking reduces the energy consumption's dependency of frequent stopping, which is characteristic for mobility in cities. Regenerative braking is only possible with electric propulsion, which is plug in vehicles, hybrids or direct electric supply vehicles as rail vehicles or trolley buses.

The main factor in energy consumption is the gross weight of the vehicle per person. Within public transport the important factor is the utilization percentage. As the nature of public transport is that the load of a vehicle varies during the route, the utilization must be counted as a share of used passenger kilometres of the offered passenger kilometres. Doing this the energy need in public rail transport is in same level as with bicycle or a scooter. Energy need with buses is in same level as a quadricycle that has a 400 kgs tare weight.

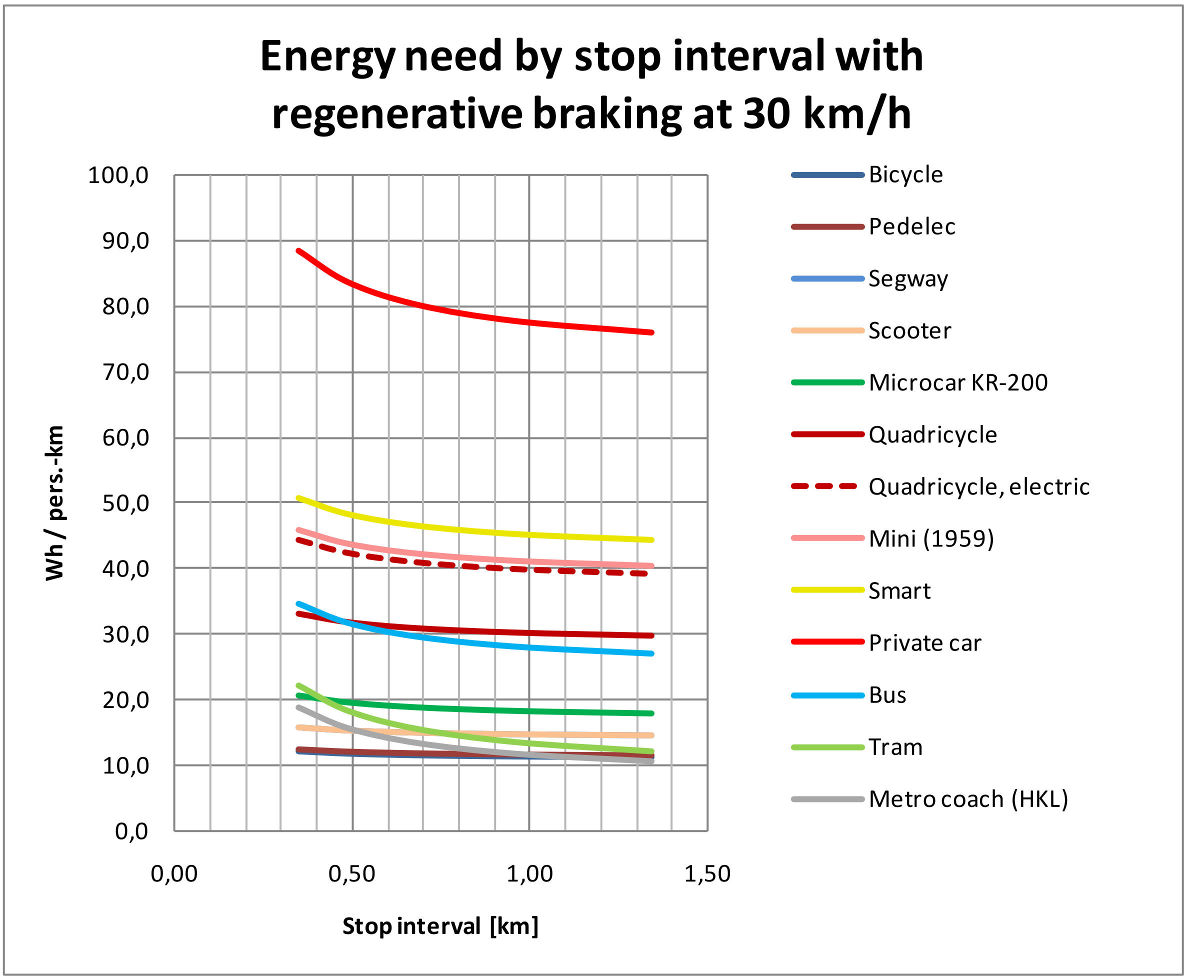

Figure 1. The energy need of various vehicles per used passenger-kilometre, when stop interval changes and the constant speed is 30 km/h. Of braking energy, 60 % of kinetic energy can be converted back into electricity (Alku & Kosonen 2011a).

The real energy consumption depends on the efficiency of the vehicle components and the driving manner of the driver. There is wide experience of real energy consumption of the cars and public transport, but naturally not about electric vehicles that do not exist yet.

In SIMBe the energy consumption of a plug in electric vehicle is set to 0,20 kWh/km as electricity taken from grid. This is based on the experienced energy consumption of middle size cars and reported by Kronstöm (2009). If this is scaled to figure above (Figure 1), the efficiency is 43 % and consumption per gross weight is 0,13 Wh/km/kg. For car like new vehicles the energy consumption in this work is calculated based on the gross weight.

For bicycle like vehicles energy consumption is calculated from the theoretical driving resistance using the 43 % efficiency figure. This is because of the rolling resistance and the wind area related to gross weight differ from those of a car like vehicle. Bicycle like vehicles differ also by the role of propulsion technology. Pedelecs use electric propulsion only as an aid for muscle power. This is the term for a pedelec is not classified as a motor vehicle requiring a driving licence and certain age. As the motor power of a pedelec is limited to 250 W, it cannot consume electricity more than 0,017–0,025 kWh/km. Using the 43 % efficiency, pedelec's maximum energy consumption from the grid is 0,06 kWh/km regardless of the gross weight of the vehicle.

In public transport the key factor is the space usage efficiency. This depends on various factors like service level, length of the trip in time and the tolerance of the passengers. All these depend on the culture. We are familiar with the pictures from far east showing stewards pushing passengers into a train to get the doors closed. From Scandinavia we may notice a person sitting on the aisle side of a twin seat to avoid no-one to come too close. From airplanes we know, that seats may be bolted tight or loose so that the capacity of the same body depends on the air operator and it's brand.

In urban transport in EU 8 persons per square meter is allowed as density of standing passengers. This equals a square with side length of 0.35 meters for one person, which may be true in far east. In eastern Europe the practice is to count 6 prs/sqm and in western Europe 4 to 3 persons. Density of seated passengers is usually 3 prs/sqm, so the density of standing passengers is remarkable higher.

The ratio between seated and standing passengers is important question for the total capacity of a vehicle. The ratio depends on the purpose of the vehicle. Standing is acceptable and also preferable by the passengers for short trips. For long trips standing is avoided. There is also a remarkable difference in tolerating standing between buses and rail vehicles. Standing in buses is usually unpleasant and in worst case difficult, because there is acceleration and jerk practically in all three dimensions. On rail the highest acceleration and jerk is in rolling direction of the vehicle. The use of automatically controlled acceleration and braking make the rolling smooth. The sideways acceleration and jerk is also limited and softened by the use of speed control in curves and using transition curves in track.

The practical situation in HSL operated public transport is, that seating is preferred in buses. Standing area is limited to the minimum having only corridors and space for two prams or wheel chairs. Trams have also reserved space for standing. Compared to continental practice in metro trains, HKL metro trains have plenty of seating capacity, but still large area for standing. Commuter trains are designed to serve for travelling as far as for one hour and the main travelling mode is sitting, but 2+3 seats in a row. Using standing density of 4 persons per sqm, passenger density in public transport varies from 1,9 to 6,4 passengers per meter of gross length of the vehicle at HSL region (see Table 1).

Table 1. Passenger density of public transport vehicles in HSL region using 4 prs./m^2 of standing passenger density and counted from gross length of the vehicle.

Vehicle type	Nominal width [m]	Passenger density [prs./m]
Bus	2,55	6,4
Tram	2,30	6,1
HKL-metro	3,20	3,9
Commuter train (Sm5)	3,20	3,3
Commuter train (Sm2), seating only	3,03	1,9

Though passenger density in heavy rail vehicles is low, they still manage well in energy consumption compared to trams and buses. This is because of the long stopping distances and high usage. The role of the heavy rail is to collect high passenger volumes from feeder bus services therefore the service offered can be optimized toward the demand.

2.2. Mobility behaviour

Current mobility behaviour is studied in Finland country wide in National Travel Survey (www.hlt.fi) and locally in larger cities. In Helsinki region the survey covers Greater Helsinki Region and nearby surrounding areas that are relevant by means of commuting to Helsinki region. The limitation of the Helsinki region survey is that it does not cover the weekend and holiday season. The purpose of the survey is to collect initial data to be used in traffic system modelling.

The long term experience in mobility behaviour is that car usage and travelled distance has grown. Also the number of trips has grown. But characteristics for the growth is that the growth is dedicated to shopping and leisure, which is done using cars.

The development in mobility behaviour is bound to the development in urban structure. Up to mid 1900's city structure was dense. Travelling modes were walking and public transport. Car import was controlled and limited in Finland to 1960's and suburbs were based on apartment buildings and buses servicing to city centre. According to planning principles, suburbs were planned for housing and workplaces were concentrated into the city centre.

Car made urban sprawl possible. It also made possible to close local shops and services at walking distance from housing (Spåre & Pulkkinen 1997). The first step during 1960's was shopping centres that killed the small shops in the basement of apartment buildings that were still built in suburbs till the end of 1950's. Urban sprawl supported the concentration of shopping and services, as growing share of citizens lived far from any public services and the use of car for any need was necessary any way.

Large share of work places disappeared from city centres also during the growing car ownership. Workers were able to travel with cars to any locations outside the dense urban area, where land was cheap and available practically unlimited. Compared to other Europe, the development of harbours near the city centre of Helsinki has happened very late. But other heavy industry except the Hietalahti ship yard moved away already decades ago.

The result of this development is a segregated urban mobility structure. There are areas which differ from each other by means of dominating mode of travelling. This is currently called urban zoning, where the main zone types are walking, public transport and car zones (Kosonen 2007). The practical background of these zones is the history, but the understanding of the zones may and have been used for urban planning as in Kuopio since 1994 (Kosonen 2007). The idea of urban zones is now taken as a base for creating new practice for urban planning in the Urban Zone -project driven by Finnish Environment Institute (Ristimäki ym. 2011).

In the first phase of Urban Zone -project the characteristics of the zones are created from the mobility behaviour data. The next phase is to construct the urban zoning as a national tool for urban planning.

Urban zoning represents clearly, that the transport mode choice is not only a question if there is other modes than car available. Instead, it is a question of the usability of the other modes. If the traveller cannot reach the destination with some transport mode, there is no use to put effort for that mode and it's service quality. This applies also to cars in densely built areas where the accessibility by walking or with public transport is better than having to walk several minutes from a parking facility far from the destination.

The mobility behaviour and modes is discussed in the SIMBe report *Development of a blueprint for the charging network needed for Electrical Vehicles* (Alku & Kosonen 2011b). More precise understanding of mobility possibilities can be seen when examining the area expressed as classified in urban zones. Though the suburban area of Helsinki is considered as an area best served with public transport in Finland, it still is very shattered by means of urban zones (Figure 2).

By means of mode choice, the trips starting or ending to car zone must be car trips, regardless where the other end of the trip is located. Expressed differently, these trips cannot be public transport trips, unless there will happen a change in urban structure. So the role of electric mobility in reducing the environmental impact of the traffic in these areas is to offer other electric mobility than electric public transport.

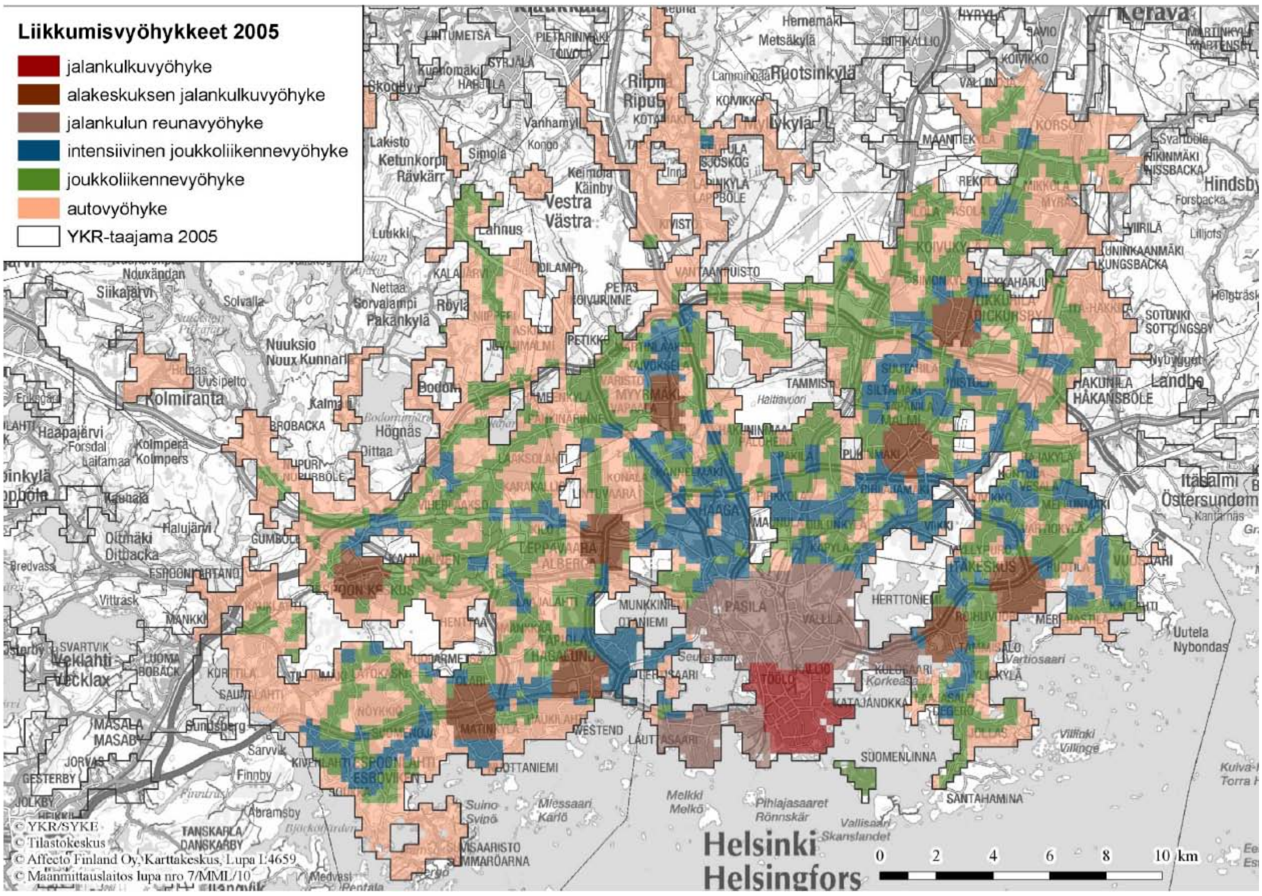

Figure 2. Urban zones in Helsinki suburban area. Light brown represents car zone (autovyöhyke). Green and blue zones are public transport zones, dark brown and red are walking zones. (Ristimäki & Kalenoja 2011)

2.3. Trip generation

The base of the traffic planning is trip generation. The usual way is to organize a survey to collect statistics of the citizens behaviour. The drawback of this approach is that it ignores the interaction between the human behaviour and urban structure. Trip generation is actually a result of the available urban and service structure and traffic system and the needs of the citizens.

This can be cleared with a simple example of grocery shopping. Let's assume a family uses daily one litre of milk and one bread. In the past milk and bread was delivered to small local shops which formed a network where shops were at walking distance from every citizen. This was a must, as there were no means of transport available and long work days and work weeks did not leave time for shopping the way that is the current practice.

Milk and bread was picked up from the shop daily. If this was done when arriving from the work, there were no trip generation based on grocery shopping, though the shop was visited daily. If the shop was visited daily by the mother that worked as a house wife, two trips by walking could be recorded to the statistics.

The same need of a litre of milk and a bread per day is currently covered by making one trip per week to a shopping mall. If the survey covers only work days like the HSL traffic survey in greater Helsinki region, no trip generation is recorded, as people use to spend time in shopping malls during weekends. If weekends are included, two trips with a car are recorded corresponding 12 walking trips or no trips at all in the past.

The food demand has not changed, but trip generation has. This has happened because of the change in the traffic system and urban structure.

Similar interaction can be observed also in the needs of the citizens. Many kind of activities have become available because of the availability of suitable transport. This can be understood as the benefit of the transport in increasing the quality of life. But the main point is, that trip generation is not independent of the solutions offered in traffic system and urban structure.

Trip generation statistics are collected from the mobility surveys (Kalenoja ym. 2008). These results are meant to be used in urban planning, but to be precise, the results are only valid as is for the similar urban structure where from the results are collected. For this reason the results are classified the way urban zones are classified as described in the previous chapter. The impact of the zone type is remarkable (Table 2).

What comes to EVs, the question is does and how propulsion technology influence to the trip generation. This will be studied in the next phase of TEKES-funded research project under a subproject eSINi in the current urban structure in Helsinki region. This study will not answer to the question of what may be achieved with the interaction between the propulsion technology and urban structure. As described in the future scenarios of the previous SIMBe report *Environmental assessment for the whole EV life cycle* (Alku & Kosonen 2011c), the change in the propulsion technology is not sufficient to follow the green house gas limits set in EU. The change in mobility behaviour and new vehicle technologies are also needed.

In this paper only assumptions of new vehicle technologies and their impact to urban structure can be used. These assumptions are based on the human needs which are projected to the trip generation data through the features of the traffic system and electric mobility.

Table 2. Traffic modes to grocery shops (less than 2500 sales sqm.) average values per annum according to location and urban zone. Data HLT 1998–1999 and TASE 2004–2005. (Kalenoja et.al. 2008)

Helsinki region	mode share of recorded trips, %			
	walking	bicycle	car	public transport
walking zone	70 %	8 %	19 %	4 %
public transport zone	42 %	12 %	44 %	2 %
car zone	26 %	9 %	63 %	3 %
average at the region	43 %	11 %	43 %	4 %
Tampere and Turku regions	mode share of recorded trips, %			
	walking	bicycle	car	public transport
walking zone	57 %	5 %	29 %	8 %
public transport zone	34 %	6 %	59 %	1 %
car zone	15 %	11 %	75 %	0 %
average at the region	35 %	8 %	55 %	3 %
Oulu, Jyväskylä, Kuopio and Lahti regions	mode share of recorded trips, %			
	walking	bicycle	car	public transport
average at the region	33 %	8 %	56 %	2 %
town regions of 45 000–80 000 inhabitants	mode share of recorded trips, %			
	walking	bicycle	car	public transport
average at the region	27 %	14 %	58 %	1 %
regions of 20 000–45 000 inhabitants	mode share of recorded trips, %			
	walking	bicycle	car	public transport
average at the region	21 %	12 %	67 %	0 %
regions of less than 20 000 inhabitants	mode share of recorded trips, %			
	walking	bicycle	car	public transport
average at the region	21 %	12 %	67 %	1 %

3. Mobility management scenarios

3.1. General approach

Mobility management is usually understood as a task to get people to use desirable mobility modes in the existing urban structure and traffic system. Nowadays it usually means to make people use less cars.

In this paper mobility management is understood more widely. Mobility management is not only limited to existing situation, instead it is to find new solution that make both urban structure and traffic more sustainable. This paper concentrates to the possibilities electric propulsion has to offer.

The base is the scenario approach used in the previous SIMBe report of this SIMBe work package. The four scenarios presented listed some actions to reduce energy consumption and green house gas emissions. This paper describes the actions and their requirements for traffic and urban planning.

3.2. Vehicle development

The scenarios include the idea of lighter vehicles than current average 1.5 tonnes car. Possible vehicle development ideas was discussed in the first report of this SIMBe work package (Alku & Kosonen 2011a). In scenarios was used a vehicle called light electric vehicle. It was described as following:

- **Light Electric Vehicle (L-EV)** is *plug in only light electric vehicle* designed for personal use in urban area. Size and performance are less than what we understand as a car today, but the vehicle is suitable for any weather condition use. Tare weight is less than 400 kgs. Energy consumption per kilometre is 0,12 kWh which is 60 % of normal EV. Annual kilometres are 6 000.

In practice this is much like a quadricycle (*mopoauto* in Finnish) of today, but without the performance limit of a quadricycle. It also means, that L-EV requires a driving licence of a car or at least a driving licence of a motorcycle and 18 years age. A model for L-EV may be found also from the micro-cars of 1950’s, which were also discussed in first report (Alku & Kosonen 2011a). Their weight was 300–400 kgs. With modern technology this weight may include the battery.

Alternative development path for a L-EV may be growing market share of smaller ordinary EVs. Though the experience of car markets is, that small models seem to grow to ”full size”, multi car households may purchase smaller cars after the first one that is a ”full size” car. Small cars weight app. 800–1000 kgs, which is significantly more than L-EV, but still less than current average.

Common to L-EV and smaller cars is, that they do not save urban space. On the other hand they fit to the existing traffic system together with old combustion engine fleet.

Pedelecs are becoming popular in Europe, though they seem to be most popular in countries where cycling is already popular. One benefit of a pedelec is that the use of a pedelec is not a hard physical task that causes sweating during driving. Pedelec can be used for travelling without having to have a shower after arriving to job and there is no need to change clothing.

The drawback of a pedelec in Finland is that a pedelec is not weather proof. Few Finnish pedelec users have reported that pedelec is suitable for winter use. The higher rolling resistance in snow is overcome with electric propulsion and slippery is managed with stud in tyres. But for rain there is no help. There seems to be a need to invent a weather proof pedelec, that is allowed to use like a bicycle, for all ages and without a licence.

The growing share of pedelecs or bicycling may need some modification to the traffic environment. The street environment of Finnish cities is not very suitable to share space with bicycles. On segregated walk and cycle paths a growing number of cycles may cause safety problems. A possible weather proof pedelec may require more space than a bicycle. If such vehicle come popular, there may arise a need to re-organize the traffic environment structure. It is to develop a third category between current street and walk and cycle path.

3.3. Alternatives for human mobility

The dominant load of the land surface traffic network is human mobility. In the early days of industrial society important human mobility was travelling to work. Today work trips is a minor share, approximately 1/3 of all trips are travelling to work. The rest of travelling is shared for shopping and other free time activities.

Telecommunication has been considered as a phenomenon that would make travelling to work unnecessary. Despite of the current capacity of internet, travelling to work still is the mainstream of working. Also it is clear, that telecommunication cannot remove travelling to work in industry. There the distributed subcontractor chain can reduce travelling to work, but the European industry culture is focusing to centralization and large scale economy benefits rather than distributed production like in far east industry.

Travelling to free time activities seems to be related to economic standard of living. With these trips the nature of the trip is to travel to a place where a person can experience something. This means that there cannot be any substitute that would make travelling unnecessary. Still internet seems to have more impact to reduce or to slow down the growth of travelling for leisure purposes. Social media offers contact and discussion, and movies or broadcasting of events let people enjoy and take part by staying home. Instead people explain the need to travel to work necessary because of the social contacts though the work could be done by the computer the same way in home as in office.

Running errands is one of the travelling needs that may have reduced by telecommunication. Many services like banking or authority errands can be processed using internet. But in shopping the development has been vice versa. Though internet offers international e-shopping that could reduce the need of visiting shops, shopping itself has grown as experience of leisure time.

Large shopping malls and hypermarkets are developed towards entertainment centres, where the purpose of the place is more to be there than having to travel there for getting something. To buy commodities is still important, but the most important is the experience of buying it just in a certain place. By the sellers point of view it is important to get the potential customers into the mall to see all the attractions to make him or her to spend money for unnecessary purposes, it is to have customers to make impulse purchases. This is simply an effective way of increasing sales.

In surveys the customers often explain the visiting to malls useful because of the large selection and a possibility to buy everything from one place. Still the sales statistics prove that the selection of the best selling products is narrow, so local grocery shops in walking distance can cover the main selection demand (Kanninen & Rantanen 2010). The development in shopping has been to give up delivery and replace it with the customers travelling to malls. So to return to the past organisation would decrease the travelling to shopping shifting human mobility to delivery logistics.

3.4. Mobility as service

Human mobility is basically a need for a person to move from one place to another. The important aspect is not the travelling mode by any other means than what kind of a service it offers. Based on the benefit theory, a person chooses the mode that offers the best mobility service.

The simple mode classification is the same as presented already with urban zones: walking, public transport and car. From these public transport is usually considered as a service. Walking and driving a car is something that one does himself, so it is not considered as a service. But to be precise, that is not as simple. Walking and driving a car is only possible when certain public services are available. Both walking and driving a car require a road, which is built and maintained as a part of urban environment.

All these three base mobility modes may be considered to be services if they are examined from the user interface of a traveller. Less services is required for walking, just the space and light to see. Public transport is quite simple as a service, as the user interface is always quite similar. There is a location to meet the vehicle, the stop or a station, and the vehicle to enter when available. To operate and maintain the vehicle is included into the service and they are not a matter of the user. Same applies to taxis and other on-demand services though with the addition, that the user must order the service.

A car offers the most complicated user interface where plenty of tasks must be taken care by the user. The user has to operate the car, but also maintain it. Some maintenance tasks have to be processed by the user, though repairs and scheduled service are often bought as a service.

The main mode of having a car is to own the car. By owning the car the user takes the risk of ownership to himself. The alternative for owning a car is to rent a car, in which case the user pays for having the car available. In renting the user naturally pays for having freedom of the risks and high and reliable availability. By renting a car the user may also get a freedom from maintaining the car more than taking care of the consumables.

Renting has plenty of variations. The lowest level of renting is leasing without any accompanying services, in which case the user is responsible for all maintaining tasks as when owning the car. This may not be a good idea for the owner of the car as there is a risk of how well the property is taken care of. The highest level is car sharing. The car is available and ready to run when required. This resembles the most the service of public transport, though the user must drive himself.

By means of mobility management, owning a car is the worst case. Mobility management is possible only when the user buys a new car. Since that the car is in service for it's life time. It will change the owner several times, but that is not relevant by means of the impact of the car during it's life time.

Car sharing and rental offers a good way to control the technology of cars. Sharing and rental also increases the usage of a single car which reduces the total investment base required for vehicles and their parking places. A rented car can also boost the shifting towards EVs as it does not require a consumer to bind himself for long time to the new and possibly uncertain technology.

One more benefit of the renting is that EV can be a part of a travel chain. If a family can travel to summer cottage using one car between the home and railway station and another one from railway station to summer cottage, the family do not need to own and use a large and heavy car for few long trips per year. Also the EVs used in both ends of this trip can be ordinary plug-in EVs, which is not possible for the long trip that exceeds the operating range of a plug-in only EV.

Car share and renting business in Finland is based on relatively new cars. That means that the business is based on the good aftermarkets for cars of couple of years age. This increases the customer price level in this business and limits it to households that were ready to pay for having a relatively new car as own property too. To widen the customer base requires to widen the supply in this business to lower cost markets. This may be challenging in Finland, where the average age of cars is high, 19 years, and the average investment cost of cars is therefore low.

The difficulty in offering mobility services in low density structure is a major challenge. Car sharing work as best in dense and mixed urban structure, where shared cars may locate as near as own car and the demand for the service is not one way. For suburbs in segregated functional urban structure car sharing is practically impossible, which can be seen also from the location of car sharing slots in Helsinki area (see figure 18 in Alku & Kosonen 2011b). The idea of car sharing is that the customer base has public transport available for regular travelling. The shared car has demand for the whole day, not only for peak hours.

Same applies to taxi services. The total economy of taxi business will not last the supply capacity to be set by the peak hour demand. Taxis may be compared to shared cars, but taxis offer a driver too and the customer does not need to take care of the parking.

For low density areas there are plans for on-demand collecting services (HSL 2011). That is not the same thing as paratransit, which competes with regular route and timetable based public transport. The difference is, that on-demand service has not at all regular routes like paratransit has. The route of individual service is formed based on the demanded destinations at each time. The service quality may not be competitive for taxi service or regular public transport if available, but the customer price is lower than in a taxi and the service is available where regular public transport is not. On-demand service may also be just a part of the trip chain, like as a feeder service for train or tram. In such case it supports public transport system. In any form on-demand service may support public transport system indirect by reducing the car dependency.

One form of human mobility service but not usually discussed is the home delivery service. In some cases it has become very popular. The most popular is probably pizza-taxi service. Goods delivery has also grown in form of courier services, but it works best for companies. Home delivery of a mail order is often not suitable service, because the delivery time is daytime and the receivers are not home that time. One positive form of delivery services is bicycle courier. In city centres they may be the fastest available service.

Food delivery from grocery shops was a common practice in 1960’s at the time of evolution from local shops to sparser shop density. In UK there has been a tradition of a milkman, fresh milk delivery to home doors early in the morning. Interesting detail is, that in UK milk delivery vans were electric vehicles for the reason they were silent in operating when people still slept in the early morning.

Along the development of e-shopping there has been trials to internet grocery shops that includes home delivery within short delivery time. At the time of writing S-group offered home delivery services under a brand Kauppakassi (Shop bag). Delivery time is within few hours and available at Saturdays too. Price of delivery is app. 10 € (Alepa 2012, Gastronautti 2012).

If compared to shopping using a car, Kauppakassi-like delivery service should be competitive. To make the order in e-shop takes shorter time than a visit in a shop and cost and time of travelling is excluded. The value of time based on the standard values used in traffic planning is more than the price of the service, so if the value of time assumption is correct, the service should be chosen rather than travelling to shopping.

Still this kind of a service has not become popular and well known. Without further research one guess for the situation may be, that customers do not like to pay for the delivery, regardless if it might be worth for to pay. This fits to the idea, that customers are not willing to pay higher prices in a local shop, though it is less expensive to deal there than to travel to a mall. Customers may also be familiar with pizza-taxis that do not charge extra for larger than just one pizza delivery. They may also be familiar with e-shopping deliveries, that often are free of separate delivery charge, even in case of small deliveries and sourcing very far away.

Another reason may be the lack of precision in delivery time. Pizzas must be delivered fast as they need to be delivered fresh and hot, but with other commodities this is not necessary. But it is not suitable for a customer to stand by for hours to wait for to get the food bag, which is the current case. On the other hand, the delivery precision is actually not necessary, unless the delivery is arranged before certain latest time, like before arriving home from work. The problem is to have a person to wait and receive the delivery. Might this be solved as having cooled refrigerator like delivery mail boxes to keep the food in condition and free the customer to wait and be available for pick-up.

When delivery in some cases is working business, as e-commerce delivery and pizza-taxis, it should be beneficial also in grocery delivery. In case of pizza-taxis the economy of the delivery may not be comparable to other business, as the cost structure and operating area may differ from general delivery business. A possible solution may be to find a suitable business structure, as with Gastronautti Oy that originally was created as an internet food delivery company, but operates currently as all kind of a small delivery company.

3.5. Development scenarios

3.5.1. Base scenario

Base scenario was described as:

- EV sales and penetration follows the base guideline (described in chapter 2.6 in Alku & Kosonen 2012).
- Combustion engine fuel and fuel used in RE-EVs extender engine is counted to be fossil fuel.
- No special actions are taken for changing mobility behaviour.

Base scenario means that there is no special actions for mobility management. Switching to electric propulsion happen market driven.

3.5.2. EU 2050 target scenario

The goal of this scenario was to fulfil the EU green house gas emission targets for year 2050. The mobility management targets were to:

- Reduce passenger car drive-kilometers.
- Increase public transport utilization rate.
- Shifting to lighter vehicles.
- Boost car sharing and rental markets to reduce ownership of heavy cars.

Two first targets require actions in urban structure. Driven kilometres reduction was partly planned to happen by reducing driving for shopping with 60 % in 10 years. This requires re-establishing the local grocery shopping services in such a good quality, that customers feel the services competitive to supermarkets.

A benefit for this development is to increase the land use efficiency and to increase the level of multi functionality of the structure. Both these increase the demand of local services. By means of urban zone types this is not actually a change of urban zone type. For more this is a change in the urban functionality.

Another action was to increase the public transport modal share by increasing the public transport service level. The target was to reduce car usage from 1,7 car trips per day to 1,1 trips which equals to the mobility behaviour of Helsinki suburbs. Looking at the urban zone map of Helsinki suburban area (Figure 2), this target may be interpreted the following way. Current public transport zones (green) should mainly be upgraded to intensive public transport zones (blue) and large share of car zone area (light brown) should be upgraded to public transport zones. Roughly the share of all these three zones should be equal.

In practice this means to increase the service density from 2 to 3 services per hour (20–30 minutes headway) to 4 to 6 services (10–15 min.). To increase the service density is practically easy but requires more money for public transport operating. If the increase in passenger numbers remain to the level of current usage difference, the increase may be 45–65 %. This may fit to the increase of operating cost, but the subsidy increases with same percentage. Therefore it is a good idea to develop the whole public transport system more cost effective, which is possible when the total ridership number increases. In practice this development means shifting from buses to modern tram operation, as heavy rail net cannot be made denser.

More challenging is to shorten the walking distances in current car zones. The walking distance in public transport zone is currently 250–400 meters (Ristimäki e.a. 2011). Urban structure in car zones is usually sparse and street network do not allow suitable routes for buses. For these reasons there are ideas in HSL to organize some kind of a demand based services (HSL 2011).

Shifting to lighter vehicles may be organized by setting directive actions. Those may be taxing or using cost differentiation. There may also be differentiation based on technical features of the vehicles, like zones which are only allowed to vehicles of certain size or energy consumption. Such actions that may call users from public transport or cycling must be avoided. A quadricycle is an example of such wrong action. As a quadricycle is allowed for persons under 18 years, it does not reduce the use of heavier cars, but it reduces the use of other light vehicles, public transport, bicycling and walking of persons under 18 years.

Shifting to lighter vehicles may happen market driven. Electric vehicles seem to be more expensive than current cars, so the consumer can reduce the price difference by purchasing a smaller car as EV.

Shifting to EVs may be a boost to rental markets by the nature of technology that is considered uncertain. But it may be worth for to consider also administrative guidance, like different taxing for rental cars. Rental is popular in business cars just because it is a good choice by means of taxing consequences.

3.5.3. Coercion scenario

The EU 2050 scenario did not fill the EU goal for 2020. The idea of this coercion scenario was to limit fossil fuel sales up to 2020 to the level that fulfils the EU goal. That means that consumers need to find alternative solutions for their mobility needs. The role of authorities is to respond to the increasing demand of alternative car use solutions, like bio fuels and EV sales and penetration growth.

By means of mobility management there is not much to be possible to do than to continue the current practice. Year 2020 is too near for any other actions described within EU 2050 scenario.

The actions for increasing the share of public transport are same as in EU 2050 scenario. Their impact come true only after 2020.

3.5.4. Bio fuel scenario

This scenario was the worst case scenario by means of EV development. The assumption was that EV sales cannot be boosted and mobility management actions to reduce the car usage will not succeed. In this case the only way to reduce green house gas emissions is to shift from fossil fuels to bio fuels.

As this scenario does not include mobility management actions, this scenario needs not to be discussed here.

4. Discussion

4.1. Limitations

This work is an overview of mobility management possibilities related to electric mobility and actions to speed up electric mobility and EV penetration. The main focus is in greater Helsinki region as was the limitation of SIMBe project.

The previous report of this SIMBe work package (Alku & Kosonen 2012) showed that the share of EVs cannot grow fast and is marginal still in 2020 which is the first target year of EU climate policy. That means, that the short term goals for 2020 need to be fulfilled with other actions than those related to electric mobility. Traffic management is important tool for the next 10 years, but it cannot base to electric mobility. For this reason the focus in this work is in long term action and the later EU target year 2050.

The previous report also showed that the electric propulsion technology alone cannot solve the green house gas emission targets. Together with that, the other impacts of road mobility cannot be solved by just switching to electric propulsion without development in vehicle and mobility concepts. Vehicle technology was discussed already in the first report of this SIMBe work package (Alku & Kosonen 2011a).

As vehicle technology alone is a wide topic, it is not discussed here more than some guidelines of the required properties for future vehicles based on electric propulsion.

Mobility concepts are strongly bound to urban structure understood widely meaning both the physical and the functional structure. Both of those are mainly topics of urban planning and includes other aspects of traffic planning than just the propulsion technology. The discussion in this paper is therefore limited to the idea of urban zoning, which is created for describing the urban structure by means of traffic modes. Urban zones as a concept of traffic planning is still in process, so the concept cannot be dealt deeply.

Does electric propulsion alone have some impact for mobility and if so, what kind of an impact, is still an open question. In this set of SIMBe reports some results are reported, but mainly large scale field tests and surveys are still in plans or just started. These experiences will be collected in TEKES-organized research programme EVE (http://www.tekes.fi/programmes/EVE) and the subproject eSINi at greater Helsinki region (http://www.tekes.fi/programmes/EVE/Projects?id=10543157).

4.2. Further Research

Electric vehicle related research is concentrated to electric car technology. The research for new vehicle concepts seems to be rare. As there remain many negative impacts of car use if only the propulsion technology changes but the vehicle concept remains as it is, there is a need to create new vehicle concepts that take the most of electric propulsion technology.

The Urban Zone concept is still in progress to be developed as a nationwide planning aid for traffic and urban planning. The current phase is based much on physical structure and experienced mobility behaviour. Widening the urban zone concept to include the functional structure is important by means of using the concept for mobility management. The level of functional blending should be taken as zone criteria. As the Urban Zone concept is based on the current mobility modes, it cannot take into account any future modes that may arise from future vehicle concepts.

The impact of propulsion technology to mobility behaviour will be researched in eSINi project as a continuation of SIMBe. The work in eSINi is also limited to greater Helsinki region as SIMBe. In future it is worth for to widen the research nationwide to understand the impacts in regions that are less public transport intensive that the Helsinki region.

5. Conclusion

The aim of this work was to look for the use of mobility management in saving energy in mobility, to reduce the need of mobility and to allocate mobility to less energy intensive mobility modes by using electric propulsion in vehicles.

One result of this work is that mobility management has to start from the urban planning. This is because of the characteristics of the urban structure specify the possible mobility modes. When electric propulsion cannot fulfil the goals for green house gas emissions if the traffic system remains otherwise as it is, there must happen a change in the modal share.

Another goal for urban planning is to reduce the need for mobility. The urban structure density alone does not solve the mobility need. The functional structure is important factor. That includes both the level of functional blending in the area and the available services. Both delivery and telecommunication have potential in replacing human mobility.

An important goal in reducing energy consumption of human mobility is to shift towards vehicle technology that uses less energy. Public transport already offers less energy consumption, but in practice it is difficult to cover all the urban structure with energy efficient public transport. New vehicle technologies and concepts between a current car and bicycling can increase the availability of public transport and replace the use of car with environmental friendly solutions.

Services related to electric propulsion technology may also speed up the shifting towards electric mobility. Developed car rental and car sharing can make a simple plug-in EV a part of a travel chain in case the complete trip is too long for the operating range of plug-in EV. Renting and car share lower the step for a consumer to switch to EV when the risk of new technology is not completely a responsibility of the consumer.

As a result of the this SIMBe work package the role of authorities rise into important position. Based on the recent experience it is unlikely to see that the shifting to electric mobility might happen market driven. To organize the conditions for electric vehicles like sufficient charging supply requires actions from the authorities. Urban and traffic planning is the responsibility and work of authorities so authorities have to adapt the mobility management basics to create urban environment which supports electric mobility and benefits from it. Authorities have the control to rules and directions to guide the behaviour of the citizens. These tools must be directed advance electric mobility and reduced human mobility needs.

Summary of the statistics used

Battery capacity/weight –relation (Li-Ion) 0.202 kWh / 1 kg (http://www.batteryuniversity.com/parttwo-55.htm)
Battery capacity/weight –relation (Li-Ion) 1 kWh / 10 kg (Haakana 2008)
Battery capacity/volume –relation (Li-Ion) 0.514 kWh / 1 L (http://www.batteryuniversity.com/parttwo-55.htm)
Battery service life (lithium phosphate) 10 years (Battery manufacturer's specification)
Battery charge/discharge amount (lithium phosphate) 3000 (Battery manufacturer's specification)
Battery specific price for consumers 5.000-10.000 € / 10 kWh (European Batteries Oy)
Specific capacity of a solar panel, considering the efficiency coefficient of inverter and regulator, 100 W/m^2 (Savonia 2010)
The average capacity corresponding to the yearly yield of a solar panel in central Finland 15 W/m^2 (Savonia 2010)
Length of a commute driven with a passenger car 15 km (average in the Helsinki area)
Average life cycle of a passenger car in Finland 19 years (HLT 2006)
Average life cycle of an EV 10 years (see chapter 2.5 in Alku & Kosonen 2012)
The average usage of a passenger car in Finland 18.000 km/year (HLT 2006)
Average daily usage of a passenger car at 80 % probability at most 40 km (passenger car usage distribution in Henkilöliikennetutkimus (HLT 2006 6_31_tapa.xls))
Tax percentage in passenger car consumer price, about 40 %
Market price for coal in a port in Finland, price per thermal value, 8 €/MWh
Tax percentage in traffic fuel consumer price, about 60 %
(http://fi.wikipedia.org/wiki/Polttoainevero 8.4.2010 17:18)
Market price for traffic fuel, price per thermal value, 0,16 €/kWh
Density of wood chips 300 kg/m^3
Industry market price for wood, price per thermal value, 10–25 €/MWh
Density of wood logs when stacked 500 kg/m^3
Population in Finland end 2010: 5,4 million inhabitants (http://www.stat.fi/tup/suoluk/suoluk_vaesto.html)
Number of households in Finland: 2,5 millions (http://www.stat.fi/til/tjt/2009/tjt_2009_2011-05-20_tau_021_fi.html)
Finnish passenger car stock 2.9 million cars in 2010 (Tilastokeskus 2011)
Car density in Finland 535 cars / 1000 inhabitants (Tilastokeskus 2011)
Maximum car density 600 cars / 1000 inhabitants (see chapter 2.2 in Alku & Kosonen 2012)
The yearly energy consumption of an electric car stock in Finland 9,2 TWh (Kronström 2009)
Practical battery capacity of an electric car 30 kWh (150 km range)
Nominal drive energy consumption of an electric car (tank-to-wheel) 0.2 kWh/km (Kronström 2009)
Consumer price of electricity 0.13 €/kWh
(http://www.sahkonhinta.fi/summariesandgraphs 8.4.2010 17:12)
Specific emission of electricity production in Finland 260 g/kWh (Energiateollisuus 2010)
Specific emission of combustion engine car in Finland 179 g/km (LIPASTO 2011)
Total GHG emissions from passenger cars in 1990: 6888 Mkg (http://lipasto.vtt.fi/liisa/paastodata.htm)
The average effect corresponding to a wind power plant's yearly production, as share of nominal power 25 % (Holttinen ym. 1996, pp. 38–39)
The planned total wind power to be constructed in Finland 2000 MW (Matilainen 2008)

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