Personal Rapid Transit systems for reduction in car dependence

Karlskrona case study

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Abstract: This research project is designed to enhance the planning process that can aid authorities moving towards sustainable and economically feasible local and regional mobility systems. The improvements that have been made to transit so far have not been successful in breaking the trend of increasing car traffic and decreasing transit trip making, therefore not reducing its contribution to emissions and climate change. Sustainable mobility is a complex system which encompasses other systems that must be visualized and worked upon in an integrated manner, from a bird's eye perspective: spatial planning, energy supply, economic structure and behaviour change. The existing synergies amongst these systems show that many downstream problems in some of them usually only have one upstream cause affecting all of them. Environmental impacts (noise, pollution, health problems), accidents and congestion are all by-products of road transport activities – they are the so-called external costs – and must be made part of the equation. European guidelines were analysed, as well as the results of many of the European Union's mobility research programs. The core of this research analyses how to move Karlskrona municipality's mobility system towards its vision of success in the future through the Framework for Strategic Sustainable Development – Sustainable Mobility (FSSD-SM). Backcasting from a sustainable vision in the long-term future is central to this process. The municipality of Karlskrona, in Sweden, is the case study. A sustainability analysis of Personal Rapid Transit (PRT) systems was undertaken to determine the feasability of integrating this modal system into the mobility solution for Karlskrona municipality.

Keywords: Personal Rapid Transit, sustainable development, sustainable mobility, land-use, energy, behaviour change, car dependency, driverless

Acknowledgements

This research project is the conclusion of our Master's Programme at the Department of Mechanical Engineering, Blekinge Institute of Technology, Karlskrona, Sweden, under the supervision of Lic. Eng. Sophie Hallstedt and MSLS BSc Fiona Wright. Many thanks to them for assisting us in structuring the whole work.

It was developed in collaboration with the municipality of Karlskrona, which asked us to assist them in their process of moving towards a sustainable mobility society. Thanks Karlskrona for such an enriching learning opportunity.

Our most sincere thanks go to Johnny Lilja, Project Leader for Energy Coordination and Advice at Karlskrona municipality, who enthusiastically guided us and facilitated our work throughout this quest. Many thanks go also to Tommy Olsson and Roger Poka, who introduced us to PRT systems, giving us the opportunity to analyse the sustainability of this cutting edge innovative mobility system.

We would like to thank the following professionals for their time and expert feedback; they have contributed so much to this research project: Jan-Anders Glantz, Karlskrona municipality; Jorgen Gustafsson, Vectus PRT; Per Hansson, Energikontor Sydost in Växjö; Pia Kronengen, Karlskrona municipality; Sven Hult, Blekingetrafiken; and all the workshops attendees: Tore Almlöf, Liliann Bjerström, Sofia Bothorp, Günter Dessin, Ove Falck, Kenneth Gyllensting, Sven Hult, Anders Jaryd, Ulf Klint, Mats Lindbom, Tommy Olsson, Sven-Olof Petersson, Roger Poka, Carl-Göran Svensson, Lars Hildingsson and Ola Swärdh.

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Karlskrona, June 2008.

Statement of Contribution

This thesis was written in a collaborative fashion, drawing on the previous knowledge and background each of the authors had to contribute with. Alexandra used her writing skills in the English language, with strong input and review by Patricia. Heleen was responsible for the referencing. Patricia developed the structure of the thesis, an iterative exercise requiring logical thinking and information flow attention.

Heleen established and conducted contact with the municipality authorities and employees, and provided the team with information on the municipality originally furnished in Swedish. Alexandra took the lead on contacting external advisors and PRT systems vendors from Patricia's research.

The original topic was derived from a request from Karlskrona municipality for research into the use of PRT systems as a means to make the municipality more attractive, supporting its growth in a sustainable manner while helping it achieve its zero emissions target in the medium-term future.

During the literature review, the work was divided to have each of us focus on specific issues: Patricia researched into PRT systems, Karlskrona's data, European mobility policy and legislation; Alexandra researched into planning integration for sustainable mobility systems, including land-use, energy, economic and behaviour change systems; and Heleen looked into additional behaviour change material.

The workshops were planned by the team and conducted partly in Swedish by Heleen, and partly in English by Alexandra and Patricia.

While not without challenges, the experience of writing a group thesis has brought far better results than what could have been achieved individually. It was a great learning experience.

Karlskrona, June 2008

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Executive Summary

Continuing economic development and the consequent increase in atmospheric pollution from motorized transport emissions (particularly in urbanized areas) have transformed cities in one of the big contributors for the climate change issue around the planet.

Renewable energy for fuels and advanced technology mobility systems are already in place to mitigate the existent transportation systems undesirable effects. However, it has been proved that only mitigating the impact will not solve the problem, therefore the need for a long-term solution is urgent.

Besides its downstream impacts on the environment due to greenhouse gas emissions, car dependency has been causing several other problems to human society in the biosphere. The most impacting are time wasted in congestions, accidents, noise pollution, the need of raw materials to produce vehicles that do not have a suitable end of life destination, and the enormous infrastructure supporting all of this.

This research project aims to assist municipal authorities' move towards sustainable mobility by offering a strategic methodology to plan for car dependency reduction – one of the main issues to overcome in the existing unsustainable mobility scenario.

Offering excellent public transport capable to compete with cars was the primary target identified in order to reach success. Moreover, behaviour change, integrated urban development and energy planning, and economic issues are also important issues related to the transportation system which deserve careful systemic (integrated) analyses when planning for sustainable mobility.

Personal Rapid Transit (PRT) systems were analysed in this study as a suitable and attractive alternative transportation system, offering the advantages of private cars while avoiding its negative sides, leading urban areas towards zero car dependency contributing to a sustainable mobility vision in the future.

Through Karlskrona municipality's case study a specific strategic planning method for sustainable mobility was defined: the Framework for Strategic Sustainable Development – Sustainable Mobility (FSSD-SM).

In order to achieve these results the research project was designed to answer the question:

Can the municipality of Karlskrona move towards sustainable mobility by integrating Personal Rapid Transit systems with other modal systems?

This question is informed by answering the sub-questions:

1. What barriers prevent European cities and regions from adopting new mobility technologies to decrease car dependency?

2. What are the gaps, threats, opportunities and leverage points for Karlskrona municipality to decrease car-dependency? How can local authorities use the Strategic Sustainable Development Framework to plan for a decrease in car dependency?

3. Can podcar systems be considered sustainable?

Methods

The methods utilised were:

Literature review informing on the issues of economics, behaviour change, energy, land-use and transport modes as related to sustainable mobility, as well as analyses of research projects (especially European Union funded and commissioned) and best practice cases on sustainable mobility and land use planning around the world;

The Framework for Strategic Sustainable Development (FSSD) approach: The FSSD was developed by Dr. Karl-Henrik Robèrt for planning in complex systems, and is used here as a main tool informing the achievement of Strategic Sustainable Development in Karlskrona's Mobility System. The core elements of this methodology are the backcasting process and the four sustainability principles which guide to a complete understanding of the unsustainable current reality as well as serve as constraints for development of the vision of success in the future:

In a sustainable society, nature is not subject to systematically increasing:
I. concentrations of substances extracted from the Earth's crust
II. concentrations of substances produced by society
III. degradation by physical means

and in that society…
IV. people are not subject to conditions that systematically undermine their capacity to meet their needs.

Compliance with these four principles was the basis for planning for a sustainable mobility society in Karlskrona in 2050, using the ABCD tool in order to perform its sustainability analysis, identifying its mobility current reality, a vision for its sustainable mobility in 2050 with zero car dependency, and compelling measures to reach this vision. Backasting from Karlskrona's mobility vision assisted the strategic planning process, ensuring that the actions taken will lead the municipality closer to its sustainable vision, bridging the gap between the current reality and the envisioned future.

A SWOT analysis provided information for building Karlskrona sustainable mobility's business case.

The sustainability analysis of PRT systems was also performed in order to identify the impact of such a system in society within the Biosphere.

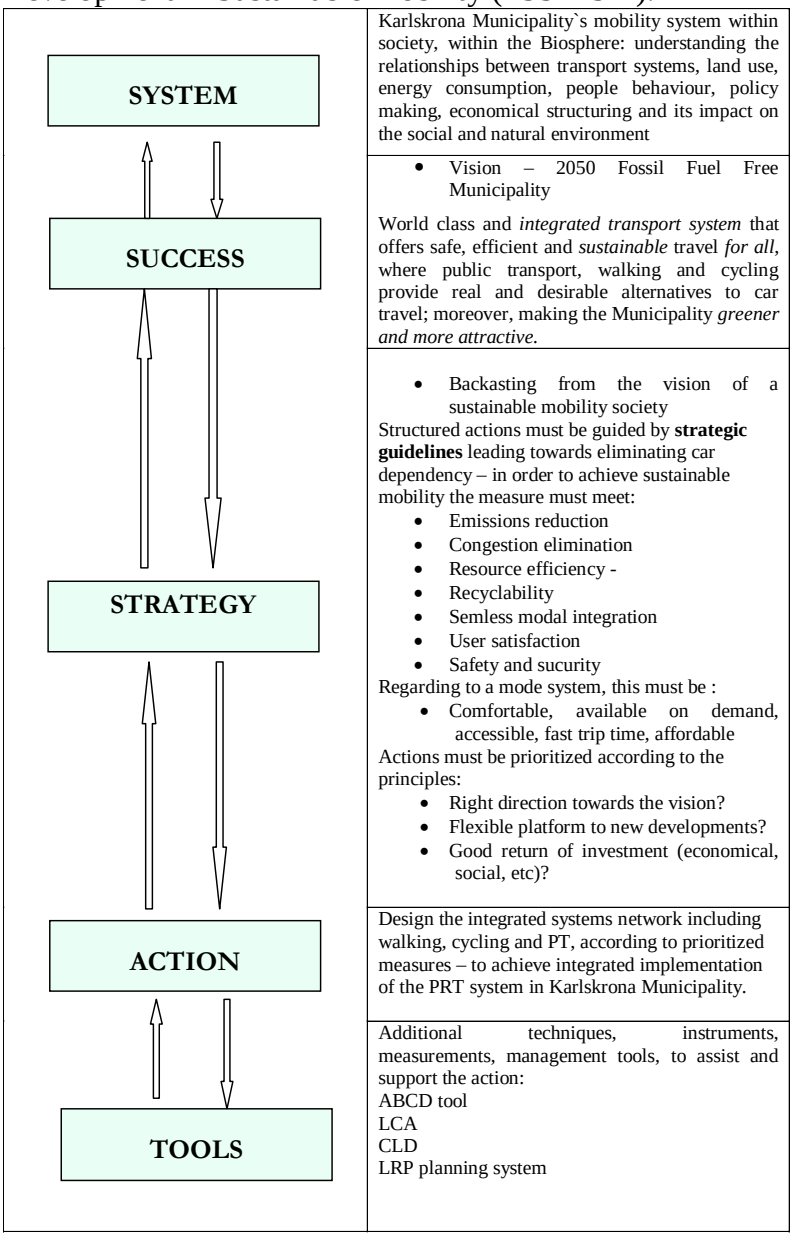
External advisors reviews and peer reviews completed the methods.

Results

Sustainable mobility is a complex system, and therefore it demands that one take a bird's eye view from this system to acknowledge what other systems closely interelate with it. Doing so enables the optimization of the use of the synergies existing amongst these closely related systems to come up with upstream solutions to many of the downstream problems existing in most of these integrated systems. The use of the ABCD tool and the best practice studies provided the necessary understanding to deal with issues concerning car dependency reduction in Karlskrona. Behaviour change campaigns, internalization of external costs of transport; integration of the planning processes in land use, transportation and energy; governmental incentives and disincentives; long-term solution by a more balanced split between high-capacity transport modes like buses and trains, and more individual transport modes, such as PRTs, and private modes like cycling and walking; technical and social innovations like IT technologies which enable work from home; all of which must be implemented in an integrated manner. Due to these complex interdependencies there are no simple

recipes or easy successes on how to reach sustainable mobility (Topp, H., 2006)

Strategic guidelines were created to assist in the priorisation of measures in order to achieve a sustainable mobility society. These guidelines can be found below in the Adapted Framework for Strategic Sustainable Development in Sustainable Mobility (FSSD-SM).



Karlskrona Municipality`s mobility system within society, within the Biosphere: understanding the relationships between transport systems, land use, energy consumption, people behaviour, policy making, economical structuring and its impact on the social and natural environment

- Vision – 2050 Fossil Fuel Free Municipality

World class and *integrated transport system* that offers safe, efficient and *sustainable* travel *for all*, where public transport, walking and cycling provide real and desirable alternatives to car travel; moreover, making the Municipality *greener and more attractive.*

- Backasting from the vision of a sustainable mobility society

Structured actions must be guided by **strategic guidelines** leading towards eliminating car dependency – in order to achieve sustainable mobility the measure must meet:

- Emissions reduction
- Congestion elimination
- Resource efficiency -
- Recyclability
- Semless modal integration
- User satisfaction
- Safety and sucurity

Regarding to a mode system, this must be :

- Comfortable, available on demand, accessible, fast trip time, affordable

Actions must be prioritized according to the principles:

- Right direction towards the vision?
- Flexible platform to new developments?
- Good return of investment (economical, social, etc)?

Design the integrated systems network including walking, cycling and PT, according to prioritized measures – to achieve integrated implementation of the PRT system in Karlskrona Municipality.

Additional techniques, instruments, measurements, management tools, to assist and support the action:
ABCD tool
LCA
CLD
LRP planning system

Discussion and Conclusion

Sustainable mobility in a small municipality where car rider ship is rising can only be achieved with the supply of a new technology system attractive enough that can compete with the use of the car (Andrèasson, I, 2008). Therefore, PRT systems were compared in this project to the use of the private car, and not to the use of other PT modal systems. To that extent, the fact that it provides personalised on demand service 24 x 7, and that it is driverless (therefore allowing for the extended service hours with no extra cost) must be added to the careful step-by-step introduction of the system with the clear aim to *supplant car use*, where additional infrastructure for the private car will not be accepted.

Karlskrona municipality's case study highlighted several benefits which the implementation of PRT systems would ensure: (i) increased competitiveness for the municipality; (ii) attracting investment and visitors; (iii) direct and indirect employment effects; (iv) access benefits to citizens who are now marginalized by poor PT and no access to cars; (v) congestions elimination; (vi) emissions and pollution reduction; (vii) accident and noise reduction.

Karlskrona municipality can and should go ahead to plan for the implementation of PRT systems in the medium term. Unless it decides to embrace this new technology and plans accordingly, as it takes time to come into place, it will go on "hitting the walls of the funnel" and not be prepared for issues like peak oil, ever more severe EU and National regulations concerning emission, etc. The next natural step would be to contract expert advice to develop a thorough feasibility study for the integrated implementation of a PRT system in the city.

Glossary

ABCD tool: a strategic planning process used for backcasting from principles. It includes four steps: (A) understanding the system, (B) assessing the current reality, (C) establishing a vision of success and brainstorming solutions, and (D) prioritizing strategic actions (Robèrt et al.2004).

Agenda 21: it is the document elaborated in consensus between governments and civil society institutions of 179 countries, and approved in 1992 during the United Nations Conference on Environment and Development, held in Rio de Janeiro. It translates into actions the sustainable development concept.

Backcasting: 'planning from success' by starting with the desired outcome in mind and then determining the steps required to achieve the outcome. Backcasting is in contrast to *forecasting***.**

Backcasting from scenarios: a form of backcasting where future scenarios are created as goals. The limitations of this approach are that it is hard to agree on a desirable scenario, scenarios are based on today's assumptions and technology and may not be truly sustainable.

Backcasting from principles: a form of *backcasting* where 'success' is defined at a principle level. Applied to sustainability, the minimum requirements for a sustainable society can be defined (using sustainability principles) without constraining any options and allowing for creative solutions to evolve.

Bali Roadmap: consists of a number of forward-looking decisions made at the The United Nations Climate Change Conference in Bali (December 2007) that represent the various tracks that are essential to reaching a secure climate future. The Bali Roadmap includes the Bali Action Plan, which charts the course for a new negotiating process designed to tackle climate change, with the aim of completing this by 2009. It also includes the AWG-KP negotiations and their 2009 deadline, the launch of the Adaptation Fund, the scope and content of the Article 9 review of the Kyoto Protocol, as well as decisions on technology transfer and on reducing emissions from deforestation

Biosphere: is the part of the Earth, including air, land, surface rocks and water, within which life occurs, and which biotic processes in turn alter or transform. From the broadest biophysiological point of view, the biosphere is the global ecological system integrating all living beings and their relationships, including their interaction with the elements of the lithosphere, hydrosphere and atmosphere.

Blind alley: Efforts towards sustainability that do not lead to future progressive or complementary actions.

Cardiff Summit: (15 and 16 June 1998) laid the foundation for coordinated Community action to integrate environmental concerns into EU policies. At the same summit the European Council invited the Transport, Energy and Agriculture Councils to define strategies of their own on this point.

Cradle to cradle design: Cradle to Cradle Design is a design paradigm developed by the company McDonough Braungart Design Chemistry (in Germany), based on principles and an understanding of the pursuit of value. At a fundamental level, the new paradigm proposes that human design can learn from nature to be effective, safe, enriching, and delightful. Cradle to Cradle Design models human industry on nature's processes, in which materials are viewed as nutrients circulating in healthy, safe metabolisms. Industry must protect and enrich ecosystems—nature's *biological metabolism*—while also maintaining safe, productive *technical metabolism* for the high-quality use and circulation of mineral, synthetic, and other materials.

Decoupling: The ability to achieve economic growth without creating concurrent growth in undesirable indicators, e.g. resource consumption.

Dematerialization - using less of the same substances (i.e. mined resources, manufactured products, energy, nature-based resources, etc.)

Downstream solution: A solution that addresses symptoms rather than causes of issues.

Flexible platform: a measure that does not inhibit future complementary investments towards sustainability and can be built upon to achieve further progress.

Funnel: A metaphor used to illustrate a narrowing opportunity to act in the presence of (1) declining ability of ecosystems to sustain pressures, and (2) increasing pressures from society.

Headway: the time interval or distance between two vehicles, as automobiles, ships, or railroad or subway cars, travelling in the same direction over the same route.

Local Authority: A generic term used to denote municipalities and agencies operating at the local level (i.e. including public transport companies or redevelopment agencies).

Peak Oil: M. King Hubbert, the late petroleum geologist and Shell oil company consultant, articulated the notion that oil production would peak when about half of the economically recoverable resource had been exploited. His successful prediction of peak oil production in 1970 in the continental United States (*Hubbert*, 1956) has encouraged numerous analysts to subsequently apply his model or variations thereof to global oil production. The concept of peak extraction of a finite non-renewable resource constrained by geology and geography has received support from similar patterns of growth, peak production, and decline of mineral resources, natural gas, and coal in specific regions.

Precautionary Principle: is a response to uncertainty, in the face of risks to health or the environment. In general, it involves acting to avoid serious or irreversible potential harm, despite lack of scientific certainty as to the likelihood, magnitude, or causation of that harm. An alternate formulation states that the lack of certainty regarding the threat should not be used as an excuse to do nothing to avert that threat.

Rebound effect: Counterproductive effect of an otherwise effective measure, e.g. an improvement in energy efficiency that is absorbed by a resultant increase in energy use.

Reductionism: Oversimplification of issues, focusing on specific aspects and ignoring ramifications and possibly consequences.

Strategic Sustainable Development (SSD) Framework: Adaptation of the generic *five-level framework* to structure efforts towards strategic sustainable development.

Substitutions/changes: changing to new types of materials, flows, management routines for ecosystems or even mindsets, for example, the `humanising aspects` of responsibly bringing services to people rather than commodities.

SWOT analysis: Managerial tool to access the strengths, weaknesses, opportunities and threats that a company or organization faces.

TERM: Transport and Environment Reporting Mechanism – an EU list of indicators, developed and implemented by the European Commission and the EEA, which should enable policy-makers to gauge the progress of their integration policies (published yearly since 2000).

The Natural Step (TNS): Non-governmental organisation focused on research, education and consultancy in the field of sustainable development.

Upstream Solutions: Solutions that address root causes of issues, rather than symptoms, e.g. addressing mobility demand as opposed to the promotion of renewable fuels.

Urban Sprawl: Expansion of built land on the periphery of an urban area at a rate greater than that of the concurrent increase in population. Often characterised by low-density development, large single-use areas, discontinuous urbanisation, and a high rate of automobile dependency.

Webinar: Short for Web-based seminar, a presentation, lecture, workshop or seminar that is transmitted over the Web. A key feature of a Webinar is its interactive elements -- the ability to give, receive and discuss information.

List of Acronyms

AGT	Automated Guided Transit
CO_2	Carbon Dioxide
EEA	European Environment Agency
EU	European Union
FSSD	Framework for Strategic Sustainable Development
HVAC	Heat, Ventilation and Air Conditioning
IPCC	Intergovernmental Panel on Climate Change
ITS	Intelligent Transport Systems
LRT	Light Rail Transit
LTP	Local Transport Plan
LTR	Local Transport Performance
MSLS	Masters in Strategic Leadership Towards Sustainability
NPV	Net Present Value
PT	Public Transport
PV	Peak Vehicle
PV	The Present Value of investment or revenue, with future payments/income discounted to the stated year
RKM, route-km	Length of a public transport route or entire network, in kilometres
SLTF	Swedish Public Transport Association

SSD	Strategic Sustainable Development
SUTP	Sustainable Urban Transport Plans
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USA	United States of America
UV	Ultra violet radiation
VH	Vehicle-hours, the time a vehicle is in operation
VKM, vkm,	vehicle-km
WBCSD	World Business Council for Sustainable Development (NGO based in Geneva) http://www.wbcsd.org/

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1. INTRODUCTION

The objective of this research is to introduce a new perspective to sustainable mobility strategic planning for small European Municipalities -- a Framework for Strategic Sustainable Development (FSSD) -- where backcasting from a sustainable vision in the long-term future is central to the process. This vision portrays mobility in an efficient, safe (for the people utilising it and for the environment) and economic manner, where the use of private cars has been substituted by attractive and reliable integrated sustainable transportation modes. It is a holistic approach based on systems thinking, which provides a structure for organising analysis and strategic planning in complex systems from the perspective of the mobility issue *and* the global socio-ecological system.

This study aims at analysing Personal Rapid Transit (PRT) systems as a suitable and attractive alternative transportation system offering the advantages of private cars while avoiding its negative sides, leading urban areas towards zero car dependency contributing to a sustainable mobility vision in the future.

Throughout this research paper the terms Personal Rapid Transit (PRT) and Podcar are used interchangeably and have the same meaning.

1.1 SOCIETY WITHIN THE BIOSPHERE

The biosphere with its human societies and organizations is a complex system. Ecosystems are the planet's life-support systems - for the human species and for all other forms of life. The needs of human biology for food, water, clean air, shelter and relative climatic constancy are basic and unalterable. The causal links between environmental change, human health, human activities are complex because they are often indirect, displaced in space and time, and dependent on a number of modifying forces, as shown in figure 1.

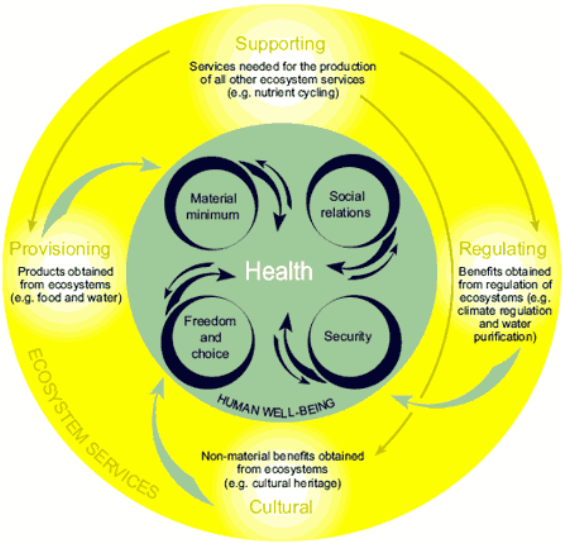

Figure 1:Ecosystem Services, human well being, and health.
Source: Corvalan et al, 2005

We live on a bountiful planet, but not a limitless one. The global economy and human population continue to grow, but our planet remains the same size. Advances in technology can help us to stretch the planet's resources further – but the pace of growth in the global economy is outstripping the ability of technology to keep up. Biodiversity, which includes the great variety of animals and plants found in nature, provides the foundation for ecosystem services that are necessary to sustain human life on this planet. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), published in 2007, provided stronger evidence (with a very high confidence classification) for the observations of a warming Earth and for the role of greenhouse gas emissions in the observed warming -- which cannot be explained by natural internal climate variations or the response to changes in natural external forcing (solar irradiance and volcanoes). The Report also presented evidence for observable impacts of warming on the biosphere and on human societies (Rosenzweig, C. et al, 2007). These results make it imperative to obtain significant reduction in car dependency in the whole world.

This scenario can be explained utilizing the Funnel Metaphor, where non-sustainable development can be visualized as entering deeper and deeper into a funnel, in which the space to succeed becomes narrower and narrower as time goes on (Robèrt, K.H. et al, 2007), as depicted in Figure 2.

The threat of climate change exposes systematically increasing trends leading to impacts on our society, where the walls of the funnel represent converging socio-ecological pressures, and increasing destructive trends. As society moves through time, less and less options are available. One "hits the walls of the funnel" when encountering stronger legislation, scarcity of resources, and natural disasters which makes reaching sustainability or even survival, more difficult. Finding sustainable solutions means strategically navigating between these two walls and finally leveraging them to live without destroying our planet and social fabric. The challenge facing us lies in finding these sustainable pathways.

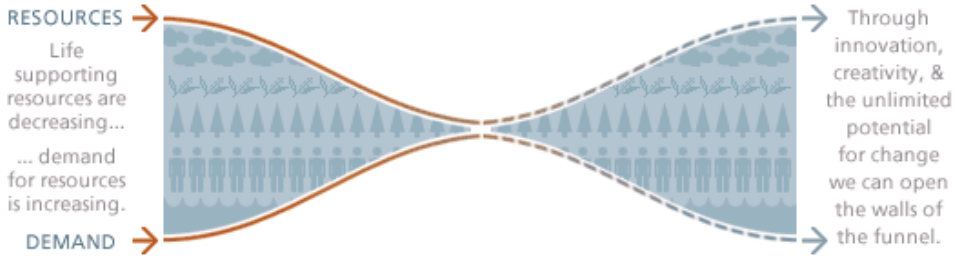

Figure 2: The Funnel
Source: The Natural Step Canada

1.1.1 Unsustainable mobility

Climate change exposes underlying flaws in our design of society. It affects people, plants, animals – the whole biosphere. How will societies and the Earth's environment adapt to or cope with this?

The Agenda 21 document (resulting from the 1992 United Nations Conference on Environment and Development), criticizes the current model of economic growth, considering it socially unfair and wasteful, and destructive from an environmental point of view. Opposing this unfair and predatory model, it proposes a new and alternative society, fair and environmentally responsible, both producer and product of sustainable development. The political path for change is participatory democracy with focus in local action and in the shared management of resources (Lichtenberg, R.A., 2006).

Yet, the present and growing trend is that continuing economic development and the consequent increasing of atmospheric pollution from motorized transport emissions (particularly in urbanized areas) are transforming cities in one of the big contributors for the climate change issue around the planet.

During the period 1990–2004, global emissions of CO_2 increased by 27 %. Energy demand from the transport sector — an indicator of global transport emissions — increased by 37 % over the same period. The two largest greenhouse gas emitters world-wide are USA and China. In the same period, CO_2 emissions in the USA increased by 19 % whilst the energy demand from the transport sector increased by 28 %. China saw the fastest increase in emissions with CO_2 emissions and energy demand growing by 108 % and 168 % respectively. Total emissions per capita (2004) show China (3.7 t/capita) being far below the USA (19.6 t/capita) and EU-27 (8.7 t/capita). In the EU-27, total greenhouse gas emissions had a decrease of only 7,9% from 1990 to 2005. In the same period, emissions from the transport sector increased by 26 %. In 2005 they represented 22 % of total EU-27 greenhouse gas emissions [1] (EEA, 2008). However, regardless of who emits more and where, climate change effects will hit the whole world haphazardly.

Although there is an intense disagreement about when "peak oil" might occur -- a factor most strongly influenced by the assumed rate of economic growth for the future -- it is widely accepted that it will occur at some point this century (Wood et al., 2003; Kerr, 2005 in Kharecha, P.A. and Hansen, J.E, 2007). This phenomenon will result in substantial price increase for fossil fuels, aiding in the reduction of car dependence – making it ever more urgent the need for renewable energy and advanced technology mobility systems (precautionary principle).

1 The transport sector presented here consists of road transportation, domestic civil aviation, railways, national navigation and other transportation. It excludes emissions from international aviation and maritime transport (which are not covered by the Kyoto Protocol or current EU policies and measures). Road transport is by far the biggest transport emission source.

1.1.2 Sustainability principles

To tackle such problems as described above, in the late 1980s Dr. Karl-Henrik Robèrt led a network of leading Swedish scientists from a variety of disciplines, which came up with a principle-based and systemic definition of sustainability. Over the years these principles have been successfully adopted by several organisations and communities.

As basic or first order principles (SPs), they intend to be: (i) based on a scientifically agreed upon view of the world; (ii) necessary to achieve sustainability; (iii) sufficient to achieve sustainability; (iv) general to structure all societal activities relevant to sustainability; (v) concrete to guide action and serve as directional aides in problem analysis; (vi) non-overlapping or mutually exclusive in order to enable comprehension and structured analysis of the issues (Holmberg and Robèrt, 2000).

Sustainability Principle #1

SP1: IN A SUSTAINABLE SOCIETY, NATURE IS NOT SUBJECT TO SYSTEMATICALLY INCREASING CONCENTRATIONS OF SUBSTANCES EXTRACTED FROM THE EARTH'S CRUST;

"We dig up substances from the Earth's crust – various minerals, oil and gas, etc. – and use them in our products and processes, and then release them into nature. We do this at a faster pace than nature re-deposits these substances back into the Earth's crust. And as a result, they accumulate in natural systems and eventually cause problems *if their concentrations get too high*. Note that the first principle does not say a sustainable society requires that we not use any material at all from the Earth's crust. It does not say that there is no mining in a sustainable society. What it does say is that whatever materials we use from the Earth's crust, *we must use them in a way that prevents their accumulation in natural systems*. This means using them efficiently, and using them in products and processes where they can be recaptured and re-used, rather than released into the atmosphere, water or soil" (Park, C., 2008). There are thresholds beyond which living organisms and ecosystems are adversely affected by increases in substances from the earth's crust. Problems may include an increase in greenhouse gases leading to global warming, contamination of surface and ground water, and metal toxicity which can cause functional disturbances both in humans and in animals.

Sustainability Principle #2

SP2: IN A SUSTAINABLE SOCIETY, NATURE IS NOT SUBJECT TO SYSTEMATICALLY INCREASING CONCENTRATIONS OF SUBSTANCES PRODUCED BY SOCIETY

"Humans combine molecules into new, more complex molecules that nature has never seen before, and use these complex molecules in products and processes that eventually allow them to be released into natural systems. Because nature has never seen them before, it cannot break them down within its regular cycles, and so they accumulate. Note that the second principle does not say that there are no chemicals in a sustainable society. Rather, it says that a sustainable society will require that we be efficient in our use of them, and most importantly that we use them in ways that allow them to be captured and re-used, rather than dispersed into nature where they can accumulate" (Park, C.,2008). Synthetic organic compounds such as DDT and PCBs can remain in the environment for many years, bio accumulating in the tissue of organisms, causing harmful effects on many species of the food chain. Freon, and other ozone depleting compounds, may increase risk of cancer due to added UV radiation in the troposphere. The solution includes gradual substitution of certain persistent and man-made compounds with ones that are normally abundant or break down more easily in nature, and using all substances produced by society in an efficient manner.

Sustainability Principle #3

SP3: IN A SUSTAINABLE SOCIETY, NATURE IS NOT SUBJECT TO SYSTEMATICAL DEGRADATION BY PHYSICAL MEANS

"We physically degrade nature's ability to run natural cycles by encroaching into natural areas, over-harvesting renewable resources, and eroding nature's ability to process our waste" (Park, C., 2008). This means humans must avoid taking more from the biosphere than can be replenished by natural systems, safeguarding nature's ability to regenerate. Preserving the integrity of any living system requires first that society understands that what effects one part of a system may ultimately impact the system as a whole.

The downstream effects we witness nowadays – climate change, acid rain, deforestation, depletion of fish stocks, toxics in our toys that accumulate in our tissues – can be traced back to one or more of these three ecological mechanisms. They are all "downstream" symptoms of more fundamental problems in how our societies are designed. An 'upstream' approach to planning anticipates and avoids problems before they occur, as opposed to a 'downstream' approach, where resources are used to deal only with the results of the problems.

Sustainability Principle #4

> SP4: IN A SUSTAINABLE SOCIETY, PEOPLE ARE NOT SUBJECT TO CONDITIONS THAT SYSTEMATICALLY UNDERMINE THEIR CAPACITY TO MEET THEIR NEEDS.

In order to achieve the first three sustainability principles and have a thriving human society, we must also consider the barriers that exist to people meeting their needs world wide. If human needs are not met then increasing poverty, conflict and other forms of social stress will result in more environmental degradation. All forms of political oppression need to be overcome and human rights respected for people to have any chance of meeting their own needs.

1.2 SUSTAINABLE MOBILITY

1.2.1 What is sustainable mobility

According to the World Business Council for Sustainable Development (WBCSD), Sustainable Mobility is the ability to meet society's need to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or ecological values, today or in the future (WBCSD,2002). All of this must be achieved in a cost-effective manner.

The definition of a sustainable transport system adopted in April 2001 by the EU Transport Council states that a sustainable transport system:

- allows basic access and the development needs of individuals, companies and societies to be met safely and in a *manner*

consistent with human and ecosystem health and promotes equity within and between successive generations, – is affordable, operates fairly and efficiently, offers a choice of transport modes, and supports a competitive economy as well as balanced regional development,

- limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of regeneration, and uses non renewable resources at or below the rates of development of renewable substitutes while minimising the impact on land use and the generation of noise.

The aim of this research project is to enhance the planning process that can aid authorities moving towards sustainable and economically feasible local and regional mobility systems. Many research projects carried out by the EU and other organisations (both public and private) in Europe on mobility have as main objectives to come up with better and more integrated mobility systems and the exchange of best practices. Most of these projects also highlight how sustainable mobility is intrinsically connected to the areas of urban development and energy. Yet, just as important as efficiency improvements and mode switching may be innovations in communications, services, behaviour change, public planning and logistics which reduce the amount of travel needed to access other people, jobs, markets or resources.

To better understand sustainable mobility, causes and effects of transportation activities must be identified and its upstream issues dealt with accordingly.

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1.2.1.1 Interaction between mobility, land-use, energy and behaviour change

Development is closely related to movement. To undertake commercial exchange, access public services, or engage in recreation and entertainment, society relies upon the ability to move persons, goods, or information from one location to another. Cities are a deliberate concentration of these exchange opportunities in order to increase both the diversity and accessibility of exchange opportunities.

Planners have long known that land use and transport are intertwined and correlate with energy consumption, particularly in urban areas. There is an inseparable link between establishing locations for human functions (living,

working and facilities), the use of space, and the impact on the way people travel. Nevertheless, land use, transport and energy issues are too often viewed and addressed separately (Novem, 2002). As a result, opportunities to *collectively address individual concerns* in each sector are lost. Planning approaches are often described as adversarial or lacking in proper representation (Van Wee 2002, Litman 2005, McEldowney et al. 2005, Waddell 2007 in Belaieff, A.,2007). Forrester states that "a systematic approach to analysing and managing urban land use, transport, and energy systems requires *systems thinking*: the evaluation of interrelated and complex systems over time" (Forrester, J.W., 1971).

1.2.2 Sustainable mobility in Europe

In the European Union between 1975 and 1995 the daily distance travelled per person doubled; *today 80% of all personal journeys are by car*. A further doubling of traffic is predicted by 2025. Congestion costs 130 billion euro annually and the total external costs of motorised road traffic are estimated at 270 billion euro per year - around 4% of Europe's gross national product. The average traffic speed in European cities is only 15kmh, and 42,000 people are killed in traffic accidents each year on Europe's roads (Tapestry – campaign solutions for transport, n.d). All these issues are external costs to road transport, which must be duly internalized.

1.2.2.1 EU guidelines

The European Council developed, in 1999, a series of guidelines to inform the European strategy on transport and environment:

- avoidance and/or elimination of the negative effects of traffic growth, particularly through land use measures and infrastructure charging;
- promotion of public transport, inter modal and combined transport and environmentally less harmful modes (e.g. railways and inland waterway);
- further research and technological development, in particular to reduce CO2 emissions and noise;
- raising of awareness among the public, vehicle drivers and the industry of how to reduce the environmental impact of transport, e.g. through indicators and vehicle standardisation. (European Council, n.d.)

In order to revitalise the EU transport policy, aiming to make a significant contribution towards reducing the impact of transport on climate change, The European Commission set out a ten-year strategy on sustainability in the transport sector in its 2001 White Paper on Transport Policy (European Commission, 2001). The strategy focused predominantly on balancing the different modes of transport, harmonising legislation within specific sectors, and enhancing transport safety.

The latest EEA TERM (EEA, 2008) report states that had transport sector emissions followed the same reduction trend as in society as a whole, total EU-27 greenhouse gas emissions during the period 1990–2005 would have fallen by 14 % instead of 7.9 %. Previous and current EU policies have mainly focused on improving vehicle technology and fuel quality to reduce pressures on the environment. Trends and projections clearly show that *these policies have not been enough* to succeed in reducing greenhouse gas emissions from transport and that the effect of introduced mitigation measures has been more than offset by *increased transport volumes*. To achieve emission reductions, measures and policy instruments must therefore also *address demand for transport* in a serious way.

Achieving ambitious targets in line with the 'Bali roadmap'[2] would require that transport volume growth is limited to + 4 to – 2 % over the period 2010–2020, compared to a growth of 15 % in a business-as-usual scenario. This would help achieve the much needed subsidiary benefits related to reduction of noise and air pollution, as well as protection of biodiversity. To address transport demand, measures and policy instruments must go beyond the transport sector itself and be introduced into sectors of the economy such as households, industry and service, *within which the demand for transport actually originates (upstream)*. Furthermore, a number of actions designed to reduce greenhouse gas emissions within the transport sector have also led to more efficient and consequently cheaper transport; a *rebound effect* that has contributed to growing demand within the sector. Present knowledge indicates that it will not be possible to achieve ambitious targets comparable to the Bali roadmap without specifically and seriously limiting private transport demand (EEA, 2008).

[2] Consists of a number of forward-looking decisions made at the The United Nations Climate Change Conference in Bali (December 2007) that represent the various tracks that are essential to reaching a secure climate future.

1.3 RESEARCH SCOPE – what is missing in sustainable mobility

Far too much time and money have been invested to date in discussing and accommodating the movement of vehicles rather than the *movement of people*. Plus, most of these projects use forecasting to solve mobility problems and address behaviour change without much innovation in the services provided. Backcasting, in contrast, starts with a desirable future situation, usually described by a set of goals or targets established by assumed events between the current and future situations. Therefore backcasting is capable of highlighting discrepancies between the current and desirable future, and incorporating large and even disruptive changes. For example, using the conventional practice of forecasting, we could say: "there are 3 000 people and 100 parking spaces on campus now. If we grow to 9 000, then we will need 300 parking spaces." This type of thinking could result in expensive and environmentally damaging construction of new parking spaces and encouragement of driving. With *backcasting*, we would instead state that in the future, our mobility will be sustainable, so we would use funds towards improving bicycle paths and bus routes to the campus instead. Temporary parking needs can be satisfied with surface parking spaces and off-site parking lots that can easily be switched to other uses (flexible platform). This methodology frees the analysis from the restrictions of current trends.

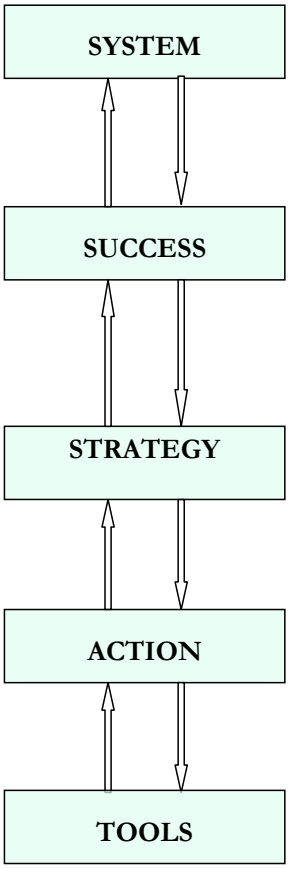
A key obstacle to achieving a mode shift from private to public transport is that more often than not PT lacks the necessary attractiveness and reliability. Low quality has a tendency to discourage users who have an alternative and very attractive option (mostly a private car). It may be easier to deter people from using public transport via low quality than to attract them back via improved quality. Thus insufficient attention to improving the quality of public transport and raising awareness about these improvements could restrict the use of public transport to only those users who do not have a choice due to factors such as age or economic status (EEA, 2007).

1.3.1 The Framework for Strategic Sustainable Development

The global and local challenges that currently face sustainable mobility as well as the major global problems highlight the need for an overarching

sustainability-based approach to long term planning. Traditional planning processes tend to focus on isolated pieces rather than on *interconnected systems*, and are generally not able to solve complex problems in a proactive manner. This work proposes moves beyond traditional planning and has been developed to address social, economic and environmental challenges in an integrated and upstream way - utilising a Framework for Strategic Sustainable Development (FSSD) - where backcasting from a sustainable vision in the long-term future is central to the process.

Table 1 : The Framework for Strategic Sustainable Development

	Describe the specific system within which the topic (e.g.company, organization) is established: What are the most basic functions, flows, laws, mechanisms, feedback loops, etc that are needed to inform what defines success and strategy, as well as potential actions and tools? How does this fit in society in the biosphere?
	What constitutes success of the topic's in the future, in the system described above? In particular, what are the most basic success principles or conditions that define a successful outcome of the planning? Here it is important to note that this vision must be *within the constraint* of the four Sustainability Principles (see item 1.1.2 for detailed description)
	What are the overall strategic principles or guidelines that will lead to success in this system? BACKCASTING FROM SUSTAINABILITY PRINCIPLES is the core guideline which guides a systematic step-by-step approach towards the defined goal, while ensuring that resources continue to feed the process towards success.
	What actions in the strategy defined will help move the topic towards compliance with success and with global sustainability?
	What additional techniques, instruments, measurements, management tools, etc can be used to assess actions to see whether they are, in fact, strategic to arrive at success in this system? Tools may also be used to assess the system itself from following the plan or access capacity building efforts of the planning team.

This framework, shown above in table 1, is a holistic approach based on systems thinking, which provides a structure for organising analysis and strategic planning in complex systems from the perspective of the mobility issue *and* the global socio-ecological system. It also suggests how organizations can plan and act to support society's transformation towards such a society while avoiding financial risks associated with unsustainable practices and foreseeing new business opportunities (Ny, H. et al, 2008).

The fours sustainability principles described in item 1.1.2 guide visioning, planning, strategic decisions and actions. They provide the boundaries within which the innovation process can be focused, within which the vision can be formulated. The core concepts of the FSSD are describe in table 1 below, and must include the approach mentioned in the first paragraph of this section.

Previous studies have repeatedly shown how this framework can assist businesses and municipalities in grappling with the complexity of the sustainability challenge and turning what is often perceived as a cost into an opportunity for innovation and cost savings (Broman et al. 2000; Nattrass and Altomare 2002; James and Lahti 2004 in Ny, H.. et al, 2008).

The essence of the Framework for Strategic Sustainable Development in the urban mobility sector is discussed and analysed in context of the Karlskrona case study, in the Results section of this work.

1.4 KARLSKRONA CASE STUDY

1.4.1 Brief description of Karlskrona

The city of Karlskrona is the capital of Blekinge County, and its historical importance resides on having been the main base of the Swedish naval industry since 1680. Nowadays its main economic activity is knowledge-based companies as well an IT regional university. After the decision of not being an exclusive naval stronghold, the city has experienced a population increase reaching 60867 inhabitants by the year 2003 (Karlskrona Kommun, 2002), approximately half of which living outside of the central Trossö (downtown) area.

In 1998 the municipality of Karlskrona received its World Heritage nomination from UNESCO, achieving international status. Seizing this event as a gateway to improve the development of the town, the municipality has built up a new platform for education, business, tourism and communications to replace the decline of the naval industry; in order to attract new companies and consequently increase population (according to the municipality of Karlskrona, only in the Telecom city 500 new jobs are created every year), the municipality now builds upon new cornerstones: an attractive living environment, growing economy, best knowledge and an open attitude. The municipality is comprised of the city of Karlskrona and six smaller towns.

In 2002, the municipality of Karlskrona became a member of the "Sveriges Ekokommuner", a Swedish network organization that uses the Finnish concept of eco-municipality model to "encourage development towards a more sustainable society, where the environment gives people the opportunity to have a high quality of life" (Sveriges Ekokommuner, n.d.). In order to become an eco-municipality the local authorities must adopt a strategic plan and program for achieving local sustainability that is in line with the four system principles described in item 1.1.2.

The municipality therefore has a target to become a "zero CO_2 emission town" in the future, tackling transportation as one of the main issues to be addressed when defining its sustainable development plan.

1.5 RESEARCH QUESTIONS

The aim of this research project is to define a specific strategic planning method for sustainable mobility to reduce car dependency, through the application of the FSSD described in item 1.3.1 above. The case study is the municipality of Karlskrona, with the expectation that the conclusions can be transferable to other small European cities. This investigation includes PRT systems as an alternative transportation system offering the advantages of private cars while avoiding its negative sides. This will be achieved by answering the question:

Primary research question:

Can the municipality of Karlskrona move towards sustainable mobility by integrating Podcar systems with other modal systems?

This question is informed by answering the sub-questions:

What barriers prevent European cities and regions from adopting new mobility technologies to decrease car dependency?

What are the gaps, threats, opportunities and leverage points for Karlskrona municipality to decrease car-dependency? How can local authorities use the Strategic Sustainable Development Framework to plan for a decrease in car dependency?

Can podcar systems be considered sustainable?

2. METHODS

2.1 LITERATURE REVIEW

A literature review to inform on the issues of economics, behaviour change, energy, land-use and transport modes as related to sustainable mobility, was conducted in the following sources to identify documents that could provide the foundation for analysis:

European Union Documents – Policy documents and research reports published by or commissioned by the European Commission, the Council of the European Union, and the European Environment Agency. Research reports constituted a significant source of information on proposed policies and on identified barriers to implementation of sustainable mobility, as well as valuable data on PRT systems.

Journal Articles – informed our discussion of the Framework for Strategic Sustainable Development, Systems Thinking and Sustainable Mobility.

Theses – published theses informed on previous research results on European behaviour change trends as well as on sustainable development, energy, spatial planning and mobility issues at large.

Books – important data on car dependence, transportation modes and their integration, eco-communities.

2.2 KARLSKRONA MUNICIPALITY'S SUSTAINABLE MOBILITY ANALYSIS

ABCD tool :

Workshops

As part of the FSSD process described in item 1.3.1 above, two workshops were conducted with employees and steering groups from the Karlskrona municipality, utilizing the ABCD tool, in order to identify its mobility current reality, a vision for its sustainable mobility in 2050 with zero car dependency, and compelling measures to reach this vision.

Interviews

Complementary necessary information was also gathered through interviews with:

- Karlskrona municipality department heads and politicians;
- Blekingetrafiken (local Public Transportation Company) department heads;
- Energikontor Sydost officials;
- Sustainable Mobility consultants;
- Personal Rapid Transit systems vendors.

All live interviews were taped, and some were conducted via e-mail.

2.3 SWOT analysis and Business Case

A Swot analysis was performed in order to identify opportunities and threats within Karlskrona's mobility system, aiming to inform how the implementation of PRT systems can be attractive to the municipality as a means to assist the achievement of its sustainable mobility vision. This method informs the construction of the business case developed in the Results section.

2.4 PRT SYSTEMS SUSTAINABILITY ANALYSIS

To identify the sustainability of PRT systems, a sustainability analysis was performed resulting in a table that informs PRT systems vendors on how to direct the development of their systems having the four Sustainability Principles (item 1.1.2) as basic constraints, thus assuring that their systems will comply with regulations, laws, policies that might restrict their actions now and in the future.

2.5 EXTERNAL ADVISORS REVIEW

- Prof Ingmar Andreásson - Adjunct professor and Director, Centre for Traffic Engineering & Traffic Simulation at the Royal Institute of Technology (KTH) in Stockholm and Senior partner at LogistikCentrum AB (professional consulting in transportation planning, logistics, computerisation and mobile data communication).
- Hannele Johansson – Move Project Coordinator at Energikontor Sydost, Växjö, Sweden

2.6 PEER GROUP REVIEW

Two scheduled peer review sessions were held for dialogue and support from fellow students in the MSLS class, the thesis supervisors and the program coordinator.

2.7 LIMITATIONS

Detailed in-depth analysis could not be performed due to time constraints and lack of more data on the several elements that make up a PRT system. Also the lack of knowledge in the Swedish language was a considerable barrier.

3. RESULTS

The following sub-sections are the result of the literature review and interviews with important stakeholders mentioned in the methods section, used to feed the development of the FSSD for Karlskrona municipality's

Sustainable Mobility (especially its strategic guidelines), as well as the Discussion section. A comprehensive list of the EU sustainable mobility projects analysed by this research team is in Appendix I. They suggest how the long-term solution may be found in a more balanced split between high-capacity transport modes like buses, trains and metros, and more individual transport modes, such as PRTs which offer the advantage of flexibility and availability comparable to the use of private cars, and still private modes like walking and cycling. A good mix of these modes will enable cities to offer improved mobility to all citizens while improving the quality of life and the sustainability of the environment and last but not least, economic and human development.

3.1 SUSTAINABLE MOBILITY AND CAR DEPENDENCE

Car dependence is a persistent problem of our present society. The car is the dominant form of maintaining personal mobility in a very attractive manner. Its benefits are difficult to match: it is a door-to-door transportation system available at any time of the day or night, the means to gaining access to life necessities and employment, and a source of pleasure and social status. So are its disadvantages, including local air pollution, greenhouse gas emissions, road congestion, noise, mortality and morbidity from accidents, and loss of open space to roads, parking lots and urban sprawl. Many people are aware of the disadvantages but see no comparable substitutes to the automobile. The dilemma of an automobile owner is similar to that of a herd owner described in the classic case of a 'tragedy of the commons'[3] (Vergragt, P., 2007).

The efforts to revert this tendency pale in face of the projected growth in population, affluence, and people's appetites for the type of personal mobility car can provide. This is clearly evident in China, where car ownership is steeply rising, from 1.6 million in 1990 to 10 million in 2000, to 80-90 million anticipated in 2020. In July 2003 over 1.07 million cars were sold in China, compared to 1.06 million in the entire year of 2002, an increase of 98% (Kobos, PH, 2003). And the number of accidents increased accordingly. In the EU car use is also on the rise, as shown in Figure 3 below.

[3] The metaphor is a community sharing a pasture. For an individual it is advantageous to increase his cattle stock. For the collective this means eventually overgrazing the field.

As stated in a report by the Low Carbon Vehicle Partnership (Kågeson, P., 2007), voluntary agreements made by the European Commission in 1998 with automobile manufacturers in Europe, Japan and Korea to reduce average emissions to 140g/km CO_2 emissions by 2009 are *far* from being achieved – and an EU regulatory framework has therefore been proposed, to be ready by mid-2008. There are a number of reasons progress has been slower than anticipated, key amongst these are: (i) consumer preference has been towards higher performance and larger cars; (ii) progress with tax incentives for low carbon vehicles across the EU has been mixed; and (iii) the three trade bodies have been unable to influence the CO_2 emissions of vehicles produced by their members and there has been no clearly laid out system of burden sharing (ibid).

All of the conflicting information about social and ecological impacts from various kinds of harmful activities in society is still perceived as inherent cost for the economic welfare part of the world enjoys. (Robèrt, K.H. et al, 2007). Part of the analysis in this project is to suggest ways of reverting the car dependence trend, including through evidencing its intricate relation to urban and energy planning, behaviour change campaigns, and a shift in the perception of how to account for the externalities of road transport.

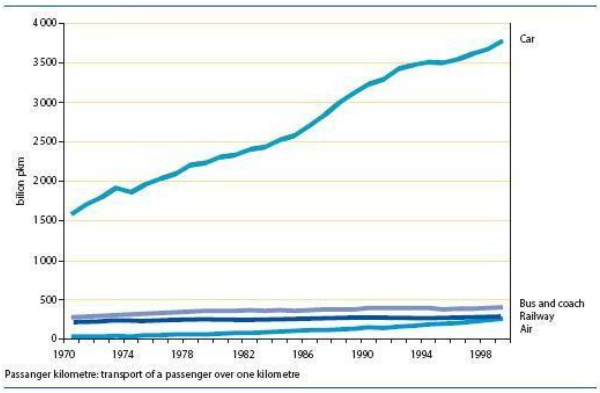


Figure 3: Passenger transport - growth of traffic by mode of transport EU-15: 1970-1999

Source: European Commission, 2001

Another consequence of the increasing car dependence is that it alienates social and age groups that have less access to it, therefore undermining their mobility. Social groups with less economical power, the elderly and children are the ones that are left out of this automobile-society and for

them everyday life becomes a maze of managing public transport infrequency, asking motorized relatives for rides or dealing with the fact that they just can't go freely to where they want. Where are the democracy and the social equity in this? (Madureira, A.M. and Mollers, A., 2006)

Car-Free development encompasses a range of ideas that places *humans before cars* and stresses a new urban order based first on quality of life.

3.1.1 Integration for change – urban planning, economics, social aspects , behaviour change

It is only by integrating our thinking, relating and acting is that "big issues" like sustainable mobility become a reality (Senge, P, 2007). Robèrt et al state that systems are entities consisting of mutually dependent parts. Development of a system in society occurs as an interaction between trends, values and human ingenuity. Reductionism, a counterpoint to this view, advances the mistaken notion that if every detail in a system is studied with scrupulous care, the entire system will eventually be understood. However, the whole is greater than the sum of its parts and must be studied in its own right. Sustainable mobility is a complex system with many components that must be cleverly and thoroughly integrated to deliver optimum results (Robèrt, KH et al, 2000).

Technical innovations in transport are often discussed, but we also need economic innovations, political innovations, social innovations, as well as behavioural changes, because sustainable mobility can only be achieved by a *broad range of integrated measures*. It requires future-oriented and societally accepted innovations not only in the field of transport, for mobility and transport are tightly interconnected with space and time, settlement, communication, environment, energy, economy, life styles etc. Due to these complex interdependencies there are no simple recipes or easy successes on how to reach sustainable mobility (Topp, H.H., 2006).

In its latest report, the EEA points out land-use strategies which positively influence travel patterns (EEA, 2008):

- Increasing densities to increase the viability of local services that are accessible on foot or by bicycle, as well as increasing the viability of public transport.
- Changing the mix and layout of development components to deliver local services and employment opportunities.
- Concentrating dense development within transport corridors.

- Reducing parking space as a trip-end restraint.
- Requiring developer contributions to transport infrastructure and including provision of public transport services as a part of the planning consent process.
- Requiring payments from commuters to aid delivery of public car parks or park-and-ride schemes.
- Adopting measures such as travel plans to reduce car use.
- Locating development close to nodes accessible to public transport.

To influence modal choice through *planning*, the LTP (Local Transport Performance) approach is based on a new design strategy essentially based on the bottom up approach. The design starts at the front door and then progresses to the higher levels of scale (neighbourhood, borough, district and city). This design is completely different from the traditional approach and is therefore also known as 'upside down' design. It encourages attention to planning details which are relevant to pedestrians and cyclists which would otherwise be neglected. Examples include direct and safe routes, bicycle parking facilities, good public transport, and urban planning aspects such as mixed functions and multiple space use (Novem, 2002). This must become the predominant approach from now on, and its why *intermodality* is one of the keywords when choosing an integrated approach, giving special attention to the combination of different transport modes, including all measures and activities facilitating interchanges or promoting such systems and facilities, e.g. spatially and temporally optimised interchanges from one mode to another, good passenger information, integrated ticketing/tariffs, etc.

For the purpose of considering synergy effects i.e. the degree to which measures catalyse, reinforce or complement each other, a limited set of 14 key policies has been selected by the SUTP research project (for more information, see http://www.sutp.org). A complex pattern of interdependencies emerges, linking land-use planning, congestion charging, PT promotion, "soft" measures, road design, parking management, noise abatement, low emission zones, clean vehicles for captive fleets, low emission passenger cars, scrappage schemes, freight management, traffic management and intelligent transport systems (ITS) (Wolfram, M. et al, 2005) (see Appendix II).

The need for integration in urban planning is best described in the Leipzig Charter on Sustainable European Cities, written in 2007 by the European Union Member States. Its key themes are upgrading the urban fabric;

enhancing local economies and labour markets, clean urban transport and integration of migrants.

Economic innovations needed

Mainstream economics, which is based in part on ideas that made a lot of sense at some point in the last 250 years but that have outlived their time and usefulness, do not comply with the current reality. These ideas—such as the reliance on GDP as the key index of general wellbeing—still dominate assumptions and thinking about economic matters in the media, governments, businesses, and popular consciousness.

This explains why transport subsidies are significant. At least EUR 270–290 billion of annual transport subsidies have been identified in Europe. Although not all these subsidies can be labeled as environmentally harmful, some of them are. The external costs of transport even exceed the size of transport subsidies. Internalising external costs should remain a main focus of transport pricing policy and reducing transport subsidies is one of the options available (EEA, 2007).

Existing scientific and expert work mainly done at EU level and within European countries was the basis for the report "Handbook on estimation of external cost in the transport sector", produced within the study Internalisation Measures and Policies for All external Cost of Transport (IMPACT) (Maibach, M, et al, 2007). Thus, this report is the basis for the analysis of the internalization of external costs to support sustainable mobility in this study, and utilized in the Karlskrona municipality case study – it can be considered state-of-the-art and most current research information.

Transport activities give rise to environmental impacts, accidents and congestion. In contrast to the benefits, the costs of these effects of transport are generally not borne by the transport users. Without policy intervention, these so called external costs are not taken into account by the transport users when they make a transport decision. Transport users are thus faced with incorrect incentives, leading to welfare losses.

The internalization of these effects means making such effects part of the decision making process of transport users. This can be done directly through regulation, i.e. command and control measures, or indirectly through providing better incentives to transport users, namely with market-

based instruments (e.g. taxes, charges, emission trading). Combinations of these basic types are possible: for example, existing taxes and charges may be differentiated, e.g. to Euro standards. Internalization of external costs by market-based instruments is generally regarded as an efficient way to limit the negative side effects of transport.

External costs refer to the difference between social costs and private costs. But in order to produce quantitative values, the definition has to be more precise. Based on the economic welfare theory, transport users should pay all marginal social costs which are occurring due to a transport activity. Considering the private marginal costs (such as wear and tear costs of the vehicle and personal costs for the driver), optimal Infrastructure charges should reflect the marginal external costs of using an Infrastructure. These costs include wear and tear costs for the use of Infrastructure, congestion costs, accident costs and environmental costs. Only parts of these costs are monetary relevant. Some parts (such as time losses, health damages, etc.) are social welfare losses. Calculating these costs is an intricate and complicated issue. For more information see Maibach, M, et al, 2007.

Thus, what is in urgent need are policies to effect the internalization of external costs in order to modify the outcome of transport users' decision making. The European Parliament has a deadline of mid-2008 for a generally applicable, transparent and comprehensible model for the assessment of all external costs to serve as the basis for future calculations of Infrastructure charges.

Political and social innovations

The solution to the sustainable mobility problem will require input from all segments of society, and must include technological innovation, changes in the physical infrastructure and land use, and social, cultural, and institutional changes. A fundamental rethinking of the entire system of personal mobility is necessary. Governments can play a significant role in promoting change: by stimulating technological innovation through regulations, incentives and subsidies, by investing in the right infrastructure, by providing leadership, and by organizing and supporting a debate with a focus on the system as a whole: its spatial characteristics, the motives for transport, and the alternatives that are presently not developed. A new and radically different way of seeing the problem of individual

mobility, and of the *roles of various stakeholders in finding solutions*, is also necessary (Vergragt, P., 2007).

The sustainable mobility approach requires actions to reduce the need to travel (less trips), to encourage modal shift (transport policy measures), to reduce trip lengths and to encourage greater efficiency in the transport system (Banister, 2008). The improvements that have been made to transit so far have not been successful in breaking the trend of increasing car traffic and decreasing transit trip making. This means that sustainable mobility also encompasses changing attitudes and behaviours, looking upstream to affect the causes of the problem instead of downstream to just fix its consequences. It must find ideas and solutions offering many of the advantages of private cars while avoiding its drawbacks (Johansson, H., 2008).

The USEPA (United States Environmental Protection Agency) report on Indicators of the Environmental Impacts of Transportation (Corrales, M. et al, 1996) depicts the causes and effects of transportation activities, as shown in figure 3.

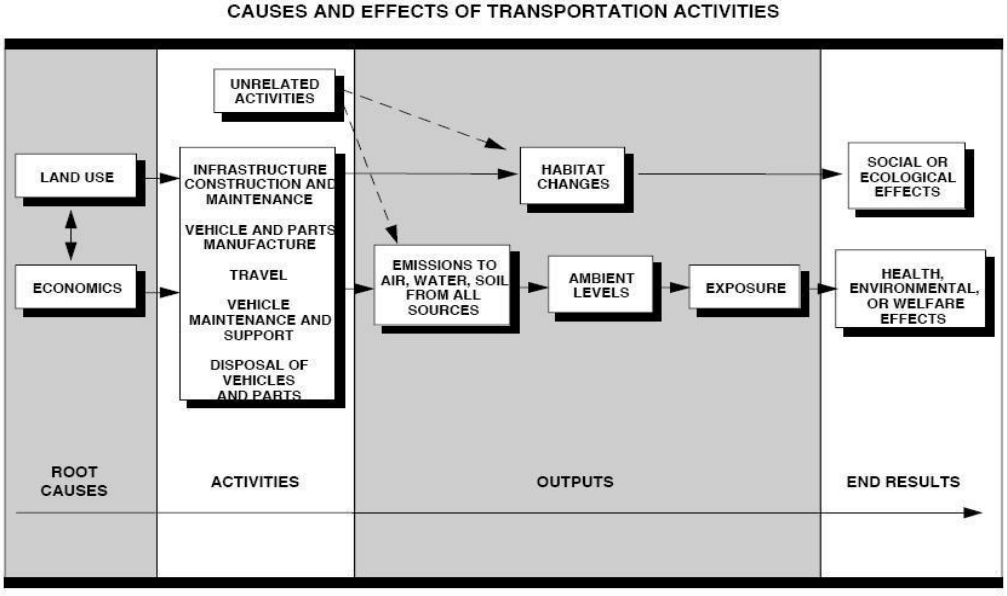


Figure 4: Causes and effects of transportation activities
Source: Corrales, M et al, 1996

This flowchart shows clearly how, in order to achieve lasting solutions to the end results problems, one must act upon the land-use and economics

part of the equation. If we just keep trying to control the outputs from the process, it will be an ever increasing and endless job.

Behaviour change – what it takes to get there

Waldo (Waldo, Å., 2002) in her study on big city commuting concludes that the most important measure to change individual travel habits is to increase the individual's accessibility to new, feasible, alternatives preferably in combination with incentives and information in order to stimulate the shift to their usage.

Successful collaborative efforts embrace three interconnected types of work that together build a healthy "learning ecology" for systemic change: (i) *conceptual*: build community through thinking together and sharing, and achieving simplicity without reduction (digesting the complexity of a problem while communicating key features that guide action); (ii) *relational*: far reaching and un orchestrated dialogue that in turn sets the tone for systematic initiatives and practices (natural self-organisation to think together, strengthen community, share knowledge and ignite innovation); (iii) *action-driven*: take time to gather input from all stakeholders so that true systemic thinking can give rise to sometimes radically innovative action. Failing to appreciate the importance of each is likely to frustrate otherwise serious and well-funded attempts at collaboration on complex problems (Senge, P, 2007)

The Austrian case study in the EU TAPESTRY research programme pointed out that the hardest jump in behaviour change is from having the awareness of the problem to accepting responsibility for it (personal or corporate), and this takes a huge effort. Awareness raising cannot be measured from one day to the other. Human beings are not machines, their behaviour has many causes, their reasons are complex, and particularly if they fail to see the connection between traffic and their own behaviour, they will stay on the first rung. They are also very inventive at finding solutions for others. Mobility is a very emotional topic, and can give rise to cognitive dissonance. Before people change their own behaviour, they find many reasons not to change. In the case studies in both Linz and Graz, teachers still stated that the car was the ideal means of transport, and had many "serious" reasons for this. How can teachers inform their pupils about ecologically-sound forms of mobility if they themselves find ways to justify their own mobility behaviour (heavy bags, long way to school), and are not aware of alternatives (public transport connections to school); and even if

they are aware of alternatives, still think that the car is the ideal means of transport? (TAPESTRY, 2003)

Communications campaign activities particularly come into their own in support of sustainable travel initiatives such as local programmes to encourage school and workplace travel plans; improving public transport information and marketing services; providing personalized journey plans; setting up websites for car share schemes and supporting car clubs. Evidence has shown the significant impact on car use that these measures can have when promoted vigorously and emphasises their continuing importance in *maximising the benefit from any investment made in the transport system*. TAPESTRY was established to research the role of campaigns in changing attitudes, awareness and behaviour in a broad range of contexts at the local and regional levels across Europe (TAPESTRY, 2003).

Banister lists the key elements in promoting the public acceptability of sustainable mobility: (i) information, (ii) involvement and communication, (iii) packaging, (iv) selling the benefits, (v) adopt controversial policies in stages, (vi) consistency between different measures and policy sectors, (vii) adaptability (Banister, D., 2008). See Appendix III for extended table.

3.1.2 Modal systems considered in this research

The spatial structure has a clear impact on the modal choice. Up to 1 km, walking can compete with driving. In flat areas, cycling can compete with driving, bus or tram up to 7.5 km. An area layout which focuses on pedestrians and cyclists will result in more walking and significantly more cycling than a layout designed for cars. From 7.5 km to 25 km a shift from driving the car to travelling by bus, tram and metro (Novem, 2002). The basic transport modes utilised in urban areas, and their corresponding range of use are listed in table 2.

Modal choice is based on speed, cost, comfort and convenience. The integrated planning approach influences this choice by aiming for optimum coordination of the location of functions, and urban and traffic design. As a result, people are more likely to walk to the primary school, as it is nearby and safe to walk to. People are more likely to cycle to the city centre as the pleasant cycle route is comfortable and the quickest option. Of course sometimes the car may still be the best option for a trip to a large shopping

centre, to get a lot of shopping and if parking is easy (Novem, 2002). This is important information to have when designing integrated sustainable mobility systems.

As recommended in the latest EU reports, travel demand must be optimized. Therefore, several improvements to travel demand have been made possible by information technology, amongst them work from home, video conferencing, webinars, carpooling and car sharing management via internet, etc. IT has also made possible the development of the driverless vehicle, making feasible systems like the PRT.

Table 2: Modes of Transport and its ranges
Source: Novem, 2002

Modes of transport - ranges

MODE	SPEED (KM/H)	RANGE	DISTANCE BETWEEN STOPS	AREA
Unpowered				
Pedestrian	5	100 m - 1 km		1 ha - 100 ha
Cyclist	20	300 m - 10 km		10 ha - 100 km²
Public transport				
Taxi	30,50,70	1 km - 10 km	-	100 ha - 100 km²
Urban bus	30,50,70	3 km - 10 km	400 m	1.000 ha - 100 km²
Regional bus	30,50,70,>70	10 km - 30 km	400 m-1 km	100 km² - 1.000 km²
Tram	15-35	300 m - 10 km	400 m	10 ha - 100 km²
Metro	30-40	1 km - 10 km	1 km	100 ha - 100 km²
Light-rail	35-60	1 km - 30 km	1-3,5 km	100 ha - 1.000 km²
Slow train	60-70	3 km - 30 km	10 km	1.000 ha - 1.000 km²
Intercity train	>80	30 km - 300 km	>10 km	1.000 km² - 100.000 km²
High speed train	>250	100 km - 300 km	>50 km	10.000 km² - 100.000 km²
Powered				
Car	30,50,70,>70	3 km - 300 km		1.000 ha - 100.000 km²
Truck	30,50,70,>70	10 km - 300 km		100 km² - 100.000 km²

3.1.3 Best sustainable mobility practices

Jaime Lerner, the former mayor of Curitiba, in Brazil (Lerner,J. 2007), one of the best practice examples on sustainable cities, describes what is most unique about the city's strategy: it maximizes the efficiency and productivity of transportation, land-use planning and housing development by integrating them so they support one another to improve the quality of life in the city. This resulted in a multi-use system structure of living and working together which allowed the city to meet strategic objectives which

sought to minimize downtown traffic, encourage social interaction by providing more leisure areas and pedestrian zones in the center of the city, and encourage the use of public transport and cycling in order to achieve an environmentally healthy city. This is a world renowned success case of integration of land use, transport and education and awareness campaigns. What makes it even more unique is that is started in the early 1970s, when climate change was not yet an issue, but population comfort and satisfaction were.

In Freiburg (Germany), 60 % of all trips are made using public transport, walking or cycling. This is much higher than the average in western Germany. The example of Freiburg illustrates the benefits of close *integration between urban development and municipal transport policy.* Compact urban development promotes the use of public transport, while efficient public transport is only possible with compact urban development. Careful planning, high-quality service and pricing are the key elements for success. The compact urban structure offers great benefits for the environment, at zero cost: less energy consumption, less air pollution and improved liveability (Wright, L, 2005). Pretty much like the Curitiba project.

The Vienna Citybike system, part of the Climate Protection Programme of Vienna (www.klip.wien.at) has installed 80-100 bike terminals, mostly at subway stations. Due to vandalism in 2002, users now have to register by using a bank or credit card to unlock a bicycle. Only the first hour of use is free of charge. For the second hour 2€ is charged, for further hours 4 €/h. The system operates without public funding. This project is extremely successful, just like other citybike projects in Copenhagen, Paris, Nancy, Koprivnica (Croatia) and many others studied under the Smile EU project.

In 1997 the city of Hasselt, in Belgium, with 70,000 residents and 300,000 commuters from the surrounding area, introduced free public transport to promote their new bus system and make it the natural option for getting around. The first full year of free-fare transit saw an increase of 900% over the previous year; by 2001, the increase was up to 1,223%. A prime lesson offered by the city is the fact that they radically improved the bus system as well as their walking and cycling infrastructure before they removed the fare boxes. Because Hasselt's policy makers understand that bikes are the most sustainable form of transport, today one can borrow a bicycle, tandem, scooter or wheelchairs and strollers free of charge. The Mobility Plan has saved the City of Hasselt millions of Euros on transportation infrastructure

costs and has eliminated the previously perceived need of a third ring road. Overall, taxes have decreased because the city spends less money on transportation with the new Mobility Plan, despite the huge increase in pedestrian, cycling, and transit infrastructure and services. The primary difference between Hasselt and most other places since 1997 is the creation and implementation of an integrated policy it calls "Working Together on a New Form of Mobility" – carefully planned and implemented (No hassle transit? Try Hasselt. Belgian city offers BC a workable, fare-free model**,** n.d.). Lund's sustainable transport strategy, LundaMaTs, was introduced in 1997. The five pillars of the strategy are better public transport with improved intermodality for city buses and regional transport services, bicycle friendly town, industrial transportation and more sustainable commuter transport, environmentally friendly car traffic and sustainable urban planning. In the framework of LundaMaTs, a large number of activities – both infrastructure and soft measures – have been carried out. The Mobility Office in Lund, established in 1999, works on mobility management measures such as car-sharing, car pooling and commuting by bike or bus. It has set up various information and awareness campaigns aimed at different target groups, like the Health Bikers and the Bus Rider projects for commuters. SMART Road User is the current campaign aimed at employees of companies. They receive information on travel time, travel costs, emissions, etc. with car, bus and bike for trips between their home and work place. Lund is one of the most bicycle friendly towns in Sweden. The modal split for cycling and walking is 45 %, as compared to the national average of 30 %.

See Appendix IV for a table of Strategies for Overcoming Car Dependence adopted in some European cities.

In spite of the great achievements shown in all of these best practice examples, none of them include new technologies that can move society towards zero car dependency -- needed to cope with climate change threat into the future -- which leads to the more careful assessment of the PRT systems below.

3.1.4 PRT systems technology

PRT systems have been in development and proposed as an alternative to the use of private cars for over 30 years, against a wide range of vested interests in the automotive and public transport industries. They have the

potential for contributing significantly to the solution of fundamental problems of modern mobility including congestion, harmful emissions, dependence on a dwindling supply of cheap oil, and most recently terrorism. And it is a concept that can enable public transport to compete with the car in urban areas. Apparently, the main barrier to its implementation seems to have been the imbalance between risks and financial support: No local authority buys a system, due to the development risks as long as it is an unproven technology; and no developer invests fully in development, as long as there is no market for the end product (Tegnér, G. et al., 2007; Anderson, J.E, 2005). There is only one system that has been fully implemented, in 1972, in Morgantown, West Virginia. It has successfully demonstrated the viability of key PRT technology components, including off-line stations, on-demand service, nonstop origin-to-destination transport and fully automated control systems (Raney and Young, 2005). Since it began operating, the system has demonstrated very high reliability of 98% or greater.

They are a system of driverless automatic cabs traveling on their own segregated guide-way network, which can be positioned aboveground, at ground level or underground, which minimizes land use. They have the flexibility to be installed in many urban districts, due to the small cross section of its guide-ways, the tight curve radii and the possibility to dynamically extend the network (Schweizer J., 2005). The stations are positioned at small intervals from each other, designed to integrate this system with other transport modes. Current PRT designs envision small automated vehicles (see figure 4 below) with short headways, or pods, seating 3-6 passengers and travelling at 25 to 50 mph.

The fundamental elements of a PRT system are:

- *On demand, origin to destination direct service*: the service is *available on demand* rather than on fixed schedules -- in most cases a pod will already be at the station for, *available 24 hours a day* at all stations on the network to *meet individual travel needs*. Its size allows for the passenger to choose to have his or her own ride. Non-stop travel service ensures *short trip times* (the stations are placed off of the main guide-way). In this system, traffic is adapted to the passenger, instead of the passenger having to adapt to traffic – and it is that which makes the difference (Lincoln/Lancaster County, 2004; Andrèasson, I, 2001).

- *Small, fully-automated vehicle:* PRT vehicles are intended to operate under computer control and require no operator or driver. They are easy to access and use as the passenger needs only to select the name or number of the destination, and use a fare card or purchase a ticket from a vending machine which allows entry to any available vehicle at the station. The system will automatically route the vehicle to the desired destination within the shortest possible time and without need for further user interaction with the system. Unlike today's conventional transit, PRT passengers will need no specific knowledge about the PRT layout (like studying complicated subway maps). They do not require drivers to support individual vehicle movement, which considerably lowers operating costs. Operations involve staff to support central control, network management and vehicle flow systems, maintenance, security, and station services as dictated by local needs (Anderson, J.E., 2007). Due to the need to provide a high degree of safety, speed and accuracy to effectively manage potentially large fleets of vehicles over complex networks, PRT networks have a number of unique operating and control system requirements. A PRT control and communication system needs to be flexible, scalable, resilient, efficient and above all safe. All command, control and communication with vehicles are supported by a centralised system.

- *Exclusive-use guide ways* : the guide ways are usually designed as elevated systems with beams and support structures sized appropriately for lightweight two-four passenger vehicles. The light weight of each vehicle allows for economic construction of the guide-ways, and also less land-use. PRT systems, as depicted in figures 4 and 5, use networked and separate guide ways which permit higher transportation capacity and higher safety levels as the system will not interfere with current modes of transportation. The guide ways will usually be positioned about 4-5 meters above street level – away from other traffic and pedestrians, and have a networked topology for large area coverage (Anderson, J.E., 2007; Carnegie J.A. et al, 2007).


Figure 5: Ultra vehicle, test site in Cardiff, Whales
Source: Dept of Rail and Public Transportation, 2008

- *Off-line stations:* off-line stations are a major breakthrough, designed with a "siding" track or guide way so that vehicles not stopping at a particular station can bypass that station and are not delayed by other vehicles boarding and alighting passengers (see figure 5); the PRT station should be sized according to the necessary number of loading berths needed to handle the demand at each station.


Figure 6: PRT system, with off line station inside building
Source: Anderson, J.E., 2007 and Skyweb homepage, n.d.

- *Low-emissions and resource efficiency:* electric power is used primarily for propulsion and vehicle amenities. Beyond the need for propulsion, a PRT vehicle needs power for on-board systems and passenger comfort. It should support limited HVAC services as well

as vehicle control and communications. The system is designed to run on electric energy using battery power, supplied by guide way power or the use of an on-board generator (a wheel connected to the generator engages the guide way and uses the motion of the vehicle to drive the generator or by a system that extracts energy from the breaks). The electric power can come from many different sources, preferably renewable ones. As with any transit system, some power is used to move around empty seats. With PRT, empty vehicles are sometimes routed to another station where there is a higher demand. Figure 7 below shows that the power required per seat to move a PRT pod is very low if compared to a bus or a car. The efficiency of the system will depend on many other factors, most of all on the occupancy of the vehicle. (Brand, C. and Preston, J., 2003).

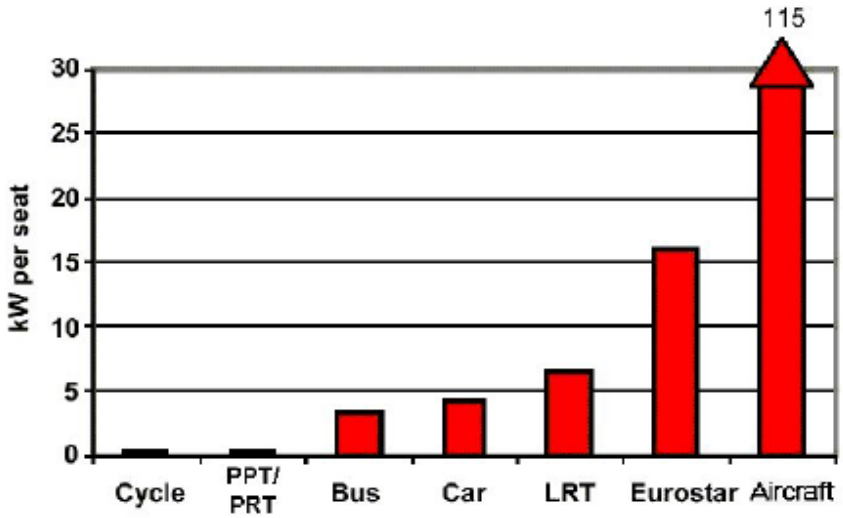


Figure 7: Power per seat installed for various types of transport (in kW per seat)

Source : Brand, C. and Preston, J., 2003

- *Vehicle and Passenger Accommodations:* the general PRT vehicle configuration is designed to be lightweight and carry at most four seated passengers. Seated passengers allow the vehicle to comfortably accelerate and decelerate. For urban environments, studies have shown that the typical private automobile has 1.63 occupants for all trips, 1.14 occupants for work trips, and that over 93% of urban trips have three or fewer co-travellers (Carnegie J.A. et al, 2007), *corroborating the need for individual PT services to compete with car use*. PRT vehicles are designed for accessibility,

including wheelchairs or other assistive devices. The vehicle door has automatic operation, allowing free and rapid access to the vehicle. It can also accommodate baby strollers, bicycles, luggage and shopping bags (using flip seats).

- *Costs:* studies have indicated that PRT systems not only can be profitable in societal terms, but also in business terms. Net present value calculations of LRT projects are most often negative, whereas they are positive for PRT projects. It is an affordable system: its capital costs are governed by the economies of mass production. The use of minimum-size, minimum-weight vehicles requires only a light track and thus reduces the capital cost to a fraction of that required for conventional rail, tram or bus systems, even on a per-seat basis. The absence of drivers and on-demand service are major factors in reducing the operating costs per passenger-km (Schweizer J., 2005; Carnegie J.A. et al, 2007). Figure 8 below in Tegnér's study shows that the PRT is the cheapest urban public transport mode among the studied ones, such as Bus, LRT, Metro and Commuter rail (Tegnér G., 2005).

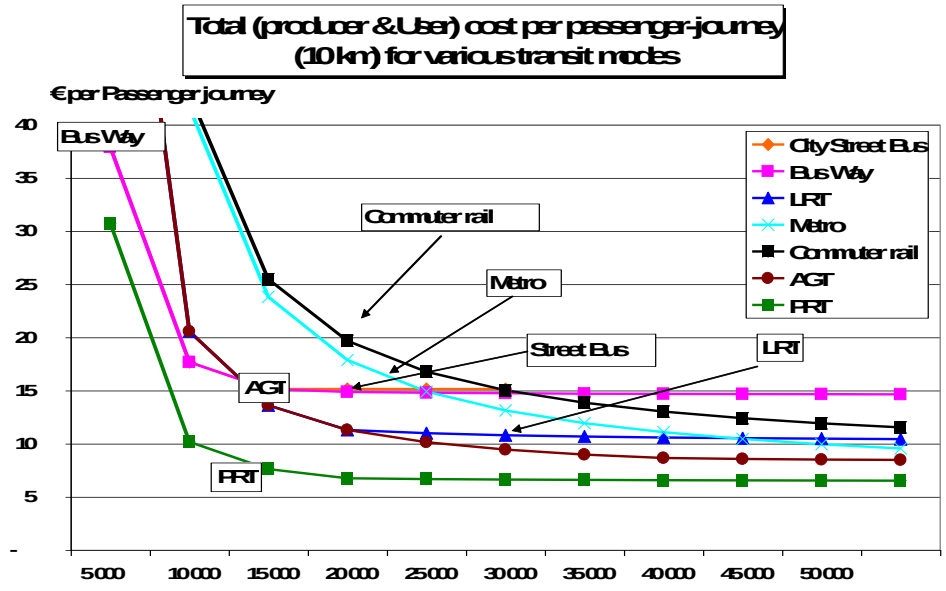


Figure 8: Total cost per passenger-journey for transit modes
Source: Tegnér G., 2005

An assessment of a public scheme needs to include the other social benefits accruing to both users and non-users of the system. These cannot all be monetarized, but they are important because they may contribute to the local policy objectives. Techniques for making these estimates have been formalised by the UK Department for Transport. The savings in travel time, car operating cost, reduction in congestion, and in accident and injury may be summed to give a monetarised benefit as a 30-year NPV, which in turn gives the social cost benefit. The net rate of return on the investment is 27% pa, greatly exceeding the required justification for public projects, while the NPV total benefit to cost ratio over 30 years is 5.2 at 3.5% discount, and 3.9 at 6% (Lowson, M., 2004).

3.1.5 The EDICT research project

The Evaluation and Demonstration of Innovative City Transport (EDICT) program was a European Union 5th Framework program supporting the "City of Tomorrow." The EDICT program sought to analyze and develop PRT as a potential urban transport solution to meet the need for sustainable new transport systems. It was a 30-month project that ended in 2004.

Davina Fereday's (transport consultant with UK company Transport & Travel Research Ltd, and the coordinator of the EDICT project) statement that "PRT has a great future in many cities, working alongside existing modes of transport. Unfortunately, nobody wants to be the first, and that has had a lot to do with politics. Now that the EDICT project has shown that PRT would have clear benefits in several European cities, I hope progress will be faster." tries to explain why, with all these advantages, plus two decades of research history, PRT has not already become popular (EDICT, n.d.).

All four of the PRT schemes studied in detail showed significant projected benefits and favourable economics. As well as cutting vehicle emissions and energy use, PRT can reduce traffic problems whilst making people more mobile, increasing the numbers of those using certain facilities and reducing social exclusion. The costs are reasonable, too. The Cardiff study, for instance, found that a PRT system would easily cover its operating costs and most of its capital costs, especially when social costs and benefits are included (EDICT, n.d.).

There are also a number of full feasibility projects developed by private consultancy firms for the implementation of PRT systems in other European and North American cities, like Uppsala, Bologna, Oslo, Malmö, Linköping, Stockholm, Cardiff, New Jersey, Los Angeles, and even in Abu Dhabi and Dubai.

The UK has the world's first Personal Rapid Transit (PRT) System already in test phase at Heathrow Airport (London). Developed by ATS Ltd and BAA, the Heathrow PRT system will consist of a fleet of 18 low energy, battery powered, driverless vehicles capable of carrying around four passengers at a time and their luggage, which travel along a dedicated guide way. The system, which will open to passengers in 2009, brings significant benefits to passengers, providing a quick and comfortable service, with near to zero waiting at stations, as well as contributing to improved environmental performance.

3.2 PRT SUSTAINABILITY ANALYSIS

Many aspects should be considered when evaluating the sustainability of mobility systems. The most pressing issues nowadays are the *energy consumption and CO_2 emissions*. As shown in Figure 2 above, PRTs demands a very low amount of energy for its operation. The energy used can be from renewable sources and acquired locally.

Table 3 below shows the benefits to the municipality and to the user of such systems. The land use required for implementation is most of the times in already built environment as PRT guide ways can be placed above existing roads and highways, walk and cycle paths.

Comparison with Existing Transport Systems

Item	PRT	Urban Metro		BUS	TAXI
		HRT	LRT		
Operation	Networked & Offline System (Nonstop Trip on Demand	Line-haul System (Stop at every stop on the pre-defined route)			Nonstop Trip on Demand
Station Spacing	200m	1,000m	800m	200m	
Service Area	Meshed Network	Line haul	Line haul	Line haul	No limits
Average Trip Speed	45~60km/h	25~35km/h	25~35km/h	15~20km/h	30km/h
Headway	2.5 sec	2-5 min	1-2 min	5 min	
Construction Cost	11M USD/km	100M USD/km	60M USD/km		
Operation Staffs	Unmanned Operation	Drivers Security Staffs	Drivers Security Staffs	Driver	Drivers Booking Staffs
Operation Time	24/7	Limited	Limited	Limited	24/7(Extra charge)
Service Charge	cheap	cheap	cheap	cheap	expensive
Quality of Service	Premium	Nominal	Nominal	Nominal	Premium

Table 3: Comparison of existing transport modes
Source: Vectus PRT, n.d.

Since PRT systems vendors are still in the process of developing the final products, this research team made an overall sustainability analysis of a PRT system, specifying how it should be built to comply with the four sustainability principles, within the "cradle to cradle" approach. In this approach waste from all materials are viewed as nutrients for other processes, either biological or technical. The dematerialization and substitution concepts were also utilized, where there must be a constant search for process efficiency and optimisation as well as finding substitution resources with the same technical and design attributes as the ones used in conventional product development.

This analysis can be found below:

Table 4: PRT Systems Sustainability Analysis

PRT SYSTEM SUSTAINABILITY ANALYSIS the design of the PRT system should follow the cradle to cradle concept				
PRT – concept aspect	**Sustainability aspects related to the SPs**			**Suggestions for PRT to be part of a sustainable solution**
1. guideways, Posts and cabin chassis	SP1	iron ore mining	1	It is suggested that the iron be procured from sustainable mining, and also that there is recycled content in the steel used. The installation of such posts and guideways for PRT systems requires light structures, demanding use of minimal amount of land, located mostly in already built environments. The planning of such networks should address visual impact with care.
	SP2	use of steel	1	
	SP3	land use for guideways and posts	1	
	SP4	visual impact	2	
2. external shell for closed stations and cabins - ultralight thermoplastics composites	SP1	oil for plastics	1	Thermoplastics composites use petrol as a raw material, but they are also fully recyclable, therefore not systematically accumulating in the biosphere. Due to the short waiting time, the stations are small in size, demanding lower amount of land-use. They should be at street level when possible.
	SP2	ultralight thermoPlastics composites (FiberForge)	1	
	SP3	land use for stations	1	
	SP4	----	0	
3. Policarbonate glazing for stations and cabins	SP1	oil for Plastics	1	Policarbonate use petrol as a raw material, but it is also fully recyclable, therefore not systematically accumulating in the biosphere
	SP2	Policarbonate	1	
	SP3	----	0	
	SP4	----	0	
4. Cabin seats - flip-down coconut fiber with latex	SP1	----	0	The coconut husk fiber is a by-product of the coconut food industry, being molded into seats together with latex. This compound is has the characteristic breathability of the fibers, durability and resistance to deformity, is 100% recyclable and ecological. Lower volume than synthetic materials; the fibers are extracted from the coconut's shell, which contains the substance Tannin, a natural inhibitor of fungus and mites (http://www.poematec.com.br/eng) The flip-down seats allow for plenty of room for wheel chairs, shopping or strollers.
	SP2	biodegradable and recyclable	0	
	SP3	by- product of coconut crop	0	
	SP4	fair trade coconut plantations and fiber processing	0	
5. Low-energy fluorescent lighting for stations and for stations and cabins	SP1	mercury, aluminum	3	Mercury is a rare metal, which if not disposed of properly has a major potential for contamination of water, soil and living systems. Fluorescent light bulbs demand much less energy than other kinds of lighting. Aluminum used in the light bulbs is easily reciclable.
	SP2	glass	2	
	SP3	major contamination potential if not properly recycled	3	
	SP4	----	0	
6. ticketing machines and computer devices - steel, plastics, electronic circuitry,	SP1	iron ore mining, oil, electonic circuits heavy metals		The steel casing should be totally recyclable, as well as the plastics components. The electronics circuitries should be recycled resSPecting human rights and avoiding contamination.
	SP2	recyclable plastics, electronic circuit boards		
	SP3	---	0	
	SP4	---	0	
7. IT systems - communications, security, control	SP1	---	0	Fair working conditions to IT developers and control personell
	SP2	---	0	
	SP3	---	0	
	SP4	personell to develop and control the several systems	0	

PRT SYSTEM SUSTAINABILITY ANALYSIS the design of the PRT system should follow the cradle to cradle concept				
PRT - concept aspect	**Sustainability aspects related to the SPs**			**Suggestions for PRT to be part of a sustainable solution**
9. energy efficiency	SP1	—		Electrically powered, thus independent of fossil fuels; consumes a fraction of energy per seat km compared with present transport alternatives - the speed profile of vehicles is almost constant from origin to destination; the high energy efficiency of electric motors and a part of the energy for braking can be recovered and stored in on-board batteries or injected in the electrical grid. The PRT systems should run on renewable energy sources, like wind/ hydro energy. The HVAC system for the cabins should be energy efficient. Zero emissions system. '- Propulsion energy waste minimized through such techniques as aerodynamic shape, regenerative braking, efficient motors, and minimal rolling resistance. • Cabin energy waste minimized through efficient lighting and passive/marginal climate control, insulation, etc.
	SP2	—		
	SP3	renewable energies - wind/ hydro power		
	SP4	HVAC system for passenger comfort		
10. Internal finishings - EPP	SP1	oil for plastics		EPP (Expanded Polypropilene particle) - light, durable, recyclable and water repellent
	SP2	100% recyclable		
	SP3	—		
	SP4	—		
11. System attractiveness fo the user	SP1		0	1. Fully automated vehicles (i.e., without human drivers). 2. Increased safety 3. Small vehicles available for exclusive use by an individual or a small group traveling together by choice. These vehicles can be available for service 24 hours a day, if desired. 4. Small guideways that can be located aboveground, at or near levelground, or underground. 5. Vehicles able to use all guideways and stations on a fully connected (a "coupled") PRT network. 6. Direct origin to destination service, without a necessity to transfer or stop at intervening stations (i.e., "non-stop" service), non-stop service. 7. Service available on demand rather than on fixed schedules, no waiting time. 8. Easy to access and use 9. No congestion 10. No noise
	SP2		0	
	SP3		0	
	SP4		0	
12. System feasability for implementation				1. The use of the vehicles is much more efficient than in the private car system because as soon as one trip is finished the vehicle is available for another, thus keeping each vehicle in operation about 10 hours a day – 6 to 10 times as much as with an automobile 2. The land under the system can be used for walking, jogging or bicycle trails
				PRT is the cheapest mode of urban public transport in a wide range of passenger demand - The bus mode is the second cheapest mode, but it has a limited capacity - LRT is a cheaper mode than the heavy rail modes up to some 25,000 passengers per day (in both directions) - Over the full practical range of demand levels, the total capital plus operating costs per passenger-kilometre for the PRT mode is less than 1/3 of a LRT system and also cheaper than Bus in the lower range, relevant for the bus mode. "Advanced automated transit systems designed to out- perform the car"

SP1: Sustainable Principle 1
SP2: Sustainable Principle 2
SP3: Sustainable Principle 3
SP4: Sustainable Principle 4

impact on the sustainable principles:

0	less impact
1	impact
2	more impact
3	most impact

3.3 ADAPTED FRAMEWORK FOR STRATEGIC SUSTAINABLE DEVELOPMENT (FSSD) IN KARLSKRONA MUNICIPALITY'S SUSTAINABLE MOBILITY SYSTEM (FSSD-SM)

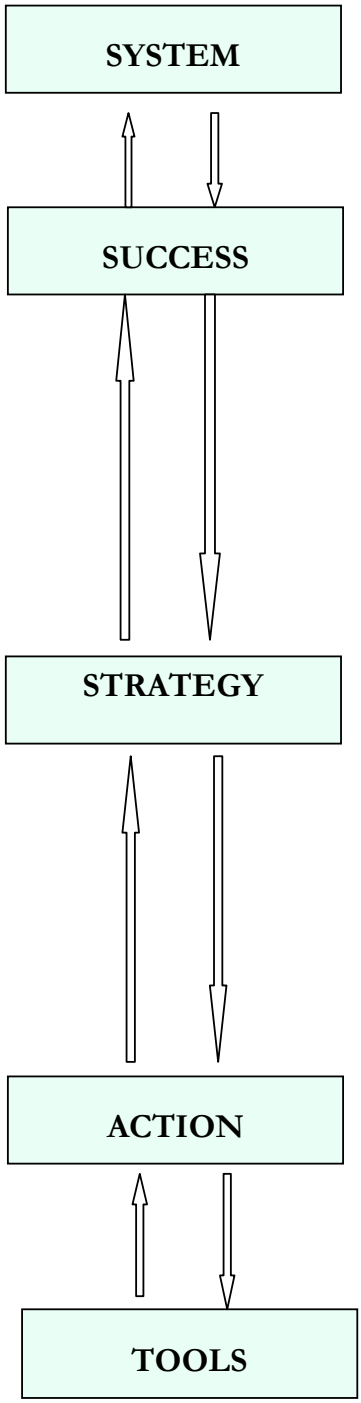
Backcasting from a desirable future is the core element of this methodology. "The major benefit of the backcasting approach is that it provides a clear sense of how things need to be, instead of just aiming at making things better than they are now. There is an emphasis on an upstream versus a downstream approach, which helps to address problems before they occur rather than after the fact." (Robèrt, M, 2004). Table 5 below is a result of the working process to apply the FSSD to achieve Karlskrona municipality's sustainable mobility. The overall methodology used is described in item 1.3.1.

The working process used for developing the FSSD-Sustainable Mobility consists in:

- Acknowledgments of the system
- Building a Mobility Vision
- Backcasting from Karlskrona Sustainable Mobility Vision – Strategy:
  - Analyses of Karlskrona Mobility System – Current Reality, C step, strategic guidelines, D step
- Suggested Actions
- Suggested tools

During two afternoons the research team facilitated an ABCD workshop with politicians and employees from the municipality of Karlskrona. The first ABC workshop resulted in a list of present barriers to sustainable mobility - B list; the beginning of the construction of a vision for sustainable mobility in the municipality in 2050, and brainstormed measures to get to this vision within the constraints of the 4 SPs - C list (see Appendix V). The final C list presented in this study is a result of the first workshop and complemented by measures taken from the best practices research projects presented in the Results section.

Table 5: FSSD-Sustainable Mobility Framework for Strategic Sustainable Development for Sustainable Mobility in Karlskrona



Karlskrona Municipality`s mobility system within society, within the Biosphere: understanding the relationships between transport systems, land use, energy consumption, people behaviour, policy making, economical structuring and its impact on the social and natural environment

- Vision – 2050 Fossil Fuel Free Municipality

World class and *integrated transport system* that offers safe, efficient and *sustainable* travel *for all*, where public transport, walking and cycling provide real and desirable alternatives to car travel; moreover, making the Municipality *greener and more attractive.*

- Backasting from the vision of a sustainable mobility society

Structured actions must be guided by **strategic guidelines** leading towards eliminating car dependency – in order to achieve sustainable mobility the measure must meet:

- Emissions reduction
- Congestion elimination
- Resource efficiency -
- Recyclability
- Semless modal integration
- User satisfaction
- Safety and sucurity

Regarding to a mode system, this must be :

- Comfortable, available on demand, accessible, fast trip time, affordable

Actions must be prioritized according to the principles:

- Right direction towards the vision?
- Flexible platform to new developments?
- Good return of investment (economical, social, etc)?

Design the integrated systems network including walking, cycling and PT, according to prioritized measures – to achieve integrated implementation of the PRT system in Karlskrona Municipality.

Additional techniques, instruments, measurements, management tools, to assist and support the action:
ABCD tool
LCA
CLD
LRP planning system

3.3.1 Acknowledgment of the system

The system analysed in this study comprehends Karlskrona mobility's system within Karlskrona municipality within Society within the Biosphere and its intrinsic relationships.

It has been made clear from the research results in item 3.1 that in order to close the gap between Karlskrona municipality's current mobility reality and their vision of success, it is crucial to understand the relationships and synergies between the several areas that affect mobility, which include: *land use, behaviour change and life styles, technological innovations, energy, communications and education, environment, economy and policies* (Topp, H.H., 2006; Corrales, M, et al, 1996; Johansson, H., 2008; Kågeson, P., 2007; Vergragt, P.,2007; EEA, 2007 and2008; Novem, 2002).

To avoid reductionism, it is best to start with a "bird's eye view" – to be able to identify the basic principles that describe the systems with its major components (just listed above), its interrelationships, and essential aspects of functioning, until higher level of detail is approached (Robèrt et al, 2004).

3.3.2 Karlskrona's Mobility Vision for Success in the Future

Karlskrona's vision for the future, to be "a Sustainable Society for the Next Generation" helped in defining its sustainable mobility vision where the four System Principles were used as basic constraints for its final formulation.

This resulting list of measures – C list - contributed for the formulation of Karlskrona municipality's sustainable mobility vision as it indicates how their authorities would like it to be in the future. This information was combined with data acquired during meetings and interviews with a few of the municipality's department heads, and complemented with concepts of a sustainable mobility society derived from the literature review (see Appendix V).

Karlskrona's 2050 Sustainable Mobility Vision – Fossil Fuel Free municipality:

"World class and *integrated transport system* that offers safe, efficient and *sustainable* travel *for all*, where public transport, walking and cycling

provide real and desirable alternatives to car travel; moreover, making the municipality *greener and more attractive.*"

This vision must be further discussed with other members of the municipality and of the community. If consensus cannot be reached around a specific vision, the best alternative is to define the future by basic principles (the 4 SPs – item 1.1.2) that would allow many scenarios, but always within the constraints of the principles (Robèrt et al, 2004).

3.3.3 Backcasting from Karlskrona's Mobility Vision – the Strategy

In order to reach its sustainable mobility vision, local authorities must define an integrated and strategic long-term sustainable development plan which can be achieved by backcasting from the desired vision of sustainable mobility in the future, described in item 3.3.2 above. This means to use that understanding of success to determine the measures that need to be taken from today (current reality) to get there in the future. Another way to express it is to "begin with the end in mind", as shown in figure 6.

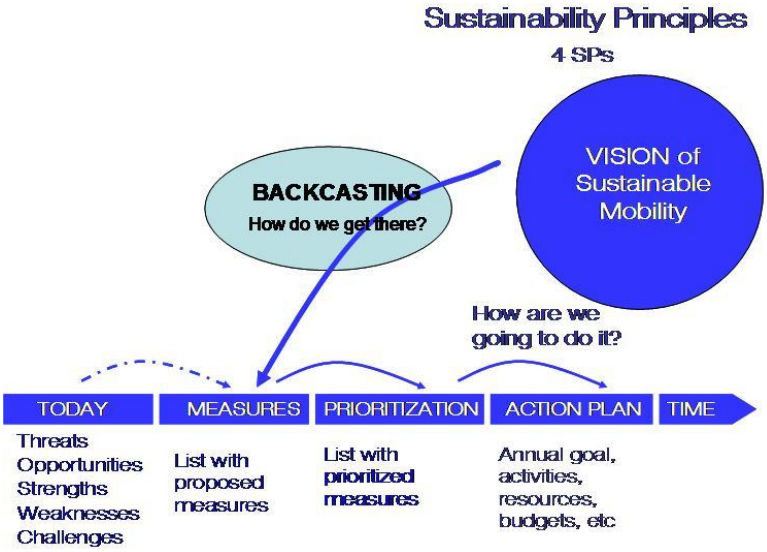


Figure 9: Backcasting from a Sustainable Vision of Success
Adapted from: Robèrt et al, 2004

The backcasting exercise led to the acknowledgment of the Karskrona mobility system's current reality as well as to a list of compelling measures

to bridge the way between the current reality and the desired future, the C list, from which measures were prioritized, resulting in the so called D list, used to strategically inform the action plan.

3.3.3.1 Karlskrona's Mobility System – Current reality

"The B step in the ABCD tool is the first step of backcasting. Here the team scrutinizes today's operations from the framework of its sustainability principles" (Robèrt et al, 2007).

The current reality of Karlskrona municipality's transportation system analyzed through the lens of the 4SPs – the B list - is the input for its Sustainable Mobility analysis (see table 2 in Appendix V), where the research team weighs the different issues according to their impacts on the 4 SPs. This process displayed at the first level a lack of integrated planning between land use, transportation and energy. This becomes clear when the decision to implement the new housing development by Bastasjö lake, north of Lyckeby, and the new job creating industrial expansion area in Verkö, in the south, were not designed taking into account the direct impact to the transportation system. Also the plan to move the train station from Trossö to Gulberna Park addresses only the efficiency of the train system and to make it closer for people living outside the downtown area to access the station. It does not address the lack of PT for people to reach the new train station.

Other important barrier identified is the increase in car dependency as another of the main challenges to address. This is a result of local culture (the car represents freedom, status, comfort, etc) as stated by Johansson (Johansson, H., 2008); the fact that Blekingetrafiken does not satisfy their customers needs; and also the fact that the existing walking and cycling infrastructure is not satisfactory. Low- density specific use housing developments characterized as urban-sprawl also leads to car-dependency. Moreover, the intensive use of cars is one of the main contributors to CO_2 emissions, amongst other downstream effects like noise, congestion, accidents, etc.

Through Karlskrona Mobility System's current reality described above it is clear that the municipality is not currently being able to integrate land use decisions made to accommodate growth and economic development while accounting for its direct impact to the mobility and energy systems. They are working with measures that address specific issues, without analysing

their long-term impact or their synergies with other possible areas – downstream versus upstream.

The problem of unsustainability is not only a series of seemingly unlinked negative impacts (downstream), but underlying systemic errors of societal design that will make things worse and worse until, in the end, it will be impossible to sustain itself (Robèrt et al, 2007).

3.3.3.2 The C list – Compelling Measures

A list of compelling measures - C list - was produced to address the challenges and barriers recognized in the analysis described above. It is the second step in the backcasting process; comprising brainstormed solutions to reach the vision (see Appendix V).

Some of the measures identified to deal with car dependency are: (i) eliminating cars and buses from Trossö, (ii) changing fuel, size and number of buses to make the operation more efficient, (iii) improve and increase cycling infrastructure, (iv) create a central and integrated traffic centre and (v) offer a driverless and on demand transportation system.

In order to direct the strategy towards a sustainable mobility future, some others measures were proposed by the research team, having in mind the need of addressing the challenges upstream, instead of proposing mitigating downstream measures: (i) integrated spatial and transport planning (ii) the creation of a sustainable mobility office (see Lund example in item 3.1.3), (iii) governmental incentives/disincentives to promote behaviour change and modal shift, (iv) implementing *intermodality* (see item 3.1.1), (v) offer an alternative transportation mode that can compete with the personal car.

Several transportation modes and their integration were considered to envision the sustainable mobility society for Karlskrona. It has become plain that what is being offered to the individual to eliminate car-dependency does not address at all the needs and wishes of the population. This has directed the efforts in procuring new technologies that could fulfil such needs and help develop real competition for the use of the private car, fostering the use of public transportation.

Such a system, described in items 3.1.4 and 3.1.5 is the Personal Rapid Transit or PRT.

3.3.3.3 Strategic Guidelines

This extensive C list must deliver a prioritized list of measures – called D list - which is classified into short, medium and long term measures. This enables the systematic move from the current reality to the vision in the future. Each one of these compelling measures must answer three very important questions: (i) does this measure lead us in the right direction towards achieving our vision of success?; (ii) is it a flexible platform, in terms of providing a stepping stone for future moves?; (iii) does this action provide an adequate return on investment (ROI) so that we can continue to invest in other measures towards the future?

As evidenced in all of the best practice research studies leading to sustainable mobility, integrated planning is the first measure to move into a strategic action plan (Robèrt, M, 2007). From a sustainable mobility perspective, specific guidelines must inform, together with the three prioritizing questions described above, the most important and strategic measures to be implemented, creating a step-by-step plan within a realistic timeline. Using experience to determine priorities at the detailed level, as well as references from the European Guidelines for the transport sector (see item 1.2.2.1) and also Prof Andrèasson's study for a new type of transit (Andrèasson, I., 2001), the following guidelines were established:

- Backcasting from the vision of a sustainable mobility society

Structured actions must be guided by *strategic guideline***s** leading towards offering quality PT in order to eliminate car dependency:

- Emissions and noise reduction
- Congestion elimination
- Resource efficiency (land-use, energy, dematerialization, substitution, etc)
- Recyclability
- Seamless modal integration
- User satisfaction
- Safety and security

Besides the above guidelines, the specific modal system must also be:

- Attractive to the user: comfortable, available on demand, accessible, fast trip time, affordable
- Renewable energy sources

3.3.3.4 The D list – Prioritized Measures

The list of prioritized measures – the D list - developed by the research team is in accordance with each measure's relevant contribution to achieve the vision of success. The approach of dematerialization and substitution together with a temporal perspective also provides guidance to this process. These measures are presented in the Prioritisation Matrix in table 6 below, where each one is analysed in the eyes of the strategic guidelines introduced in item 3.3.3.3 above.

Therefore, the implementation of the PRT system in Karlskrona has been thought of in an integrated manner with the other mobility modes, as well as with the existing infra-structure challenges in order to deliver what all urban centres must strive for: sustainable mobility. In order to accomplish this, several previous measures should be implemented as stepping stones leading towards the success. Such measures should respect a chronological order to be put in place, serving as a flexible platform for new developments as well as bringing a good return of the investment, be it economical, social, environmental or institutional – in order to reach the vision for success in Karlsskrona municipality's sustainable mobility system within society within the biosphere.

Some of these measures are: (i) integrate transport modes; (ii) improve infrastructure for cycle and walking paths, bus stops and stations (iii) improve PT services (iv) awareness campaigns for behaviour change ; (v) provide parking places outside Trossö and eliminate the use of cars and buses in it's central area (vi) plan new developments according to transport efficiency.

Table 6**:** Prioritization Matrix (D list)

ACTION PLAN - priorization matrix															
		stratigic guidelines													
		genaral			specific to mobility								specific to modes		time frame
mode	Measure	right direction?	Flexible Platform?	good rol?	Emissions and noise reduction	Congestion elimination	Resource efficiency	Recyclability	seamless modal integration	user satisfaction	safety and security	attractive	renewable source	Short, Med, or Long term Action?
walking	transport mode integration	Y	Y	Y	Y	Y	Y		Y	Y		Y		short
	improve walking paths	Y	Y	Y	M	M			y	y	y			short
biking	integrated planning/design of bike paths network	Y	Y	Y	M	M			Y		Y			short
	carry-on bikes in buses and other modes	Y	Y	Y	M	Y	Y		Y	Y				short
	bike facilities/bike park	Y	Y	Y		M	M	M	Y	Y	Y			short
buses	procure sustainable buses/products	Y	Y	Y	N	N	Y	Y	N	Y	N	Y	Y	short
	change in number and size of buses	Y	Y	Y	Y	N	Y	M	Y	Y		Y	Y	short
	computerized routing and schedule/real time	Y	Y	Y	Y	M	Y	M	Y	Y	Y	Y		short
	biogas fuel	Y	Y	Y	Y	N	Y	N	N	Y	Y	Y	Y	long
	design new protected bus stops	Y	Y	Y	N	N	M	M	Y	Y	Y	Y		short
	remove buses from Trosso	Y	Y	Y	Y	Y	Y	N	Y	Y	Y			med
	free bus fare	Y	Y	Y	N	N	M	N	Y	Y	N	Y	M	long
	fare scheduling	Y	Y	Y	N	N	Y	N	Y	Y	N	Y		short
cars	remove car from Trosso	Y	Y	Y	Y	Y	Y		Y	Y	Y			long
	create parking spaces outside Trosso	Y	Y	Y	Y	Y	Y		Y	Y	Y			medium
	cradle to cradle cars	Y	Y	Y	Y	N	Y	Y	N	Y	N			long
	driveless eletric cars	Y	Y	Y	Y	N	Y	M	N	Y	Y	Y	Y	long
	pod cars flexible personal transports available 24x7 B	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	medium

ACTION PLAN – priorization matrix																		
mode	Measure	stratigic guidelines													specific to modes		time frame
		genaral			specific to mobility													
		right direction?	Flexible Platform?	good roi?	Emissions and noise reduction	Congestion elimination	Resource efficiency	Recyclability	seamless modal	user satisfaction	safety and security				attractive	renewable source	Short, Med, or Long term Action?
General measures	create Mobility Management Office (eg Lund) A++	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y						short
	networked car-sharing in companies	Y	Y	Y	Y	Y	Y		Y	Y	Y						short
	it developments – more people working/shopping at home	Y	Y	Y	Y	Y	Y		Y	Y	Y						medium
	automated and integrated traffic control and planning	Y	Y	Y	Y	Y	Y		Y	Y	Y						medium
	driverless transport system	Y	Y	Y	N	N	Y	Y	Y	Y	Y				Y	Y	long
	water taxis in the summer	Y	Y	Y	N	Y	N	N	Y	Y	N				Y	Y	short
	urgent integrated spatial and transport planning	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y						short
	behaviour change campaign	Y	Y	Y	Y	Y	Y	Y	Y	Y							medium
	neighbourhood concept	Y	Y	Y	Y	Y	M	Y	Y	Y	Y						short
	change train station to Gulberna Park	Y	Y	Y	M	M	Y	M	Y	Y	Y						midium
	biogas power plant(Sydkraft Gas as a co-investor – Kristianstad)	Y	Y	Y	Y		Y		Y	Y	N						long

Y: yes; N: no; M: maybe – according to specific circumstances and/or integrative measures

3.3.3.5 Karlskrona's Business Case for Sustainability

From a business perspective, a key imperative is to demonstrate the relevant opportunity provided by sustainable development principles to both current and future activities within the municipality. This requires a more explicit analysis of the potential opportunities and threats posed by sustainability issues, particularly in areas of strategic concern to the sustainable mobility, as shown in the Karlskrona municipality's sustainable mobility SWOT analysis (see Appendix V – SWOT analysis table).

The SWOT analysis identified that several investments in transportation systems must be made in order to provide the citizens excellent mobility.

Such investments are a great business opportunity and can provide competitive advantage, when considering the municipality's leaders willingness to pursue it's development into the future in a sustainable manner - in order to make it an attractive place to live and be able to draw new ventures and economic sustainable development and growth. They will also lead towards reaching its goal of becoming a Zero Emissions municipality.

The municipality's recurring annual deficit from the PT that is presently offered to the population can be reversed by the implementation of innovative ideas such as the PRT system. This initiative can account for the elimination of several of the downstream problems that occur today (pollution, congestion, etc), which must be monetarised as part of the equation, as discussed in item 3.1.1. According to Willard, the business case is designed to help companies identify wider justifications for improved performance in ethical, environmental and social dimensions beyond matters of regulatory compliance, or risk and impact control. It does so by presenting an approach that focuses on potential business benefits as a key driver for improved company performance in these areas (Willard, B., 2005). The awareness and monetarisation of these potential business benefits which the shift for a sustainable mobility society can offer is the bottom line to encourage Karlskrona municipality's moves towards its vision of success.

The Daventry PRT system feasability study can be used to compare to the Karlskrona case study since they are similar sized cities, both looking for growth in a sustainable manner. This study points at the following benefits as confirmed but hard to quantify at this stage. These include increased competitiveness for Daventry, attracting investment and visitors, direct and indirect employment effects, access benefits and the possible creation of a "Transport Technologies Park" (Sinclair Knight Merz., 2008).

3.3.4 Action

After prioritising the measures to be taken within the necessary timeframe, actions must be decided upon that will follow overall strategic guidelines (level 3) to help move the system towards the sustainable mobility (level 2) in Karlskrona municipality's sustainable mobility system within society within the biosphere (level 1).

Due to the time limitations the research team could not establish the necessary action steps, and recommends that the municipality follows on with this work.

3.3.5 Tools

In order to achieve success, there are several additional techniques, measurements, monitoring, management approaches which can be used to assist in the movement towards success – such as the ABCD tool used in the workshops with Karlskrona municipality described in item 3.3, the Sustainability Analysis used to establish the sustainable performance of PRT systems, and CLD (Causal Loop Diagrams) to assist planning in a complex system. Other tools frequently used are LCA (Life Cycle Analysis), the ISO 14001 certification (to make public the accomplished efforts), the Balanced Scorecard strategic planning implementation tool (BSC), etc.

4 DISCUSSION

In spite of it being clear that cutting emissions and cutting energy use is vital to fighting climate change, car usage is still growing all over the world. This issue is everybody's concern, because the harmful effects impact many aspects of our lives. Although most people are nowadays able to acknowledge this fact, very few people are able to be proactive and do something about it.

In order to answer this work's primary research question:

Can the municipality of Karlskrona move towards sustainable mobility by integrating Podcar systems with other modal systems?

We must begin by answering the secondary questions:

Can podcar systems be considered sustainable?

The extensive literature review together with the results of the EDICT project clearly demonstrate that PRT systems are convenient, energy-

efficient and cheap to run, zero emissions if powered by renewables like wind energy and are the only innovation out there ready for implementation that can compete with the private car in order to reduce car dependency in urban areas. Furthermore this mobility mode complies with all the strategic guidelines identified in the prioritisation of measures to be implemented in Karlskrona, in order to reach its vision of success in the future.

Podcar systems offer the following benefits: (i) land use required for implementation is most of the times in already built environments, as the slim guide ways can be placed above existing roads and highways, walk and cycle paths; (ii) demand a very low amount of electric energy (passenger/km) for its operation – plus the energy used can be from renewable sources and acquired locally; (iii) zero local emissions, and the total emissions are dependent on the kind of energy used to power the system; (iv) driverless cabs – lower operating costs and reduced accidents; (v) the service is available on demand rather than on fixed schedules, 24x7 at all stations on the network to meet non-stop individual travel needs (ensure short trip times); in most cases, passengers do not need to wait for a vehicle; (vi) the personal size of a podcar allows each transit rider to have his or her own ride; (vii) system capacity is similar to that of buses or guided buses (from 4.500 to 7.500 passenger/hour); (viii) slim PRT guide ways are less expensive and intrusive than a guide way that supports large conventional transit vehicles (trams, surface metro); (ix) operation and installation costs of PRT systems are smaller than heavy rail, light rail and urban bus - PRT systems can easily cover its operating costs and most of its capital costs, especially when social costs and benefits are included.

To ensure that the continuing development of this extraordinary technology moves toward total compliance with the four SPs and total sustainability, this research team has developed a sustainability analysis of the parts of the system, like the guide-ways and the cabs (see item 3.2). This analysis recommends that a cradle-to-cradle approach be used, and goes on to identify several opportunities to make this system truly sustainable. This means that every component of the system, at the end of its life, must become “food” for either a biological or a technical process. One of the suggestions is to make the inner shell of the pods out of EPP (Expanded Polypropylene Particle) light, durable, recyclable and water repellent material.

What are the gaps, threats, opportunities and leverage points for Karlskrona municipality to decrease car-dependency? How can local

authorities use the Strategic Sustainable Development Framework to plan for a decrease in car dependency?

Widening the understanding of the mobility system to include the other systems which closely inter-relate with it creates the necessary holistic vision to identify invaluable synergies between them, and also to avoid dead-ends in the municipal planning process (like urban-sprawl). By identifying the inherent problems within these systems, it is then possible to envision the *root cause* upstream (many times one issue causes different problems in more than one system downstream) and deal with it in the most effective manner. Utilising the medical metaphor, one must treat the cause, not the symptoms of a disease.

In the mobility system that has been developed since the 1950's in the western world, the root cause for the main mobility consequences society faces today is the urban sprawl approach adopted for spatial planning in urban areas. This approach has led to an excessive dependence in the use of the private car, causing a series of downstream effects that nowadays seriously jeopardize quality of life in such areas.

Systems thinking is essential for change, although not common practice yet. Sustainability awareness has been growing because systems thinking, in different forms, is exposing more interdependencies than were ever imagined in the past. It is those interdependencies that show it is both stupid and reckless to think of commercial sustainability in isolation of either social or environmental sustainability. As a conceptual tool, systems thinking can help to clarify interdependencies and complex change dynamics.

Kalskrona municipality does not utilise an integrated planning approach or systems thinking methodologies. The common practice is to circulate decisions made separately in one department for approval in other departments. This is very different from integrated planning, for one loses the opportunity to interact with peers in the conceptual phase of planning, where the identification of the common root causes for different problems can be made, and synergistic solutions agreed upon. Otherwise, time and resources are spent in measures that will only maintain the status-quo and not help in bridging the gap towards sustainability. The intended measure to buy biogas mini buses to circulate in the downtown area, without integrating this with the procurement and optimisation for the use of the fuel (such as planning for the production of biogas from landfill areas like

in Helsingborg) does not bring them closer to their sustainable mobility vision, as the use of resources is scattered instead of concentrated.

Once integrated planning is adopted, the next step is to offer the population an integrated mobility system attractive enough to compete with the use of the private car, identified in this paper as being the PRT system. The use of the FSSD-Sustainable Mobility in Karlskrona municipality guides the way for local authorities to achieve their sustainable mobility through backcasting from their vision of success in the future within the four sustainability principles.

What barriers prevent European cities and regions from adopting new mobility technologies to decrease car dependency?

As identified in the EDICT project final report, with all the conditions for successful implementation of PRT systems tested, simulated and approved, the only barrier that can explain the non-implementation of the many projects developed is that nobody wants to be the first. That most probably has a lot to do with politics as well as heavy lobbying from the automotive industry. The fact that there are only two vendors to date which are qualified to bid on any system also narrows the possibilities (because they are the only ones that already have the stringent safety approvals from authorities in the EU, which take at least two years to get) (Andrèasson, 2008). Implementation of a small initial system though, can be rather fast, from 2 to 3 years. (Gustafsson, J., 2008)

Nowadays there are many initiatives to bring together local governments, businesses, industry and academia in schemes like Public Private Partnerships. They make feasible projects which would otherwise never blossom. The fare free bus initiative in Hasselt for instance (see item 3.1.3) does not cost the local authorities anything – it is all sponsored by local businesses, who obviously profit from it, since it has been in effect for over 10 years now.

Can the municipality of Karlskrona move towards sustainable mobility by integrating Podcar systems with other modal systems?

Getting back to the main research question, sustainable mobility in a small municipality where car rider ship is rising can only be achieved with the supply of a system that can compete with the use of the car (Andréasson, I, 2008).

Therefore, PRT systems were compared in this project to the use of the private car, and not to the use of other PT modal systems. To that extent, the fact that it provides personalised on demand service 24 x 7, and that it is driverless (therefore allowing for the extended service hours with no extra cost) must be added to the careful step-by-step introduction of the system with the clear aim to *supplant car use*, where additional infrastructure for the private car will not be accepted.

The PRT infrastructure must be carefully planned in order to be minimised and totally integrated with the other existing modes in Karlskrona to make it a true acceptable alternative. Any bus service would only be comparable if it provided low waiting times and highly reliable journey times – attributes not known to have been achieved so far. What PRT offers is very low (forecast) waiting times for passengers and fast in-vehicle journey times comparable with the private car (Sinclair Knight Merz, 2008). Careful consideration must be given to the interference of any system in the landscape, as one of the objectives is to make cities more attractive, including its visual attractiveness.

A study developed for Daventry municipality in the United Kingdom, which is similar in size to the municipality of Karlskrona, states that the municipality should consider a pilot PRT scheme serving an existing developed area and avoiding property demolitions. It should be of minimum scale needed to demonstrate all key service features, cost should be limited and it should have reasonable potential demand (Sinclair Knight Merz, 2008).

This survey indicates that Karlskrona municipality can and should go ahead to plan for the implementation of PRT systems in the medium term. Unless it decides to embrace this new technology and plans accordingly, as it takes time to come into place, it will go on "hitting the walls of the funnel" and not be prepared for issues like peak oil, ever more severe EU and National regulations concerning emission, etc. The next natural step would be to establish a Mobility Department in the municipality, which would be in charge of the *long term integrated planning* to achieve sustainable mobility in the future. They should then contract expert advice to develop a thorough feasibility study for the integrated implementation of a PRT system in the city.

5 CONCLUSION

In order to reduce car dependency, better and more attractive PT alternatives plus extra charges for car rider ship must be introduced. The alternative has to have a different image than what has been offered so far as PT. It cannot be like the bus, it has to be radically different – in a way that the customer will not think of it as PT, it must almost be a luxury product. Only then will authorities in the European Union member countries be addressing the real needs of their societies and be capacitated to fight car dependency and its negative impacts, while still providing the population with sustainable mobility systems. It's also imperative that this mobility system be an economic venture as well as environmentally sound system.

Through the use of the FSSD-Sustainable Mobility for planning in complex systems, it was possible to identify and acknowledge, with a bird's eye view, the various synergies between the overlapping systems at play: mobility, land-use, energy, economic structure and behaviour change. Furthermore, through the compliance with the strategic guidelines it was possible to prioritize the measures that must be put in place in order to structure the action plan for achieving the goal. This made it possible to analyse the integration of a PRT system into the city's existing mobility modes as a means to reach its sustainable mobility vision in the future, within the constraints of the fours sustainability principles.

Karlskrona municipality's case study highlighted several benefits which the implementation of PRT systems would ensure: (i) increased competitiveness for the municipality; (ii) attracting investment and visitors; (iii) direct and indirect employment effects; (iv) access benefits to citizens who are now marginalized by poor PT and no access to cars; (v) congestions elimination; (vi) emissions and pollution reduction; (vii) accident and noise reduction.

The realisation of these benefits partly depends on who drives/implements the project. Social inclusion benefits from better access to employment and activities are likely for a larger PRT network but probably not for the pilot. We can, therefore, conclude that PRT offers major potential benefits and can, in principal, offer a more attractive alternative to car use than any bus system developed so far.

It is important to realize that PRT systems are not the one and only magical solution to sustainable mobility – they will only be an effective solution when properly integrated to the existing modal infrastructure already in place. And that integration will vary from city to city, from region to region. In smaller cities like Karlskrona, they must be integrated to the existing bus (road) and train infrastructure, as well as to the shorter distance mobility systems like walking and cycling. This also means that the bus service must be reshaped to provide reliable and timely scheduling and routing in order to attract more customers. This might be more productive than trying to substitute the fuel the buses presently run on (if bus ridership raises, emissions per capita will lower considerably). Bus stops must be redesigned to provide the necessary shelter from the weather, bike paths must be planned and implemented, etc. And once planning is completed and implementation is under way, then a marketing campaign can be launched in consonance with the implementation lead times.

Any investment in infrastructure is resource intensive, takes time to implement and is supposed to serve its purpose (to last) for about at least 50 years. Due to the fast increase in car ridership of the last 20 years, road infrastructure has not been able to serve this purpose, becoming obsolete very fast, demanding costly expansions and using up precious land space. The expansion of the road network can be substituted for PRT system implementation, where the guide way network can be implemented over already developed land and reach even farther than the roads presently do.

5.1 OPPORTUNITIES FOR FURTHER RESEARCH

Proposed strategies do not constitute a comprehensive roadmap towards sustainable mobility applicable throughout Europe. Rather, local and regional authorities should use the developed FSSD- Sustainable Mobility model to define their own system that incorporates land-use, energy and mobility - their own principle-based vision - a set of strategies and actions that are relevant to their system and important to overcome their barriers.

At this stage it is also very useful to run Causal Loop Diagrams (CLD) simulations to verify if certain actions will really lead to fulfilment of the strategy. Understanding a cause and an effect enables us to analyse, sort out and explain how changes come about both temporarily and spatially in common problems (Haraldsson, 2004). This tool will help in prioritizing

measures. Unfortunately it was not possible to run such simulations due to time and resource constraints.

Further research should contemplate an economic analysis comparing PRT systems to the use of the private car, internalising the externalities inherent to the use of the car. This team feels it is not adequate to analyse the implementation of PRT systems as a substitute to other public transportation modes, as this is not its target. The goal of introducing such a system is to *reduce car dependency integrating PRTs to other modal systems.*

The next main steps in implementation of PRT systems should be to assess funding opportunities, to contract the preparation of a full technical study and business case which should help determine the detail of the PRT system procurement approach, as each system has somewhat different parameters.

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Appendix I - EU RESEARCH PROGRAMS TO INFORM THE THESIS

"Towards a new culture for urban mobility" is the title of the European Commission's new Green Paper on urban transport. It was adopted on 25 September 2007 and opens a debate on the key issues of urban mobility: free-flowing and greener towns and cities, smarter urban mobility and an urban transport which is accessible, safe and secure for all European citizens.
(http://ec.europa.eu/transport/clean/green_paper_urban_transport/index_en.htm)

ASTUTE: is a three-year project, funded by the European Commission, Intelligent Energy Executive Agency (IEEA). Its aim is to increase the number of journeys taken by walking or cycling (http://www.astute-eu.org/aboutastute.asp).

COST: is one of the longest-running instruments supporting co-operation among scientists and researchers across Europe. COST now has 35 member countries and enables scientists to collaborate in a wide spectrum of activities in research and technology. It is supported by the EU RTD framework programme. (http://www.cost.esf.org/). Specific to this research project are Cost Action 350: Integrated assessment of environmental impact of traffic and transport infrastructure, and Cost Action 356: Towards the definition of a measurable environmentally sustainable transport (EST) (http://www.cost.esf.org/index.php?id=240&action_number=350 and http://www.cost.esf.org/index.php?id=240&action_number=356)

EDICT: Evaluation and Demonstration of Innovative City Transport (from 01/12/01 to 30/11/04, commissioned by DG Research of the European Commission) - The EDICT project assesses and demonstrates the concept of Personal Rapid Transit (PRT) as a potential solution to meet this need. The assessment is being undertaken in 4 European cities: Cardiff (Wales, UK), Eindhoven (Netherlands), Huddinge (Sweden), and Ciampino (Italy). Six further cities in EC and Accession countries will participate as followers. These are Sigtuna (Sweden), Bristol (UK), Almelo (Netherlands), Reggio Calabria (Italy), Maroussi (Greece) and Olomouc (Czech Republic). Practical assessment of user and community benefits will be accomplished through full-scale demonstration in Cardiff. The results

will be disseminated widely to provide information on best practice for assessment and introduction of PRT systems to improve future transport in Europe. The specific objectives of the EDICT project are:
* To demonstrate and evaluate PRT in a European Capital City
* to examine the opportunities for PRT for practical improvement of both public transport and the environment in four European cities.
* To assess the environmental impact of PRT compared to other forms of transport, including energy, emissions, noise, visual intrusion, severance etc.
* To assess the key social economic and cultural issues of PRT systems in Europe.
* To assess, recommend and disseminate best practice for the evaluation and introduction of PRT. Studies to evaluate the technical, environmental, social and economic effects of PRT will be undertaken in four cities, of different sizes, location and transport issues against a common framework agreed at the start of the work. Each local study will involve the definition of a preliminary PRT route to match existing and projected transport needs and to integrate well with existing public transport

GRACE: international collaborative project Generalisation of *Research on Accounts and Cost Estimation* (coordinated by The Institute for Transport Studies at the University of Leeds (ITS)). The aim of GRACE is to provide new evidence on the costs of transport infrastructure use for all modes of transport, and on the consequences of charging these costs to users. This involves studies to measure the marginal cost of wear and tear, congestion, accidents and environmental impacts. (http://www.grace-eu.org/)

GTZ: As an international cooperation enterprise for sustainable development with worldwide operations, the federally owned Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH supports the German Government in achieving its development-policy objectives. It provides viable, forward looking solutions for political, economic, ecological and social development in a globalised world. One of its theme subjects is Urban Mobility. Although their focus is in developing cities, much of what they research applies to developed countries as well. (http://www.gtz.de/en/themen/umwelt-infrastruktur/transport/20269.htm)

MOVE: is a EU-project about organising and improving our future mobility. Different institutions from seven member-states are developing

criteria to find out the best ways how to implement the necessary changes in our urban and regional transport infrastructure. The project runs from January 2006 till December 2008. The purpose of this project is to select tools, establish methods and standards within the partnership based on existing European initiatives that can be used to achieve *changes in attitudes and behaviour* leading to a change towards less energy intensive transport modes. (http://www.move-project.org/)

PROCEED: research into public transport operations in small and medium sized cities and on how to improve its attractiveness to the users, its efficiency and effectiveness. Initially the project will map and analyse successful case cities, and this will lead to a tool for planning and delivering successful public transport. The project will give a better understanding of the key factors that influence public transport, as well as how the position of public transport in the transport system can be strengthened so its market share can increase.
(http://proceedproject.net/index.php?option=com_content&view=section&layout=blog&id=5&Itemid=28)

PROPOLIS: Planning and Research Of Policies for Land use and transport for increasing urban Sustainability. 2000—2003 EU-funded research, development, and testing of integrated land use and transport policies. It is part of the *TRANSPLUS* project.

SCATTER: Sprawling Cities And TransporT: from Evaluation to Recommendations 2001—2004 EU-funded study of the causes and effects of urban sprawl. (http://www.casa.ucl.ac.uk/scatter/)

SUTP – GTZ: main objective is to assist developing cities meet their sustainable transport goals, through the dissemination of information about international experience and targeted work with particular cities. The Project has two main branches in Asia and Latin America. In Asia (SUTP-Asia), the project is carried out in cooperation between German Technical Cooperation Agency (GTZ), the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), CITYNET, UNHABITAT and the Bangkok Metropolitan Administration (BMA). The office is based in Bangkok (Thailand). In Latin America, the project receives cooperation from Cooperación Andina de Fomento (CAF), ARPEL, UNHABITAT and TransMilenio and is based in Bogotá

(Colombia). There are also selected activities in Africa, though the project does not have an office in that continent (http://www.sutp.org/)

TAPESTRY: 'Travel Awareness Publicity and Education Supporting a Sustainable Transport Strategy' The overall aim of TAPESTRY is stated as: "to increase knowledge and understanding of how to develop effective communication programmes to support sustainable transport policies in Europe".(http://www.max-success.eu/tapestry/www.eu-tapestry.org/index.html)

The IMPACT study

In the light of this mandate from the EU legislator, the European Commission has commissioned the IMPACT study in order to summarise the existing scientific and practitioner's knowledge. The central aim of the study is to provide a comprehensive overview of approaches for estimation and internalisation of external cost and to recommend a set of methods and default values for estimating external costs when conceiving and implementing transport pricing policy and schemes. The study also provide technical support to the Commission services to carry out an Impact Assessment of strategies to internalise transport external costs search to identify best practices in the organisation of land use and transport measures, including the reduction of automobile dependency in Europe. (http://www.isis-it.com/transplus/index.asp)

Appendix II - ECONOMIC INCENTIVES AND INSTRUMENTS

Table 1: A survey of possible economic incentives and instruments
Source: Breithaupt, M. 2004

Type of incentive or disincentive	Possible Economic Instrument(s)	Selected Economic Measure(s)
- Discourage motorized vehicle ownership	- tax/charge on vehicle purchase/ownership/ scrappage	- annual vehicle tax - registration tax/charge - (re)sales tax/charge - scrappage tax/charge
	- restricting the number of vehicles and/or new registrations	- auction schemes competitive bidding for new licenses - licensing car ownership
- Discourage motorized vehicle use - Encourage switch to public or non-motorized transport	- tax/charge on vehicle use	- fuel tax - pay-at-the-pump (sur)charges
	- tax/charge on road and/or infrastructure use, - restricting access to urban centres or special areas	- parking fees - city tolls - road pricing - bridge tolls - cordon pricing - congestion pricing
	- subsidies for public transport and/or multimodal transport (modal subsidies)	- subsidised public transport fees - subsidies for public transport networks and operation - tax-deductable public transport expenses - P&R schemes
- Encourage lower emission technology use and innovation	- taxes/charges on vehicle purchase/ownership/ scrappage, - taxes/charges on vehicle use, - taxes/charges on road and/or infrastructure use	- tax differentiations based on emissions - carbon/energy taxes - emission fees - emission-based surcharges - subsidies, tax rebates for low emission vehicles/technologies

Appendix III – Public acceptability of sustainable mobility

Table 1: Key elements in promoting the public acceptability of sustainable mobility
Source: Bannister, D., 2008

Information	Education, awareness campaigns, and promotion through media and social pressure are an essential starting point Explanation of the need for sustainable mobility, emphasising the positive economic, social and health benefits to the individual and businesses
Involvement and communication	The process must be inclusive, with clear aims and an understanding of the consequences to those on whom the strategy will impact Designed to gain support and understanding, so that stakeholders can buy into the proposals Raise levels of consistency between expectations and outcomes
Packaging	Push and pull policies measures need to be combined in mutually supporting packages. Policies restricting car use or raising its costs should be accompanied by well-publicised programmes to improve the availability and attractiveness of alternatives to driving alone, including car pooling, public transport, cycling and walking, all financed by dedicated revenues from car pricing measures
Selling the benefits	It is necessary to widely publicize the benefits, even if there are costs, inconvenience and sacrifice. Car drivers support funding of alternative modes to reduce congestion on the roads they drive on. Overweight or obese individuals would directly benefit from better walking and cycling conditions. Everyone benefits from cleaner air and safer traffic conditions. More walking, cycling and public transport use would help relieve parking shortages. These are important and direct impacts that all individuals can support
Adopt controversial policies in stages	Support needs to be built up in terms of positive outcomes and measurable improvements in the quality of life Politics is about reflecting prevailing preferences and also forming opinions Acceptance of responsibilities and commitment to change through actions is the key to success

Consistency between different measures and policy sectors	Some measures (e.g. pricing) that are common to all futures. Such measures need to be implemented now, even though their impacts may not be immediate Regulations, standards, subsidies and tax incentives should all be used to encourage manufacturers and other transport suppliers to develop and adopt the most energy efficient and environmentally friendly technology possible The precautionary principle should be followed, particularly on the global warming effects of transport emissions, and actions should be consistent over the longer term Many of the problems created for the transport system do not emanate from the transport sector, but from other sectors. So a more holistic perspective is needed that integrates decision-making across sectors and widens the public discourse
Adaptability	Decisions today should not unnecessarily restrict the scope for future decisions, so that the adaptive behaviour of individuals and agencies can be assessed There is no prescription or blueprint for the correct procedures to follow. Each situation requires separate analysis and implementation, including flexibility to change policy measures if intentions and outcomes do not match up. Assessment of risk and reversibility are both strong components of sustainable mobility Adaptability is not an excuse for inaction or weak action. It is an argument for clear decision making, leadership, supported by analysis and monitoring to check on the effectiveness of policy action

Appendix IV – Strategies to overcome car dependency

Source: adapted from Newman, P. and Jeffrey, K., 1999

STRATEGIES FOR OVERCOMING CAR DEPENDENCE Adapted from Newman, P. and Jeffrey, K., 1999							
Traffic calming		**Favoring Alternate Modes**		**Economic Penalties**		**Non Car dependent Land Uses**	
Regional traffic calming,	Stockholm Copenhagen Freiburg Zurich	Emphasis on bike lanes and pedestrianization	Copenhagen	Usual European fuel tax and high vehicle registration costs	Stockholm Copenhagen (very high) Freiburg Zurich	Corridors of growth	Copenhagen
but extensively pedestrianized in city center	Stockholm Copenhagen Freiburg	No extra road capacity, and reduction of parking by 3%/yr for fifteen yrs	Copenhagen Zurich (cap on parking)	No congestion pricing	Stockholm Copenhagen Freiburg Zurich	Corridors of transit oriented development (TOC) around rail system and no other growth	Stockholm Freiburg
Extensive 30km/hr zones	Stockholm Copenhagen Freiburg Zurich	Culture of respect for byciclists	Copenhagen	High parking fees	Stockholm Copenhagen Freiburg Zurich	(New) Urban villages around rail lines	Stockholm Copenhagen Freiburg Zurich
Enforcement of car restraint	Stockholm Copenhagen Freiburg Zurich	Rail system and feeder buses provide highly coordinated, effective system	Stockholm Freiburg	Tolls on new roads	Stockholm	with high levels of walking and cycling within and between adjacent centers	Stockholm Freiburg
Development of selected transit malls and pedestrian zones	Zurich	Total segregation of pedestrians and bicyclists from road traffic in New Towns	Stockholm			Mixed use in centers	Stockholm Copenhagen Freiburg

APPENDIX IV – Strategies for overcome car dependency – cont.

STRATEGIES FOR OVERCOMING CAR DEPENDENCE Adapted from Newman, P. and Jeffrey, K., 1999							
Traffic calming		**Favoring Alternate Modes**		**Economic Penalties**		**Non Car dependent Land Uses**	
reclamation of traffic lanes for light rail	Zurich	Little extra road capacity	Stockholm Freiburg			Road penetration into urban village sites strictly limites	Freiburg
		and tolled	Stockholm			Transit directed growth	Zurich
		Strong commitment to light rail transit and bicycle infrastructure	Freiburg			Some mixed use	Zurich
		Rainbow pass for transit system	Zurich Freiburg				
		Expansion fo the light rail and heavy rail systems and bike/ pedestrian lanes	Zurich				
		Carefully coordination among all services and modes	Zurich				
		Professional marketing and passenger information campaigns	Zurich				

Appendix V – Swot analysis; Karskrona Mobility System's Sustainability Analysis; Sustainable Mobility in Karlskrona

Table 1. Karlskrona's SWOT analysis

	transportation modes	strenths	weakness	opportunities	treats
What are we depend on?	walking	good for the health	depending on weather	improve sidewalks/banches /lights/signs	better ways of transport
		not polluting	can not transport many goods	improve the walking experience	
		freedon/no wait	only for short distances		
			no good for disable		
		cheap	can be dangerous		
	cycling	good for the health	depending on weather	improve bike's design	better public transport
			only for short distances	improve planning of bike paths	
		not polluting	easy to steal	build better bike shelters	
		freedon/no wait	not enough bike paths/dangerous		
		no fares or taxes	can not transport many goods		
		cheap			
		easy to park			
	busses	confortable	not timely	provide optimal bus services (time table, routs)	availability of clean cars
		accessible	bad itinerary		low density
		clean	bad bus shelters	change some buses for smaller ones	expensive fare price
		seating availability	bad integration w other modes	build better bus shelters with facilities including bike shelters	lack of integrated planning
		enough bus stops up to lickeby			
		eu4 class buses	run on diesel	buses that carry bikes	
		easy to transport luggage		icrease MKT shares and revenues	
				change to renewable fuel	
	car	comfortable	polluting	clean cars-fuels	increasing taxes
		no waiting / immediate	CO2 emissions	safer/smaller cars	increasing fuel prices
			accidents		increasing resources prices
		transport goods			tolls and taxes for roads
		freedom	parking takes lots of space		
		status/ identity	traffic congestion		
			expensive		
	train	no CO2 emmissions	wait for the train	better connections and timetable	better ways of transport
		confortable(luggage)	not good connections	make it faster	increasing prices
		can work during the trip	long travel time		
				make it cheaper	
		long distances	tough to carry luggage	better design/luggage	
		facilities(toilet/restaurant)			

Table 2. Karskrona Mobility System's Sustainability Analysis

What are we depend on?

mobility mode	Materials from the earth's crust SP1		Man-made materials SP2		Degradation of biosphere SP3		Undermining people's capacity to meet needs SP4	
walking	sidewalks	1	paint for sinagling	3	land use for sidewalks	1	safety	2
	red lights	2	red lights	3			long distances	4
			clinquer	1				
			lighting	2				
cycling	cycle paths	3	paint for sinagling	3	land use for bike paths	1	no continuity in bike paths	4
			lighting	2			depending on distance	4
	bike production	2	red lights	3			no bike shelters	4
			asphalt	4			depending on weather	4
buses	bus is oversized	4	chemicals used to clean the bus	4	land use for roads	4	bad timetable travel time	3
	bus production	2	the bus itself	4			bad availability in the country side	4
	roads	4	bus stop	3	land use for bus stops	2	expensive depending on the trip	4
	fossil fuels	4					bad itineraries/ connections	4
	bus stop	2					decresed freedom	4
							noise	4
							accidents	4
car	car production	2	chemicals used to clean the car	4	land use for roads	4	bad road distribution	4
	roads	4	the car itself	4	parking space	4	noise	4
	fossil fuels	4	CO2 emissions	4	gas stations	4	pollution	4
							accidents	4
							high costs	4
rail	rails	2	chemicals to clean and maintain wagons	4	land use for tracks	2	customers must come to Central St to catch train	4
							lack of information	4
			train stations	4	land use for stations	2	not enough seating	4
	wagon production	2	wagon itself	4			expensive	4
							bad integration	4
							bad scheduling	4
boats	fossil fuels	4	CO2 emissions	4	docking space	3	too few regular trips	3
	boat production	2	chemicals used to clean the boat	4	gas stations	4	depending on seasons	3
	docking space	2	boat itself	4				

Criteria for the weight of the impact on each SP

1 Less impact
2 impact
3 more impact
4 most impact

SP1 according to how it accumulates on the earth's crust and the possible side effects (we must use them in a way that prevents their accumulation in natural systems)
SP2 according to if the man made material can or cannnot be broken down by nature, and so it accumulates (whether the product is recycled or not)
SP3 according to how much more it takes from the biosphere than can be replenished by natural systems
SP4 according to how much it contributes to barriers that prevent individuals and communities from generating their own livelihood.

Table 3. Sustainable Mobility in Karlskrona

SUSTAINABLE MOBILITY IN KARLSKRONA workshop - B and C lists		
TRANSPORTATION MODE	**B (what to address?)**	**C (brainstormed measures)**
Walking	safety long distance - 500m or 5 minutes* depending on weather	transport mode integration improve lighting and signage improve rest places- make them appealing (with green)
Cycling	no continuity in the bike paths no bike shelters depending on distance - 5km depending on weather	integrated planning/design of bike paths with other modes build shelters according to mode integration bike park close to destination business bikes for commuters pump stations carry-on bicycles in buses and other modes highway bike lanes
Buses	chemicals for cleaning bus itself bad time table expensive decreased freedom noise accident bad routing not available everywhere	procure sustainable and certified cleaning products procures sustainably built buses use renewable bio fuels hydrogen cell buses biogas fuel computerised routing and schedule planning change in numbers and sizes of buses remove buses from Trosso design new protected bus stops free bus fare fare scheduling rain water to wash buses
Rail	customers must come to central station to go to other places chemicals to clean and maintain wagons train stations lack of information/ communication not enough seating in rush hours expensive bad integration between companies/ between modes	change Central station to Gullberna computerised routing and schedule planning - integrated with other modals procure sustainable and certified cleaning products retrofit/ design green stations
Cars	the car itself fossil fuel free bad road distribution noise pollution accidents high cost land use for roads parking space gas stations chemicals to clean and maintain cars	remove cars from Trosso hybrid cars cradle to cradle cars driverless electric cars podcars eliminate cars procure certified chemicals to clean create parking spaces outside Trosso
Boats	CO2 emissions docking space gas stations boat itself chemicals used to clean boats	podcars hydrofoil boats maybe smaller boats procure certified chemicals to clean
General		IT developments to enable: more people will work at home video conferencing networked car-sharing in companies information and communication over the internet/cell phone, etc less motorized trips driverless transport system no waiting for transport automated and integrated traffic control and planning flexible personal transports available 24x7 neighbourhood concept personal rocket device water taxis in the summer PRT system network integrated with other modals light trams urgent integrated spatial and transport planning mixed use developments behaviour change campaign create Mobility Management Office (eg Lund) bike and ride biogas power plant(Sydkraft Gas as a co-investor - Kristianstad)

APPENDIX VI – Karlskrona maps

Karlskrona municipality with bus routes

Map 2. Karlskrona City and downtown area (Trossö) with bus routes