Light Rail Impact Study
An Ecologic and Economic Assessment
Final Report

A joint Analysis by the City of Turku and Siemens
The light rail network review is the first concrete result of the three-year strategic cooperation between the City of Turku and Siemens, which was initiated in early 2012. The aim of the cooperation is to promote urban planning in the spirit of sustainable design, particularly within the fields of transport, housing and finance.

Strategic cooperation between the public and private sectors is new. We do not know of any other long-term, strategic cooperation projects which are expected to have equally concrete results.

The aim of the cooperation is to combine the skills and competence of the City of Turku and Siemens in order to generate new urban solutions. All results of the cooperation will be public.

From the City of Turku’s perspective, the cooperation provides a unique opportunity to benefit from the know-how of an international technology company. Siemens is the technology partner of a number of major cities in the world with experience of different kinds of technology solutions and efficient practices all over the world.

The majority of the cities in the world are medium-sized towns of about 200,000 inhabitants. Turku is one of these. The cooperation with Turku is an excellent opportunity for Siemens to learn about the characteristics and challenges of these medium-sized cities, which will help in developing specific solutions for the cities’ needs.

Siemens’ newest business sector focuses on cities’ infrastructure solutions. The sector provides technology solutions for transport, property and electricity distribution. The fields of competence include smart grid solutions which are essential for electric cars and renewable energy, among other things, to become widespread.

Before the work on the light rail network review was initiated, a political decision was made in the City of Turku to execute the review project. Turku provided the project its vision, strategy and expectations of what the review should include. In addition, Turku supplied the project with the basic information on which the review could be based.

Siemens brought the project its technology know-how, visions on the comprehensive solutions as well as an experienced project manager who was responsible for the project’s timely progress. In addition, Siemens provided the methodology as well as experiences and practices from other cities of similar size.

We are very pleased with our first cooperation project which has met with our expectations and produced a concrete review of the light rail network. This review presents the benefits and disadvantages of the light rail network from financial and environmental perspective. The results will support the decision making in the future when the investment decisions will be made.

It will be good to proceed from here to the next strategic cooperation project which is about new urban areas carried out in accordance with the principles of sustainable development.

Aleksi Randell
Mayor of Turku

Martti Kohtanen
CEO
Siemens Osakeyhtiö
# Contents

1 Executive Summary 5  
2 Evaluation Framework 7  
   The City Of Turku 8  
   Study Goals And Scope 9  
3 Integrated Light Rail Solution 10  
   Policy Framework For An Integrated Solution 10  
   Example From City Of Freiburg 11  
4 Evaluation Results 12  
   Impact On CO₂ Emissions And Air Pollution 12  
   Impact On Real Estate Value 16  
   Other Benefits 19  
5 Recommendations & Outlook 20  
   Summary Of Recommendations 20  
   Critical Success Factors 20  
   Way Forward 21  
6 Appendix 22  
   Methodology 22  
   Data Sources And References 23  
   Abbreviations 23  

This document is a result of work within the context of the three-year strategic cooperation agreement between the City of Turku and Siemens Osakeyhtiö signed in February 2012. This study is a result of the joint research and development project “Light rail impact study” in the City of Turku and is a property of the City of Turku and Siemens AG and its affiliates. While every effort has been made to verify the accuracy of the information contained in this document, neither the City of Turku nor Siemens AG nor its affiliates can accept any responsibility or liability for reliance by any person on this information.  

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The City of Turku and Siemens Osakeyhtiö have signed a groundbreaking three-year strategic cooperation agreement. The cooperation will focus on concrete research and development projects. This ecologic and economic impact assessment of a light rail system planned for Turku is the first joint activity in the context of the strategic cooperation.

A focus in this study is put on the impacts of CO₂ emissions and air pollutants (PM, NOx) within the city boundaries due to an assumed light rail introduction. The economic part of the study mainly focuses on analyzing the impact on the real estate values along the tracks. The City of Turku expects the “Blue Line” track routing to be implemented by 2025. Its extension – the “Red Line” – is expected to start operating in 2035. The upgrade of cars and buses towards Euro 5 and 6 norms allow to reduce PM and NOx emissions despite the rise of road kilometers, which are increasing CO₂ emissions.

The impact of the integrated solution, based on the decrease of road kilometers via the shift of car and bus users towards the light rail, is a reduction of 11 % in 2035 on traffic CO₂ emissions, corresponding to a level of emissions of 110,000 tons. NOx emissions decrease by a further 12 % compared to the business-as-usual projection to reach approximately 250 tons in 2035. PM exhaust emissions are also due to decrease by a further 8 % in 2035 while PM emissions from winter sanding and spike tires will diminish by 7 %.

In the year 2011 the real estate volumes in Turku, Kaarina and Raisio are approximately 13.5 million m² in total. Almost 60 % or 8 million m² of it is located in the 800m buffer zone along the planned track routing. A verification of international experience values by an expert group in Turku was conducted to specify the sensitivity of the local real estate market to the introduction of an integrated light rail solution.

By introducing an integrated light rail solution it is predicted, that real estate values will increase at least by approximately 480 – 850 million € in 2035 even in the most conservative scenario. This represents a weighted average uplift in real estate values of ~2 - 3 %. According to the simulation results, about 32 – 58 million € can be allocated to city-controlled real estates. This equals ~6 – 7 % of the total fair value uplift. Both the total fair value increase and the value increase in city-controlled real estate could be a source for financing options.

Additional opportunities may be generated in the fields of city image, city development, ecology, economy and socio-economy. Given the positive evaluation results and the underlying potentials it is recommended to pursue with the planned process of introducing an integrated light rail solution in the City of Turku.

1 Projection based on Turku structural model (i.e. population and working places growth), assuming no technological break-through or major changes in the future
The City of Turku and Siemens Osakeyhtiö have signed a groundbreaking three-year strategic cooperation agreement. This is the first time that one of the world’s largest conglomerates Siemens has made such a long-term strategic cooperation agreement with a city.

Siemens Infrastructure and Cities Sector is the world’s leading supplier of power distribution, transportation, building and lighting solutions. Siemens increases its customers’ productivity, flexibility, and efficiency. Siemens offers consistent hardware and software innovations and comprehensive industrial solutions within all industries and infrastructural areas. The Infrastructure & Cities Sector employs about 87,000 people worldwide.

From the City of Turku’s point of view, this is the first long-term development cooperation agreement with the private sector in Finland to cover several different sectors in the municipality.

Within the strategic partnership both partners commit themselves to jointly work on efficient and environmentally friendly urban solutions which are suitable for mid-sized cities like Turku.

The cooperation will focus on concrete research and development projects. An ecologic and economic impact assessment of the light rail system planned for Turku is the first joint activity in the context of the strategic cooperation.

Sirpa Korte, Director of Public Transport, City of Turku

What are the challenges from the growth of the population on the transport system?

The public transport system is constantly developed in the most populated areas of Turku. However, the capacity of the bus system is not sufficient in areas like Varissuo and Runosmäki. We have a positive challenge: It is difficult to advertise PT and get more people to use buses when there is no room for new passengers during several hours of the day. This, of course, applies only to the best bus lines as mentioned.

We will have a very big challenge for the transport system in Turku city and the surrounding areas if the growth of population is spread in a large area. This has been the earlier trend of growth and this would mean that the use of private cars would increase, the road network would be heavily loaded, the quality of air would get poorer and altogether the comfort of life would get worse.

What are the key cornerstones of the transport strategy and the new regional transport authority to meet these challenges?

Public transport has to be so good that people will prefer PT to private car. This means fluency of travelling using PT. Easiness of use of PT. Pleasantness of travelling with PT. Depending on the area, LR or a developed bus system are key cornerstones in the transport strategy. Regionally uniform ticketing and information system are developed. City planning goes together with public transport – they support each other. This is a key factor especially in new residential areas.

How can the integrated LR solution contribute to the vision of the city of Turku?

Light rail is a proven way to make PT more attractive, faster and easier. It is an important public transport project and even more an important way to increase the comfort of the city centre to a living-room-to-all, to increase the attractiveness of the city altogether and to make PT so attractive that the citizens will prefer to have their homes along the LR routes.
The City of Turku

Turku is one of Finland’s leading cities with a population of approximately 180,000. It’s also the oldest city in the country and an important center of culture and education. Sustainable development is a core value and Turku has been internationally noted for its efforts (for example ICLEI Honorary Award 2006). The city is signatory to the Aalborg Charter and Commitments as well as to the Covenant of Mayors.

The Turku Climate and Environment Program launched in 2009 targets greenhouse gas emissions per capita 30% below the 1990 level by 2020. The Program is supported by detailed targets and resource budgets and has already achieved significant progress in areas such as renewable energy and public transport. Actions target also buildings, equipment and transport as well as influencing markets and citizens’ consumption patterns. The greatest cuts in greenhouse gas emissions are expected to be achieved by increasing the share of renewable energy in district heating and electricity production, enhancing energy efficiency in all operations and furthering sustainable transport. The city believes that preventing climate change and creating a low-carbon society present significant opportunities for businesses in the region. Seizing these opportunities is a feature of the city’s Expertise and Businesses Program.

Transport supports business growth and prosperity of the 180,000 inhabitants of Turku. However, it is responsible of approximately a quarter of the city’s carbon emissions. Other negative impacts include noise and air pollution, accidents and congestion. The goal is to reduce these negative impacts by making the best use of all transport modes – known as co-modality. This includes introducing cleaner vehicles and combining private transport with a significantly higher share for public transport, walking and cycling. Turku’s Climate and Environment program envisages co-existence of all transport modes. Travel by bicycle is expected to increase by at least 50% from the 2006 level and travel by public transport to increase by 2% per year from 2010 to 2030. Public transport is seen as the priority for any increase in traffic from the suburbs to the center.

The city also aims to reduce the need for travel by making the urban structure denser and locating employment close to where people live. Better traffic safety and the promotion of co-modality will encourage the use of the most effective mode. More accessible services will offer equal transport opportunities to different age and population groups. Private cars currently have a high share of total transport but the use of public transport has grown during the most recent years faster than targeted. Public transport has a good image but expanding the network is costly. A Bus Rapid Transit system is under development and the city council has agreed to create a light rail system, subject to funding and land use constraints. Initial planning of the system (feasibility) was made in 2009 and the general planning process has been initiated based on the decision by City Council in December 2011.
This project aims to evaluate the ecologic and economic impact of the planned introduction of a light rail system in the City of Turku. The study focuses on two major modules.

In the ecologic modules the impact of the planned light rail system was assessed regarding CO₂ emissions and air pollutants (PM, NOₓ) within the city boundaries. The economic module mainly focuses on analyzing the impact on the real estate values along the tracks. The evaluation results will be the basis of further decision-making by the city authorities and will be an input to a more detailed planning process.

There is a strong political will to implement a light rail system by the municipality and an initial planning on two possible tracks has already been conducted. The following picture presents the currently drafted track routing for the Blue line which is planned be introduced latest by the year 2025 and the Red line which was assumed to start operations in 2035.

The Blue line connects the suburbs Runosmäki and Nättinummi, Varissuo, Hirvensalo, New Castle Town and Harbour side. Additionally, the Red line fully connects the branches Raisio, Kaarina and the major part of Hirvensalo.

As a general foundation of this impact study the Structural Model 2035 for Turku Region serves as an underlying data source. It assumes a population growth of 60,000 in the urban area by 2035. In the same timeframe approximately 20,000 new working places are planned in the urban area.

This strategic commitment of the Turku Region and its municipalities represent an even stronger growth than forecasted by Statistics Finland. In this context, an integrated light rail solution, more than being only a solution to transportation challenges, can act as a powerful tool for city development. From that perspective the light rail solution could be one important measure for the City of Turku to achieve the strategic goals defined in the Structural Model 2035.

Draft routing for the Blue and Red line

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Implementing a light rail is commonly seen as a way to improve air quality and diminish environmental impact by reducing CO₂ and pollutant emissions via traffic reduction and optimization. Light rail gives also an opportunity to reshape, harmonize and develop a city. In these circumstances, an isolated light rail system would not allow the city to fully benefit of the light rail’s potential. Without pro-active policies the city would be creating a new transportation offer without integrating it into the city dynamic. Building a comprehensive solution around the implementation of a light rail is therefore necessary. Inducing new travel behaviors is a difficult challenge, which many cities face.

In this context an integrated light rail solution would nourish cities’ development and improves the overall quality of life (neighborhood refurbishment, increased connectivity etc.), and in return, tailored city planning and induced behavioral changes will favor light rail utilization. An integrated light rail solution could then be the opportunity for Turku to take the path towards a sustainable transportation system and a wealthy and livable environment.

The integrated light rail solution is the result of both the implementation of the light rail and a set of targeted policies aiming at favoring green transportation as well as triggering city development. This scenario is based on a case study of ten international cities out of which the most conservative case was taken as a benchmark for the city of Turku.

In order to take plain advantage of the light rail opportunities, key policies should accompany the light rail implementation. Some of these core policies are presented below:

- Integrate land use planning and traffic planning. The plans are reviewed simultaneously, and are strongly interconnected to link transportation offer and transportation need, a solution chosen by Dijon to prepare the implementation of the light rail.
- Closely integrate the population during all the phases of the light rail implementation (dialogue, meetings and workshops), involve local media, and organize specific support/meetings for shop owners concerning light rail works. For example in Nantes, before the opening of the 1st line in 1985 only ½ of inhabitants were in favor of the light rail. After the 2nd line was built in 1994, 95 % favored it.
- Transform the urban environment either in terms of architecture (design of the stations) or stations/tracks look (trees, grass covered platforms). For example in Marseille (France) 2,000 trees were planted along the tracks of the light rail.
- Design tailored fares. Freiburg (Germany), for example, introduced an integrated pass in 1984 which increased public transport ridership by 12 to 23 % within 1 year.
- Favor social inclusion by favoring social housing along the tracks and serve low-income areas. For example in London (Docklands), deprived areas were connected to the tramway, allowing a successful integration, which significantly improved the image of these areas.
- Regulate car use by decreasing parking places & introducing pricing constraints for commuters, reducing speed in city center streets, implementing P&R solutions.
- Give priority to soft modes of transport in the city center (cycling, walking) by building cycle lanes, developing friendly pedestrian areas, proposing secured crossing of roads and tracks for bikes and pedestrians, allowing bike transportation in

Policy framework for an integrated solution

Hass-Klau “Bus or Light Rail: Making the Choice”, 2000
the light rail. In Santa Monica (USA), a bike way was designed along the track and in connection to the station to enable passengers to go by bike to their work, nearby the tracks or to easily reach leisure areas such as the beach.

- Create a real inter-modality: train station as a hub between train, light rail and bus, improving bus-light rail interconnections.
- Provide a high quality service (example: in Nice, France, biding quality process implemented with the companies operating the light rail) and reliable information to the users (scheduled timetables easy to remember, short interval, also outside peak hours.).
- Give priority to public transport via traffic management. Such systems as red light optimization can be designed to give priority to the light rail over other means of transportation on cross roads. This would also enable the light rail to be the faster mode of transportation and be competitive, when compared to cars.

These sets of policies are recommended to be implemented as soon as possible in order to be fully effective.

Example from City of Freiburg

Freiburg im Breisgau is a German city with circa 220,000 inhabitants and 130,000 working places. Freiburg is known as an eco-city. In the city of Freiburg, light rail has been used as one element of integrated solution, which aims to create a sustainable city.

In an integrated solution land use and traffic have been planned together. For example supermarket locations are regulated strictly and new land use is being implemented in coordination with public transportation improvements. Freiburg has had a continuous traffic concept from the 1970’s which favors public transportation, cycling and walking. The goals have been supported by traffic management, park-and-ride solutions and mobility management methods.

Freiburg has an excellent public transportation system which is based on light rail routes and feeder buses. Light rail network has been expanded and is planned to be further expanded with 126 million euros investments from 2011 to 2018. Public transportation is attractive because it is fast, cheap, easily understandable and available (good frequency and close to inhabitants). In Freiburg’s internal traffic public transportation’s share has increased from 11 % in 1982 to 18 % in 1999.

Cycling has increased even more in Freiburg: in 1982 cycling’s share was 15 % of internal traffic and in 1999 it was 28 %. Cycling has grown due to improved and extended cycle network, right of way solutions and redesigning of streets. In Freiburg city center there is a pedestrian zone where cars are not allowed. For comparison: in Turku the mode share of public transportation was 9 % and mode share of cycling 13 % in 2008.

The newly built neighborhoods of Vauban (ca 5,000 inhabitants) and Rieselfeld (ca 10,000 inhabitants) were developed and built according to the idea of sustainability. With short and attractive routes and areas priority has been given to cycling, walking and public transportation instead of cars. Traffic-calmed streets, low speed limits and priority to the right reduce cars’ speed. In Vauban car parking is mainly in parking garages on the edge of the area. In Rieselfeld the light rail was implemented in the beginning of building. Mixed land use has been implemented in order to create short distances from home to work and to favor social inclusion. Grass-lanes are used for light rail. Density of private cars is much lower in Vauban (16 cars / 100 inhabitants) and Rieselfeld (28,5 cars / 100 inhabitants) than in the whole Freiburg (35 cars / 100 inhabitants). For comparison: in Turku the density of private cars is 47 cars / 100 inhabitants.
To quantify the impact of an integrated light rail solution on the City of Turku, detailed analysis and calculations were conducted. For the environmental analysis, the calculation framework was based on COPERT software and methodology that incorporates results of several technology, research, and policy assessment projects coordinated by the European Environment Agency (EEA). It is one of the main tools used to fulfill the European Union requirement of publishing traffic emissions each year. Traffic input data for the light rail integrated scenario as well as overall traffic emissions reduction were assessed through Traffic Emissions Simulation Model (TE Sim, © Siemens AG 2012). Incorporating the projected development of real estate floor space volumes and specific price levels in the City of Turku, an Urban Property Simulation Model (UP Sim, © Siemens AG 2012) was applied to calculate the fair value uplift in real estate for a most conservative light rail scenario. Additional benefits of an integrated light rail solution have been derived from best-practice examples of other cities as well as qualitative interviews with infrastructure experts and other stakeholders of public transportation systems.

### Main results out of the international case study

<table>
<thead>
<tr>
<th>Increase of PT trips</th>
<th>Share of LR out of PT modal share</th>
<th>Share of previous car users in LR passengers</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>+163%</td>
<td>64%</td>
</tr>
<tr>
<td>High</td>
<td>+111%</td>
<td>59%</td>
</tr>
<tr>
<td>High</td>
<td>+105%</td>
<td>30%</td>
</tr>
<tr>
<td>High</td>
<td>+93%</td>
<td>20%</td>
</tr>
<tr>
<td>Low</td>
<td>+35%</td>
<td>59%</td>
</tr>
<tr>
<td>Low</td>
<td>+20%</td>
<td>10%</td>
</tr>
</tbody>
</table>

### Modal split in Turku BAU projection

<table>
<thead>
<tr>
<th>Year</th>
<th>Car</th>
<th>Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>78%</td>
<td>22%</td>
</tr>
<tr>
<td>2025 and 2035</td>
<td>77%</td>
<td>23%</td>
</tr>
</tbody>
</table>

### Impact on CO₂ Emissions and Air Pollution

A case study on more than ten cities in Europe and the US have been conducted and show that the effect of the implementation of a light rail solution ranges between 163% and 20% of public transportation modal split increase, varying in a time scale of 3 to 15 years. Hence, the most conservative case study was selected as a benchmark and led to a result of +40% of public transportation trips (for both...
bus and light rail) in Turku over 16 years. This rise being far less important than in the other cities studied, an even higher impact may be expected. In order to reach this 40 % increase, leading to around 11.5 million light rail trips per year in 2035, pro-active policies orientated towards public transportation should start, at the latest, in 2019, 6 years before the implementation of the light rail.

Based on the above mentioned increase, the light integrated solution would increase public transport modal shift by 5 %, i.e. from 23 to 28 % compared to the Business-as-usual projection (BAU), in 2035. The light rail would represent more than a third of it with a modal split of 11 %. Car modal split would decrease correspondingly and represent 72 % of the modal shift in 2035. Cycling and walking are not included.

From 1990 to 2010, CO2 emissions from heating have been reduced by around 10 %, while traffic CO2 emissions reduction was limited to 1.8 % and still represented 20 % of Turku CO2 emissions in 2010\(^5\). Traffic emission reduction is then a factor, which can contribute to reaching the overall target of the city of Turku of -30 % CO2 emissions by 2020 \(^5\) (compared to 1990 level \(^6\)) but it will need to be reinforced by other measures to entirely fulfill the target.

In this context, the low environmental footprint of the light rail, powered by electricity, represent a first step towards CO2 emissions reduction. In this evaluation, the electricity was supposed to be provided by Nordpool \(^7\), whose electricity mix is around 270 g/kWh of CO2 in 2010 and is projected to decrease to 45 g/kWh \(^8\) in 2035. Moreover the light rail does not emit NOx (Nitrogen oxide) or PM exhausts (particulate matters induced directly by engine exhaust fumes) \(^9\) and thus allows improving air quality within the city. Indeed, these

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5 Turku environmental department 6 Turku Region Air Protection Co-Operative Group. 7 Nordpool is the largest market for electrical energy in the world. It operates in Norway, Denmark, Sweden, Finland, and Estonia. 8 Source: Turku environmental department 9 Emissions from energy production considered out of scope
two pollutants can provoke health problems (e.g. asthma, skin irritation) at a certain concentration and also impact the environment (e.g. acidification of water systems and soils by NOx).

In order to assess the impact of the light rail integrated solution, the projected emissions of a business-as-usual scenario have been calculated. CO₂ emissions include emissions from combustion, air conditioning, and lubricant oil emissions as well as hot emissions (pollutant emitted during driving and idling after the engine is warmed up) and cold emissions. These over emissions occur when the engine has not reached its optimal operating temperature after starting.

CO₂ emissions are directly linked to the amount of fuel burned in vehicle engines and thus to the amount of kilometers driven. In a BAU projection, car kilometers increase by 25% and bus kilometers by 35% over the time period 2010 - 2035. Consequently traffic CO₂ emissions from buses and cars would rise by 25% over 25 years, reaching more than 130,000 tons in 2035. Out of these emissions, 88% are due to cars and 12% buses.

The light rail integrated solution would allow to considerably slow down CO₂ emissions by 11% in 2035, equivalent to a reduction of 15,000 tons of CO₂. This reduction is due to the decrease of kilometers driven by cars and buses (respectively -7% and -42%) thanks to the light rail implementation. Turku light rail is assumed to transport in average 40 passengers (average train capacity of around 200 passengers and average load assumed at 20% \(^{10}\)). The passengers carried would represent 40 cars less or 2 buses less on the road (average bus capacity of 40 passenger and average load 50%). This is why the impact of the light rail can be extremely high if car users are attracted towards the light rail and bus lines replaced progressively by the light rail, where possible (especially in the city center where the light rail.

Traffic CO₂ emissions in Turku BAU scenario vs Integrated solution

Traffic NOx emissions in Turku BAU scenario vs. integrated solution

\(^{10}\)BAU projection input data provided by Turku traffic model  
\(^{11}\)Based on Siemens expert evaluation
rail has a fine coverage and traffic jams are located. In the current integrated solution, the source of light rail passengers chosen is also issued from the case study analyzes. The most conservative repartition was applied, namely 10% of passengers are coming from cars, 85% form buses and 5% from non motorized trips. An even higher share of previous car users may be reached if strong pro-active policies are implemented.

Considering NOx and PM emissions, the BAU projection shows already a decrease of 42% from 2010 to 2035. This is due to the renewal of car and bus fleet. Pre Euro cars and early Euro norms emit much more NOx or PM by kilometers driven than new euro norms (Euro 5 implemented in 2008/9 and Euro 6 to be implemented by 2014). The difference can exceed a factor 150.

Nevertheless, these potentially toxic emissions can be further reduced respectively by 12% and 8% in the integrated solution in 2035 compared to the BAU projection.

In addition to PM exhaust emissions PM emissions from sanding and spike tires have been considered.

Winter sanding emissions are noticeably high compared to PM exhaust emissions: in 2035, they amount to 36 tons in BAU when exhaust emissions reach 15 tons. Resuspended road dust emitted by vehicles driving on sanded roads has then a high impact on overall PM emissions. Vehicle fleet age having no impact on them, only the amount of kilometers driven on sanded roads has an influence. The light rail integrated solution would reduce both types of emissions by 7%.

The integrated light rail solution is a powerful tool to induce trip behavioral changes in order to improve the environmental impacts of traffic in Turku, but as any tool it reaches its full potential when used within a comprehensive toolkit. Thus tailored policies have to accompany the implementation.
A good transit system provides a high level of access to work and other activities for households, customers and employees. The monetary value of this access will be reflected in the value of a home or a business real estate, in addition to the value of other features such as the specific physical attributes of the building and neighborhood characteristics. The impact of light rail transit on property values has been studied from many perspectives, including analyses of residential and commercial impacts and studies have shown strong benefits in both cases.\textsuperscript{12}

The additional benefit on property prices due to a light rail system has been evaluated by this study for the specific case of Turku. Since the accessibility benefit is only valid for homes and companies within walking distance to the transportation system, the most significant part of the light rail price uplift is assumed to take place in an 800 meter buffer zone along the planned track routing. Thus, real estate value uplifts have been calculated by accounting the additional price impact of an integrated light rail solution to the existing and future real estate volumes in the City of Turku located in the planned light rail buffer zone.

The real estate stock for the year 2011 in Turku, Kaarina and Raisio is approximately 13,5 million m\(^2\) in total. Almost 60 %, or 8,0 million m\(^2\) respectively, of this existing real estate stock is located in the 800m buffer zone along the track routing of the planned Blue and Red line. Hence, the major part of office property and more than half of the existing residential and retail real estate is covered by the planned light rail track routing.

Looking to the year 2035, the coverage of all types of real estate is showing an increasing trend due to a very high increase of commercial floor space volumes along the light rail track routing. Based on the structural model master planning the real estate stock of 8,0 million m\(^2\) in 2011 in the light rail buffer zone will increase by 46 % to a total number of 11,7 million m\(^2\) in 2035.

The iterative survey of a real estate expert panel\textsuperscript{13} based on international experiencedataled

### Coverage of real estate types

<table>
<thead>
<tr>
<th>Real Estate Type</th>
<th>Coverage in 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential real estate</td>
<td>58%</td>
</tr>
<tr>
<td>Office real estate</td>
<td>86%</td>
</tr>
<tr>
<td>Retail real estate</td>
<td>53%</td>
</tr>
</tbody>
</table>

\textsuperscript{12} Carmen Hass-Klau, Crampton, Benjari: Environmental & Transport Planning, 2004, Economic Impact of light rail: The Results of 15 Urban Areas in France, Germany, UK and North America

\textsuperscript{13} Expert panel participants: Turku Municipal Property Corporation, TVT Social Housing Corporation, Turku School of Economics, real estate agency with knowledge of the local market
to the identification of a weighted average uplift of real estate square meter prices along all property types ranging from ~2 % to 3 % due to the integrated light rail solution in the most conservative scenario. The highest impact factor is expected for office real estate square meter prices, even if the value uplift for commercial property is considered to decrease significantly with the distance from light rail stations. This is due to the fact that employees and customers are considered to be less willing to walk distances from stations of more than 400 meters, compared to residents walking to their homes.

Applying the most conservative price uplift factors, the total value of real estate stock affected by the light rail system is considered to increase by a fair value of ~335 - 595 million €\textsuperscript{14} by the intended first year of operation of the light rail Blue line in 2025. Incorporating the benefits from extending the light rail system by the Red line, the fair value uplift is projected to add to a total of ~480 – 850 million € in 2035. A high impact scenario would increase these impact estimates by a factor of 1.5 – 2.2 and can result in a maximum real estate value uplift of ~1,69 bn € in 2035.

In most urban areas the properties with highest values are located in the city center. As the planned Blue line track routing will cover the city center area and also one of the major development areas, New Castle Town, 80 % of the fair value uplift due to light rail can be found in the Blue line buffer zone. The simulation results also show that about 1/3 of the projected light rail uplift in 2035 is coming from properties developed during the years 2012 and 2035, while the rest of value uplift results from property stock already existing in the year 2011. Residential real estate will benefit with more than

\textsuperscript{14} Asset value increase discounted by 3% to the present
50 % from the light rail value uplift followed by office and retail property.

The City of Turku itself is also a player on the local real estate market. By selling building rights to investors, real estate developers and private persons, the city can also directly capture a certain share of the expected value uplift. Additionally a major part of the real estate stock controlled by the social housing corporation TVT Lehtolaakso is located in the light rail buffer zone. According to the simulation results, approx. 32 – 58 million € can be allocated to the City of Turku. This equals ~6 – 7 % of the total fair value uplift.

Both the total fair value increase and the value increase in city-controlled real estate can be a significant source to finance the planned light rail solution. There are several examples from other cities where tax based or development based methodologies have been applied to increase the share of value uplift in real estate assets captured by the municipal government. These so called value capture methodologies make funds available for financing the transportation infrastructure.

The stated fair value uplifts are based on the assumption that Turku can meet its goals of population and workplace growth in the region. This will ensure a healthy market for real estate with a stable relation between supply and demand.

Compared to a linear population projection based on historic data\(^\text{15}\) the structural model targets show an increase of 26 % in regard to the floor space volumes analyzed by this study. To realize this challenging goal, sustainable city development measures need to be defined. Light rail systems have proven to be a major tool for goal-oriented development in several cities\(^\text{16}\).

However, as already mentioned in chapter 3, city development measures should not be applied isolated since their effects are strongly interlinked. It is rather recommendable to strive for a sound, comprehensive and integrated city development concept. This also includes ensuring balanced decision making regarding the track routing and specification of transportation infrastructure. Authorities should aim to address both transportation and development needs of the city.

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\(^{15}\) Statistics Finland \(^{16}\) International Regional Science Review, Vol 28, No. 2, pp. 146-167, 2005
Other Benefits

Beside the described benefits in CO₂ emissions, air pollution and real estate values for the City of Turku, several important qualitative benefits should be highlighted.

**Improved City Image**
In combination with other measures, the light rail could positively contribute to realize the overall city vision and ambitious population growth projections since the light rail may attract people to live in the City of Turku.

The modern image of the light rail may improve the perception of the public transportation in the Turku Region. A vibrant, attractive city life will be supported by the light rail, the backbone of the public transport system.

**Accelerated City Development**
As known from other examples, a light rail can be used as a tool to accelerate the development of the city, e.g. by fostering requalification projects in the city area or by increasing the attractiveness of the city center. The light rail implementation can facilitate the city development by transforming the look and feel of the urban environment (station design, trees, grass covered platforms etc.).

**Improved Economic Climate**
Implementing a light rail system is a long-term commitment of the city authorities and provides a strong positive signal to potential investors and neighboring communities nourishing the economic environment of the city. This may improve both the wealth of the citizens as well as local businesses. In turn this may have further positive indirect effects on public finances.

**Improved Socio-economic Climate**
Social inclusion of minorities and immigrants can be supported by connecting districts such as Varissuo, although the pricing strategy will significantly influence the acceptance of the integrated light rail solution.

Introducing a light rail can also facilitate the access to public transport especially for disabled people and the elderly. Long-term demographic change in the Turku Region increases the requirements for safe and convenient transportation which can be addressed by a light rail system.

**Improved Sustainability and Security**
Further activities can be intensified in order to improve the sustainability of the light rail system, e.g. watering with recycled water, photovoltaic panels on the roof of the depot, use the light rail works on the street to upgrade existing infrastructures (e.g. water pipes or district heating), use rain water to clean light rail trains and many more.

Increasing public transport use and environmentally friendly travels (cycling or walking) will reduce stress due to traffic congestion and decrease road traffic. Hence reducing the risk of car accidents will increase overall security.

**Improved Quality of Life**
By decreasing time commuting and enabling people to dedicate time in public transportations to pleasant activities such as reading, writing or using their smart phones, the light rail will be a factor of improvement for the overall quality of life.
In this chapter the analyzed and described recommendations and potentials are summarized. In order to provide an outlook for the required next steps the identification and description of critical success factors and the way forward are provided in this chapter.

Summary of Recommendations

Integrated Light Rail Solution
City development measures should not be applied isolated since their effect is strongly interlinked. It is rather recommendable to strive for a sound, comprehensive and integrated city development concept. This also includes ensuring a balanced decision making regarding the track routing and specification of transportation infrastructure. Authorities should aim to address both, the transportation and development needs of the city.

Ecologic Recommendations
The light rail integrated solution is an opportunity for Turku to fulfill its goals to decrease CO₂ emissions and becoming a wealthy and sustainable city. The focus needs to be on implementing possible policies increasing the use of public transport as early as possible, and by doing so, decreasing the car dependency. The light rail would thus first answer and then trigger a need for an affordable, efficient and pleasant mode of transportation, together with improving both CO₂ and pollutant emissions and Turku overall sustainability.

Real Estate Value Capture
Both the total fair value increase and the value increase in city-controlled real estate can be a significant source in financing the planned light rail solution. Even if the value uplift in city-controlled real estates is not sufficient for financing the light rail project it should be analyzed whether and how the potential value increase in real estates in Turku can be used to enhance the financing opportunities for the City of Turku.

Critical Success Factors

Introducing an integrated light rail solution as it is planned in the City of Turku is a complex and cross-functional long-term project. General experience based on the introduction of such complex turnkey projects, and the specific knowledge about the real situation in Turku some important critical success factors need to be highlighted.

Strategic Communication
The open and target oriented communication towards citizens and a convincing concept towards investors how to efficiently develop new areas in Turku plays an essential role in achieving a sustainable population and workplace development. The expected growth of population in Turku Region is an essential element for the economic viability of the light rail project (minimum ridership for the light rail required) and the potential real estate value increase. Therefore the Structural Model 2035 for Turku Region should be underpinned with an appropriate combination of measures to ensure that the expected growth will be achieved.

Stakeholder Involvement
Customer needs and lifestyle are the main drivers for mobility services. All stakeholder groups have to be involved and informed already in the early planning phase. Ensuring actual and future requirements are met by offering high quality, integrated services with an improved image of the public transportation is an important factor to optimize light rail usage.

Integrated Planning & Solution
Continuously integrate land use planning and traffic planning: these two plans should be revised at the same time and be strongly interconnected to implement the appropriate activities (business, residential, mix used area) at the right place. Rethink the interconnection and integration of the regional public transportation system as well as the circulation in the city center will help to create a smooth and functional transportation network. Define integrated urban transport policies to optimize the benefits of public transportation for the citizens. Bus transport routes have to be
re-organized and aligned with the light rail rout-
ing. Overall transportation planning should be
complementary not competitive. Switching be-
tween different means of transportation must
be user-friendly. The layout of light rail system
has to be carefully designed and aligned with
overall city planning.

Transportation Management
Actively influence the mobility behavior and
travel patterns of the citizens by long-term ur-
ban planning, traffic management and traffic
guidance systems, parking policies as well as
company travel plans for employers and infor-
mation campaigns is another key requirement;
as well as simplifying the use of public trans-
portation, for inhabitants but also tourists who
can then easily find stations and understand
the network map at the 1st glance. It may be
necessary to rethink ticket pricing and billing
procedure in the light rail scope (especially
City of Turku, Kaarina, Raisio). The fares should
be studied carefully due to social inclusions,
ridership impact but also to the cost-benefit
analysis of the light rail.

Monitoring & Risk Management
A continuous management of project risks is es-
tential to identify deviations from the original
project goals and timeline and to define alter-
native solutions and measures. A potential risk
related to the potential real estate value uplifts
induced by public transportation infrastructure
is property speculations. It is important to man-
age this risk and control value uplifts especially
to avoid social injustice and increasing gentrifi-
cation\textsuperscript{17} of city areas.

Project Funding
Ensure stable project funding to facilitate imple-
mentation and to avoid unexpected financial is-
sues is as well a factor to take into account. It is
then required to evaluate alternative funding possi-
bilities, such as public private partnerships and pro-
motion of light rail usage to increase revenues etc.

Way Forward

The City of Turku strives to combine economic
growth with ecological sustainability. The overall
goal is to strengthen City of Turku’s position with
a vivid economy and a proactive region as well as
building a sustainable and attractive city.

Main results of this study suggest that City of
Turku’s idea to plan an integrated light rail solu-
tion is a very positive way forward in terms of
ecologic sustainability and economic prosperity of
its citizens and businesses. There are many addi-
tional qualitative opportunities provided by such a
strategic long-term project.

The available impact assessment for the planned
light rail in Turku is one – but very important long-
term project in the mobility arena in Turku Region.
The positive momentum created by the City of
Turku and accelerated during the course of the
strategic cooperation with Siemens should be kept
on a high level and exploited in order to make the
light rail project a success and to support City of
Turku’s overall goals. The city authorities, the inter-
viewed partners and project participants through-
out this study project and obviously the people of
Turku Region are willing to positively contribute to
a sound and future oriented decision.

\textsuperscript{17}Gentrification describes the process of wealthier residents moving to an area, and the changes that occur due to the influx of wealth.
Methodology.

The assessment of the impacts resulting of the introduction of new transportation infrastructure is based on a business-as-usual methodology. The business-as-usual scenario creates a picture of the future for the respective city or urban area if the normal course of events and activities will keep their past track, without encountering any circumstance out of the ordinary e.g. no technical breakthrough, no dramatic improvements in consumption or travel patterns nor in efficiency or no tremendous economical/demographical overturning. This includes a constant technological adoption at the same pace as in the past. Therefore the picture is based on a forward projection of historic trends in several fields e.g. population growth, modal split or cost of living. Ultimately the business-as-usual scenario builds the baseline for delta calculations allowing the assessment of the impact of specific changes in the analyzed environment.

The ecology business-as-usual scenario is based on the traffic model data provided by City of Turku in April 2012. Comprehensive desk research and qualitative interviews were the first step to validate and enrich this consultancy experience backbone for the specific case of Turku.

The light rail integrated solution is the result of both the implementation of the light rail and a set of targeted policies aiming at favoring green transportation as well as triggering city development. In order to evaluate the impact of such an integrated system on Turku traffic, a list of ten cities in France, the USA, the UK and Belgium which implemented or plan to build a light rail has been analyzed. Out of this list, the most conservative case study, the city of Dijon (France), has been selected to be used as a benchmark to assess the effect of the light rail integrated solution on traffic in Turku.

Based on this benchmark analysis, Traffic Emissions Simulation Model (TE Sim, © Siemens AG 2012) was used to calculate the specific impacts and provide input data for overall traffic overall emissions assessment.

COPERT software and methodology was then used to calculate CO₂ and pollutant emission. COPERT 4 is a software tool used worldwide to calculate air pollutant and greenhouse gas emissions from road transport. The development of COPERT is coordinated by the European Environment Agency (EEA), in the framework of the activities of the European Topic Centre for Air Pollution and Climate Change Mitigation. COPERT has been developed for official road transport emission inventory preparation in EEA member countries. However, it is applicable to all relevant research, scientific and academic applications.

The impact assessment of the integrated solution being based on the most conservative projection of Light Rail impact on travel patterns in Turku, a specific traffic model calculation integrating the main features of the integrated solution chosen may give different data on travel pattern.

The ecologic impact assessment was conducted under the following main assumptions:
- Traffic emissions presented in this report are only cars and buses emissions. Heavy duty vehicles will not be impacted by a light rail implementation and were thus not integrated. Mopeds and taxis were considered negligible.
- The share of passenger cars sorted by norms and type of fuel (2010 - 2030) is based on national data and applied to the car fleet in Turku (source: EU / Emisa data). The bus population sorted by norms is provided by the city, 2025 and 2035 are assumptions on the development of the bus fleet.
- The effect of global warming on Turku temperature is considered negligible over the time period (25 years)
- LR energy consumption is considered to be ~100 Wh/pax/km based on Siemens expert evaluation
- The blue and red lines are supposed to reach their full effect respectively in 2025 and 2035
- The assessment is not a life cycle analysis: It does not take into account emissions from the production of the Light Rail system or for building the LR, but only emissions from the operation of the system
- PM emissions due to spike tires are calculated based on an average emission per km driven (environmental department of city of Turku) on dry winter days (representing 50% of winter days).
- Studded tires are used approximately on 80% of private cars
- Road gradient and load factor for buses are not taken into account in the calculation (data unavailable)

The impact assessment of the planned light rail solution on real estate values in Turku is using information on the existing real estate stock coming from the GIS tools of the city authorities. Main source of data for the projection of real estate floor space volumes in the Turku region was the Structural Model master planning. Specific real estate price levels in the city for various types of real estate were gathered from the Municipal Real Estate Corporation and were cross checked with reviews on the Finish property market from major real estate agencies. Factors for real estate price change due to the potential light rail solution were obtained from international research studies and validated in a structured process following an iterative Delphi approach. Therefore a number of real estate experts with knowledge of the local market were interviewed and surveyed iteratively to quantify price impact ranges in a detailed expert panel questionnaire.

The gathered information was finally integrated into an Urban Property Simulation Model to calculate various real estate asset value scenarios and thereby enabling the required delta calculations for the impact assessment. The impact assessment for real estate values was conducted under the following main assumptions:
- Future projections are based on a stable economic environment and a stable real estate market.
- Standard real estate price development is...
based on the forward projection of a linear growth trend.

• The additional growth in the Structural Model planning is mainly coming from outside of the Turku region.
• Light rail impact zones are defined for 0 – 400 meter and 400 – 800 meter.
• Price impacts are considered to be fully effective in the years 2025 and 2035. In reality price changes may occur already before first year of operations or might fully occur later on in the operation phase.
• Only undeveloped land in the impact zoning for which the development until 2035 is foreseen in Structural Model master planning is included in the model.
• Growth of gross floor space for commercial real estate mainly concentrated on three major development areas.
• All existing industrial real estates will move outside the 800 m zone of the track routing and will be replaced by a mixture of office and retail properties.
• Future asset value uplifts due to light rail are discounted to the year 2012 to allow a comparison to the potential investment needs.
• Confidence levels for price impact due to light rail gathered in the expert panel approach are high for residential property and medium-high for commercial real estate.

Resulting limitations of the real estate impact assessment methodology are:
• No counteracting shifts of real estate values from areas outside the 800 m Light rail impact zone considered since the growing demand of floor space is coming from outside the Turku region.
• No consideration of negative impacts on prices due to noise levels since the possible changes in traffic noise are assumed to be insignificant.
• Structural changes of the assumed volume distribution pattern coming from city master planning can not be simulated in the model.

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Abbreviation

CO₂ Carbon dioxide
COPERT Computer Program to calculate Emissions from Road Transport
EEA European Environment Agency
GHG Green House Gas
KM Kilometer
NOX Nitrogen oxide
PM Particular matter
P&R Park & Ride
PT Public transportation