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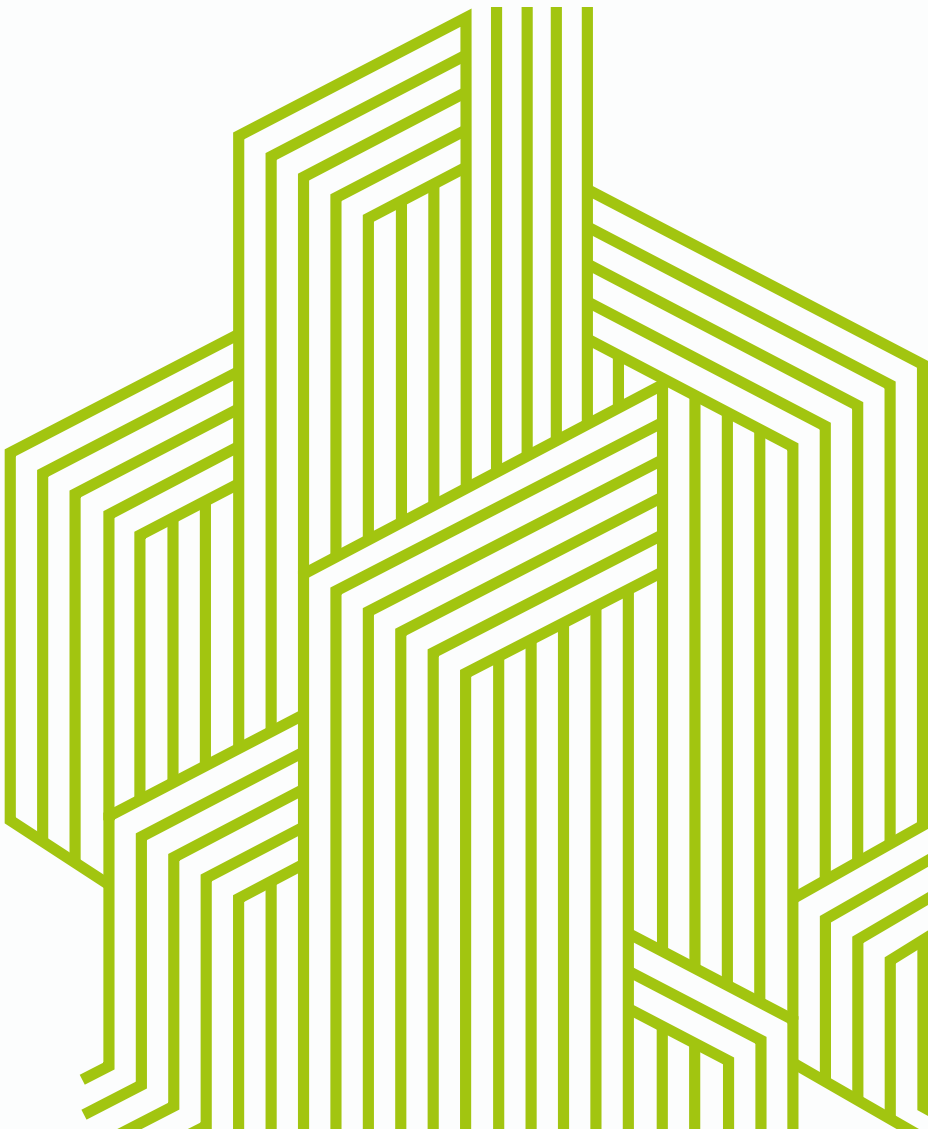
October 2015

The Co-Benefits of Sustainable City Projects

DAMVAD ANALYTICS

Realdania

CITY OF COPENHAGEN



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1. Introduction

BIG CITIES DRIVE ECONOMIC GROWTH. 60% OF GLOBAL GDP IS GENERATED IN ONLY 600 URBAN CENTERS.

At the same time, urban areas consume more than two-thirds of the world's primary energy and produce nearly four-fifths of all global greenhouse gas emissions (GHG emissions). It is thus a key challenge for cities across the globe to initiate and implement measures that can contribute to sustainable city development and decouple economic growth from GHG emissions.

Mayors have to make strong arguments on economic as well as environmental aspects of green projects to foster viable greening of their cities.

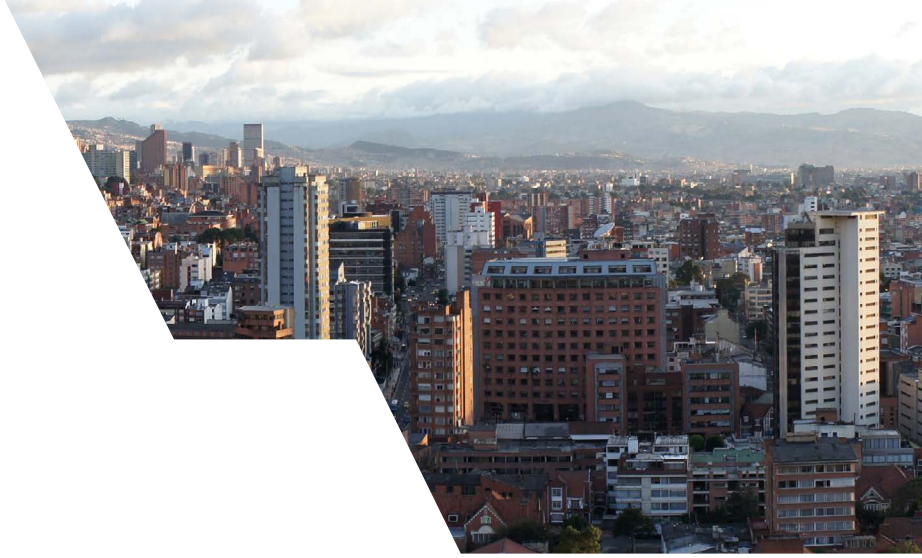
However, existing knowledge about the economic value of sustainable city projects is limited. Despite being a frequent precondition for project implementation, the economic value of green city projects is rarely verified in operation.

This report is an attempt to provide a bridge between the published estimates of economic benefits and estimates obtained directly from cities, and the use of such estimates by decision-makers in specific settings. The report aims to provide best practice insights into the economic co-benefits of green city initiatives, how they are measured and the data and methodologies used.

In the context of GHG emissions, a co-benefit can be defined as the additional effects derived from direct reductions of GHG emissions (OECD 2015). The case studies carried out in this report tell us that co-benefits usually take the form of:

- Economic indicators, such as job creation and return on investments in infrastructure.
- Social indicators, such as livability and health in urban areas.
- Environmental indicators, such as air-quality and pollution levels.

The availability of city data on green initiatives is extremely limited – more limited than expected when the project was initiated. Nevertheless, information and detailed data has been collected from specific green growth



initiatives and literature from international organisations and academic research.

Information has been gathered from selected cities and five key sectors where data is available, namely the buildings sector, public and private transportation, energy efficiency and community scale development. The economic benefits of sustainable city initiatives are presented for each sector in the form of city case studies.

For the public transportation sector, the benefits of the initiatives of the BRT (Bus Rapid Transit) TransMilenio in Bogotá and the Metrobüs in Istanbul are assessed. For the private transportation sector, the initiatives of congestion taxes in Stockholm and London are explored. For the energy efficiency sector, LED Street lighting projects in Sydney and Los Angeles are studied. The report also examines community scale development, focusing on the green area initiative in Copenhagen. Finally, the building sector is studied, focusing on ecoroofs in Portland.

When looking into the data and specific estimations connected to the project, a number of general benefits were identified, such as increased energy savings, reduced pollution, lower GHG emissions and improved health. The initiatives also led to sector-specific benefits such as reduced erosion, cooling of urban heat islands (ecoroofs), reduced transit travel time, reduced traffic accidents, mitigated traffic congestion, decreased transit operating costs (all TransMilenio/Metrobüs), reduced electricity consumption (LED street lighting) and increased property value (community scale development).

Based on these city case studies, policy reflections and recommendations have been developed. It is our hope that the case studies and discussions of how to best measure economic benefits will inspire city officials worldwide to collect data to better understand the wider value of their green initiatives.

The study has been initiated and financed by C40, The City of Copenhagen and Realdania.

2. POLICY REFLECTIONS AND RECOMMENDATIONS

IT IS IMPORTANT THAT CITY OFFICIALS ARE ABLE TO MAKE STRONG ARGUMENTS ABOUT THE ASSOCIATED CO-BENEFITS AND ECONOMIC IMPACTS OF SUSTAINABLE CITY SOLUTIONS TO BE SUCCESSFUL IN THE ONGOING AND FUTURE GREENING OF CITIES.

Convincing economic arguments are based on hard evidence stemming from solid quantitative data and advanced methodologies.

In the following, the results and lessons of case studies are discussed, followed by policy reflections and recommendations that can help cities build stronger economic arguments for sustainable city solutions. The two questions we want to answer are:

- What initiatives can cities take to strengthen their economic documentation of specific green initiatives?
- What methodologies should be applied to build a strong economic argument for sustainable city solutions?

In general, co-benefits from reduced GHG emissions appear to play an important role in policy implementation.

The importance of co-benefits for policy-making is dependent on the sector and the benefits' credibility. It is also important that the benefits are convincing compared to the costs. The case studies presented in this report exemplify green growth initiatives where the benefits are credibly estimated and convincing from a policymaking perspective. Not only do the initiatives combat climate change, they display several co-benefits that strengthen the political argument.

The green growth initiatives in the sectors analysed in this report lead to increased energy savings, reduced pollution, lowered GHG emissions and improved health. Job creation is also connected to several of the initiatives. Furthermore, there are sector-specific benefits, like the retention and evaporation of rainfall from ecoroofs or the significant cost savings stemming from installation of Light Emitting Diodes



(LED) in Los Angeles. More specific information is presented in the case studies. The case studies show that it is possible to establish sustainable city policies successfully and that such policies can have a large positive impact on the economy.

2.1 Using co-benefits

While a growing number of studies seek to characterise the factors that make sustainable and green cities, questions about the socio-economic impacts of specific green policies on co-benefits like job creation, economic attractiveness and environmental quality are often left unanswered (OECD 2011). Therefore, we know very little about which types of policy instruments and program activities are most successful for delivering green growth. The case studies in this report provide examples of successful initiatives that lead to economic and environmental benefits.

According to a study by Rydin et al. (2012), the UCL Lancet Commission outlined several suggestions to improve urban health and sustainable city conditions. The study suggested city governments should work with a wide range of stakeholders to build a political alliance for urban health. In particular, urban planners and those responsible for public health should be in an ongoing dialogue with each other. Attention to health equality, a positive co-benefit, within urban areas should be a key area of focus when planning urban environments, necessitating community representation from platforms of policy making and planning.

It is not an easy task for cities to work with co-benefits when making a sustainable city argument. It is complex to illustrate the extent of different initiatives, since data is often limited or nonexistent. Even with perfect data, the evaluation process is rigorous and complicated,

since many of the measured variables are dependent on multiple other variables that are difficult to include, making it challenging to isolate the effects of a certain initiative. Yet as this report shows, there are many ways to reliably gain benefits from sustainable initiatives in several important areas. If project evaluation became easier to carry out, with better access to data, it is likely that cities would carry out many more sustainable city initiatives, as it would be easier to build a strong argument for a clear positive economic impact.

There have been several studies evaluating sustainable city projects and green growth initiatives in the sectors of interest in this report. The fields that have attracted the most academic attention are transportation, infrastructure, methodology and general green growth studies. There are no consistent trends in the literature regarding the treatment of economic, social and environmental benefits. However, economic and environmental benefits are more frequently assessed than social benefits, which are most often left blank or are inconclusive.

2.2 Enabling action with co-benefits

Meeting the challenges outlined in this report can be achieved through mapping the data variables used to analyse different types of initiatives. This report provides recommendations for how this can be done for the different project types.

Based on the case studies in this report and the process of identifying and evaluating them, this report concludes that cities can build strong economic arguments by:

Increasing transparency: When cities have completed an analysis, they can make their calculations public so others can recreate them. This strengthens credibility and helps other cities with their own calculations. In general, it is very difficult to find evidence for the calculations made.

Undertaking a comprehensive data gathering or efforts: To make calculations credible, cities need to ensure the reliability and availability of the data. This can be done by:

1. Using surveys to identify user behaviour, which can be used to value green spaces, bike paths and physical activity, etc.

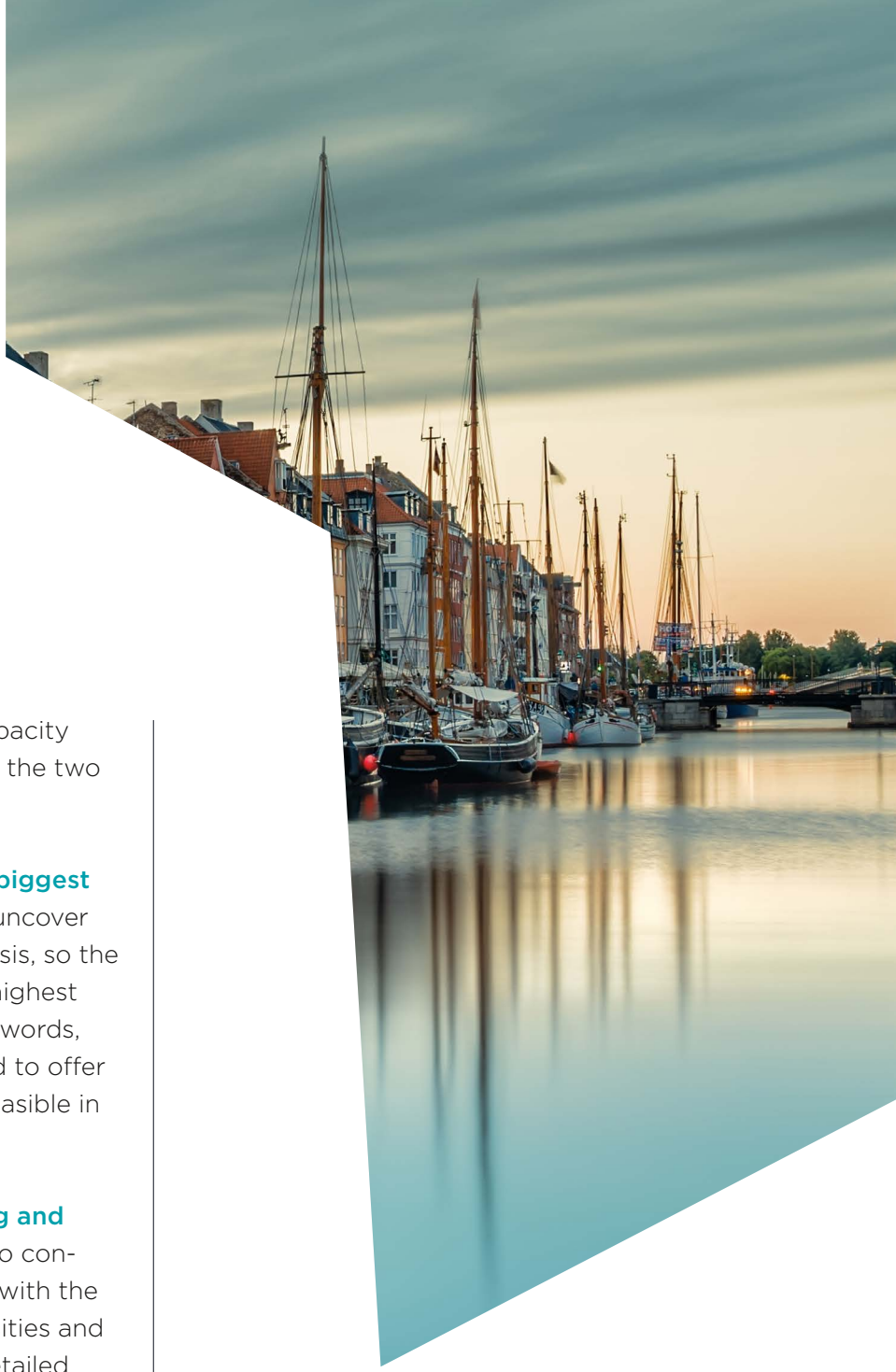
2. Collecting technical data of different technologies and meteorological conditions, for example, ecoroofs energy efficiency, energy prices, annual rainfall, etc.

3. Implementing modelling, for example, transport models to calculate the value of time savings.

4. Contacting technical and social science universities to gather knowledge from the field on more complex connections, such as effects on physical activity/pollution/etc. on people's health.

Making statistics more adaptable to local conditions: It should be possible to adjust the input factors for local conditions to increase the accuracy of results. Local conditions include income, pollution, geography and other observable metrics used in calculations.

For instance, it is trickier from a cost / benefit perspective to build an elevated cycle track in a city like Stockholm than in Copenhagen since the soil and the drainage infrastructure differs



and there is a big difference in the capacity of the public transportation system in the two cities.

Prioritise data gathering in areas of biggest potential impact: It can be costly to uncover all the facts of a comprehensive analysis, so the channels where effects will have the highest impact should be prioritised. In other words, focus on the effects that are expected to offer the most benefits and are the most feasible in terms of data.

Build city expertise in data gathering and interpretation: Expertise is required to conduct tests. It is essential to have staff with the required skills and contacts to universities and other knowledge environments for detailed knowledge.

If cities follow the insight and advice presented above and throughout the case studies as well as the best practice guide in the last part of the report, we believe that it will be easier to make strong economic arguments that can facilitate decisions on green city projects.

3. **CASE STUDIES OF GREEN CITY PROJECTS**

THE FOLLOWING FIVE CHAPTERS REVIEW HOW THE ECONOMIC CO-BENEFITS OF GREEN CITY PROJECTS HAVE BEEN DOCUMENTED IN EIGHT SELECTED CASE STUDIES ACROSS FIVE DIFFERENT URBAN SECTORS.

The study is based on numerous interviews and dialogue with city officials and experts as well as desk research of available articles and publications.

The eight cases represent best practices of data and methodologies to quantify co-benefits of green city projects. Since co-benefits and relevant city projects vary across sectors and countries, the cases have been selected to cover as many different sectors across the globe as possible.

To ensure that the benefits have actually been achieved, the cases focus on studies completed after the implementation of the projects.

The case study chapters begin with a description of sector characteristics and a review of the common types of co-benefits identified in the literature. Each case study explains why the city has taken action, followed by key case facts and an overview of how various benefits have been measured and documented. The results are then examined further.

Finally, case specific lessons are supplemented with key insights from other research along with an overview of considerations policy makers should make before undertaking similar projects.

Altogether, the cases provide useful insights into sustainable initiatives and how the cities can build a strong economic argument for implementing these projects by applying proper data and methodologies.

The case studies show that it is possible to establish sustainable city policies successfully and that such policies can have a large positive impact on the economy.

Below is a short overview of the selected case studies and their benefits.



PUBLIC TRANSPORTATION

CASE 1

Bus Rapid Transit in Bogotá. This case demonstrates how Bogotá developed a public transportation system, TransMilenio, based on Bus Rapid Transit (BRT). The system includes buses, trains, trams and subways, including the BRT. It transports more than 2.2 million passengers per day and is one of the BRT systems with the highest capacity globally.

CASE 2

Bus Rapid Transit in Istanbul: This case reviews Istanbul's experience with their BRT-system, Metrobüs. The Metrobüs is newer than TransMilenio, and distinguished by being a highway-speed BRT, operating at near highway speeds in designated lanes. Documented benefits include, among others, reduced transit travel time, reduced transit operating costs, travel cost savings, CO_2 emissions reduction, road safety impacts, changes in air pollutant exposure, and physical activity benefits to citizens.

PRIVATE TRANSPORTATION

CASE 3

Congestion charges in London. This case demonstrates how a congestion tax in London yielded net benefits to private car drivers, private bus riders, government, and society as a whole. The tax, introduced in 2003, represents the first congestion pricing programme in a major European city.

CASE 4

Congestion tax in Stockholm. This case demonstrates how Stockholm has succesfully introduced congestion taxes to curb congestion problems in central Stockholm. The case is particularly interesting, as it was initially introduced as a large scale trial system before permanent establishment in 2007.

Documented benefits include travel time savings and more reliable travel times for businesses and private travellers, tax revenues and public transit revenues (government), local pollution and health benefits, increased traffic safety and avoided GHG emissions.

ENERGY EFFICIENCY

CASE 5

LED street lights in Los Angeles. This case demonstrates how Los Angeles has successfully launched the largest LED (Light Emitting Diode) retrofitting programme ever undertaken. The programme has resulted in significant cost savings, carbon emission reductions, less hazardous waste, local jobs, reduced light pollution and increased community liveability.

CASE 6

LED street lights in Sydney. This case documents Sydney's experiences with a similarly large scale street light project.

The two cases with LED street lights point to numerous benefits from sustainable street light projects, including cost savings from reduced energy use, cost savings from reduced maintenance and longer life times, carbon emission reductions, less hazardous waste, local jobs, reduced light pollution and increased community liveability. Moreover, improved street lighting might contribute to other benefits e.g., increased traffic safety and increased physical activity among residents due to better lighting infrastructure.

COMMUNITY SCALE DEVELOPMENT

CASE 7

Green areas in Copenhagen. This case demonstrates how Copenhagen rebuilt a central traffic corridor into a park and documented several benefits for the citizens. These benefits include increased property values near the park, new park activities, and to some extent, health effects due to increased physical activity. The value created for the service sector was found difficult to isolate. Lessons from other cities and research indicate that urban spaces also contribute to urban cooling, slowing rainfall run-off and air filtration and thus improved health.

BUILDINGS

CASE 8

Ecoroofs in Portland. This case demonstrates how Portland has achieved a wide variety of benefits by installing green ecoroofs. Identified benefits include storm water management through reduction of rooftop runoff, reduced energy demand through better insulation, improved local air quality, creation of natural habitats and improved community liveability through aesthetics and green spaces. Lessons from research and other cities with similar projects indicate that building sector projects often contribute to reduction of carbon emissions and energy costs, climate mitigation and provide short term job creation, health benefits and community liveability, etc.



4. **PUBLIC TRANSPORTATION**

PUBLIC TRANSPORTATION SYSTEMS WORK BEST WHEN THEY ARE WELL-PLANNED AND INCORPORATED INTO GENERAL URBAN DEVELOPMENT PLANS (WORLD BANK).

4.1 Characteristics of the sector

Sufficient and well-functioning public infrastructure is particularly important in rapidly urbanising cities, where urban sprawl and the related increase in cars propagates significant environmental and congestion challenges.

Climate actions aimed at mass transit are generally intended to improve existing infrastructure, transit times, fuel economy and reach of services within the following means of transport:

- Buses
- Rail, metro and trams
- Ferry and river boats

Public transportation generally yields high benefits for cities and is highly prioritised by city planners. Among 59 global megacities, 90% have initiated climate actions in mass transit (CAM 2.0).

Public transportation systems work best when they are well-planned and incorporated into general urban development plans. Integrated transit and land development plans that create spaces and situations where less private transportation is required can efficiently address increasing urbanization by making public transportation options an attractive alternative (World Bank 2013).

Transportation is a very well-developed area in benefit assessment. There is a long history of using cost-benefit analysis to make proper socio-economic assessments of economic, social and environmental benefits. Many countries also have public manuals with official figures and benchmarks for calculations and even well-developed models to estimate benefits based on key project parameters.

4.2 Sector benefits

Improvements in public transportation have several positive impacts.

Improved infrastructure and organisation of public transportation significantly reduces travel times for the passengers. This can be achieved, for example, through the creation of segregated busways, pre-paid boarding, advanced traffic signal management and congestion reduction. Users of public



transportation and private vehicles both benefit from reduced congestion. Reduced travel times often account for a large portion of the benefits included in typical cost-benefit analyses of transport projects.

Improving public transportation can also improve road safety by reducing interactions between vehicles, improving pedestrian crossings etc., leading to fewer expenses in the health sector because of the consequent reduction in crashes and fatalities.

Public transportation also leads to improvement in air quality and reduced CO_2 emissions by replacing private cars and using cleaner vehicle technologies and fuels.

Vehicle operating costs are also reduced by i) replacing older buses, trams, trains etc. with newer and more efficient ones, and ii) shifting users from private cars to public transportation.

Finally, public transportation projects have several indirect benefits, often because of reduced travel times. Reduced travel time reduces the time passengers are exposed to air pollution and increases citizens' willingness to walk or cycle longer distances to stations, thereby increasing physical activity levels. Both effects have positive health impacts.

Bus Rapid Transit (BRT) systems are an efficient mass transport mode and have been implemented in several cities worldwide in recent years. BRT systems typically have segregated busways, stations with off-board fare collection, station platforms and bus priority. As a result, BRT provides capacity and speed comparable with urban rails.

Bogotá and Istanbul have both implemented BRT, giving several large benefits to the cities and their citizens. The cases are presented in more detail on the following pages.


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TRANSMILENIO
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CASE 1

4.3 **BUS RAPID TRANSIT BOGOTÁ**

THIS CASE DEMONSTRATES HOW BOGOTÁ DEVELOPED A PUBLIC TRANSPORTATION SYSTEM BASED ON BUS RAPID TRANSIT (BRT), TRANSMILENIO.

CASE FACTS

Name: TransMilenio
City population: 7.3 million
Project inception: 2000
Number of buses: 1,697
Daily ridership: 2.2 million.

TransMilenio is the mode for more than 43% of public transport journeys in Bogotá.

Emissions reductions: approximately 235,000 tonnes per year.

Bogotá aims to reduce high levels of pollution and CO_2 emissions by replacing existing diesel buses with hybrid and full electric models. The effect of which is not included in this analysis.

The mass transit system includes buses, trains, trams and subways, and the BRT system. The TransMilenio System transports more than 2.2 million passengers per day and is globally one of the highest capacity systems. The peak load – passengers per hour per direction is 48,000 passengers (EMBARQ 2013). TransMilenio accounts for 74% of total public transit trips in the city and two-thirds of the city's population lives within a kilometre of public transport.

Political context and motivation – why has the city taken action?

Bogotá has been focusing on mobility to enhance economic efficiency, improve environmental conditions, and promote social equality. The decision to develop the Bus Rapid Transit (BRT) TransMilenio was made in 1998. The decision was driven by rapid urban expansion and a chaotic transportation situation in Bogotá. Before TransMilenio, the public transportation system had an oversupply of buses with unorganised line-structure serving the city.

TABLE 4.1 **BENEFITS INCLUDED IN THE ASSESSMENT**

Area: Bogotá

- ✓ Reduced transit travel time
- Reduced private vehicle operating cost
- ✓ Reduced transit operating cost
- ✓ CO_2 emissions avoided
- ✓ Road safety impacts
- ✓ Changes in exposure to air pollutants
- ✓ Physical activity benefits

Source: EMBARQ 2013

The BRT system was set to organize the chaotic line structure, and address social equality and environmental conditions. Additionally, TransMilenio has recently started to focus on cleaner buses with low carbon technologies.

Case facts

TransMilenio provides Bogotá with a relatively low-cost, high-volume alternative to traditional modes of public transport in larger cities (metro, light rail, etc.). By 2013, TransMilenio had approx. 1,700 buses on 11 corridors, plus 715 so-called feeder buses operating extensively in Bogotá. It has since grown larger. This case rests on an analysis carried out by EMBARQ in 2013. The assessment covers a 20-year period, 1998-2017, and captures private and public costs and benefits (EMBARQ 2013).

How benefits have been measured

The economic, social, and environmental benefits are assessed through cost-benefit analysis, which includes the benefits for the BRT system in Bogotá shown in table 4.1.

The benefits are calculated by comparing the current situation with the hypothetical situation without the project in the before mentioned 20 year period. Benefits thereafter are not included in the calculations. However, EMBARQ (2013) notes a gradual increase in benefits over time. As a result, the net value of benefits for TransMilenio is likely to grow in 2017.

Travel time savings and the monetary values of these savings are estimated using transportation modelling based on data from the National Secretary of Transit and Transportation. This is also used to model the number of reduced accidents.

Reduced transit operating costs originate from savings on the operation of traditional buses removed from service after the implementation of the TransMilenio.

The effects of pollution reduction are estimated using an analysis conducted for Mexico by the National Ecology Institute (INE 2006) as a proxy since there are no local or national analyses available. Using this data on regressions, it is possible to estimate deaths prevented, averted cases of bronchitis, and numbers of restricted workdays avoided due to reduced pollution. To put an economic value

on this, the statistical values of life are based on those used by the INE in Mexico. Increasing road safety gives the following general benefits: decreased injury costs (for example, injury treatment), fewer lives lost, and increased quality of life due to fewer people living with the effects of injuries.

Calculating road safety impacts is limited by poor quality crash data and a lack of clear and standardized definitions of injury severity levels. EMBARQ (2013) points out that developing countries often lack accurate data. Furthermore, there is only limited information on the costs associated with crashes. For this reason, the cost of injury crashes in Bogotá (and Istanbul) is developed using costs in the United States, adjusted for local conditions.

The value of fewer lives lost and increased quality of life is calculated by estimating the value of a statistical life (VSL). EMBARQ (2013) uses estimates from research, again adjusted for local conditions.

The estimations of the impact on physical activity are based on household surveys of before and after data on mode of transport, and a cross-sectional dataset of walking minutes per trip by mode. The health benefits from increased walking are assessed using the World Health Organization's Health and Economic Assessment Tool (HEAT) model and by applying estimates for the value of a statistical life.

Results

The BRT system's benefits amount to a net present value of $3,759 million and a benefit-cost ratio of 1.59. Over the 20 year period, it gives a 23% internal rate of return (higher than the minimum 12% from national authorities).

TABLE 4.2 **PRESENT VALUE OF BENEFITS, BOGOTÁ**

Source of benefit	Value (USD mil 2012)
Reduced transit travel time	1,741
Reduced transit operating cost	1,393
Road safety impacts	288
Changes in exposure to air pollutants	131
Physical activity benefits	99
CO_2 emissions avoided	108
TOTAL	**3,759**

Source: EMBARQ 2013.
Note: 12 % discount rate is used.

The analysis concludes that the largest benefit of the TransMilenio is travel time savings for transit users. Travel time savings accounts for almost half of the calculated benefits.

Savings from operation of traditional buses removed from service is another substantial benefit.

The calculated benefits are listed in table 4.2 above.

Lower and middle-income groups make up the largest proportion of users of the BRT system and therefore accrue the majority of the benefits.



CASE 2

4.4 **BUS RAPID TRANSIT IN ISTANBUL**

EMBARQ (2013) HAS ALSO LOOKED AT THE BRT SYSTEM IN ISTANBUL, METROBÜS, AND PERFORMED A SIMILAR ANALYSIS.

The Metrobüs is newer than TransMilenio, with construction beginning in 2005 and the initial introduction of buses in 2007. The Metrobüs system is distinguished by being a high-way-speed BRT, operating at near highway speeds on designated lanes.

Political context and motivation – why has the city taken action?

Istanbul experienced a high level of congestion in the urban area and sought to provide citizens with a timely and effective alternative public solution. Istanbul has a comprehensive public transportation system, including commuter rail, metro, light rail and a network of city and mini buses.

Construction of underground public transportation options can be a challenge in Istanbul due to the plethora of historical buildings and undiscovered archaeological sites. As a result, the city's above-ground public transport options are more developed than its metro (EMBARQ 2013).

Existing public transportation was inhibited by heavy congestion. Thus, space was appropriated in the median of Istanbul's highway, D100, for the construction of a dedicated bus lane in both directions, to allow the Metrobüs to operate at near-highway speed. As more than 90% of transportation in Istanbul is road-based, public transportation is very important for the citizens (Yazici et al. 2013).

CASE FACTS

Name: Metrobüs
City population: 13.6 million
Project inception: 2007
Number of buses: 415
Peak load: 24,000 passengers per hour per direction
Daily ridership: 750,000
System length: 52 km

Source: BRTdata.org

Case facts

The Metrobüs BRT in Istanbul was developed over 4 phases, and now consists of more than

TABLE 4.3 **BENEFITS INCLUDED IN THE ASSESSMENT**

Area: Istanbul

- ✓ Reduced transit travel time
- ✓ Reduced private vehicle operating cost
- Reduced transit operating cost
- ✓ CO_2 emissions avoided
- ✓ Road safety impacts
- Changes in exposure to air pollutants
- ✓ Physical activity benefits

Source: EMBARQ 2013

TABLE 4.4 **PRESENT VALUE OF BENEFITS, (2007-2026), ISTANBUL**

Source of benefit	Value (USD mil 2012)
Reduced transit travel time	16,369
Reduced transit operating cost	2,154
Road safety impacts	531
Changes in exposure to air pollutants	350
Physical activity benefits	392
CO_2 emissions avoided	152
TOTAL	**19,948**

Source: EMBARQ 2013.
Note: 12 % discount rate is used.

50 km of transit way, served by more than 400 buses. 750,000 passengers use the BRT daily, with peak loads of 24,000 passengers per hour per direction.

The BRT is intended to ensure efficient transportation between the residential area in the East and the business district in the West. The BRT generally operates on designated lanes, but merges with regular traffic on the heavily trafficked Bosporus Bridge. However, the Metrobüs is able to skip the queue and enter the bridge more quickly than general traffic.

How benefits have been measured

The economic, social and environmental benefits are assessed through cost-benefit-analysis, which includes the following benefits for the BRT system in Istanbul.

Method and data collection

The analysis of Istanbul's Metrobüs is based on a 20-year time horizon from 2007 to 2026. Some of the benefits assessed in the TransMilenio case in Bogotá are not assessed in the Metrobüs case. This includes reduced transit operating cost and changes in air pollutant exposure (EMBARQ 2013). The data used to assess the net benefit of the Metrobüs are not as case-specific as the assessment of the TransMilenio in Bogotá. It relies more heavily on international data adjusted to Istanbul

specifics, though there are areas where data has been locally collected.

The Istanbul Electricity, Tramway and Tunnel General Management (IETT) does a yearly survey assessing the use and value of the Metrobüs. This serves as an important source of information in the EMBARQ (2013) cost-benefit analysis. The survey includes information on number of rides, how passengers get to the station, reasons for using the Metrobüs, demography, satisfaction, travel time, etc. From this information, it is known that the typical Metrobüs passenger saves 52 minutes per day (Yazici et al. 2013).

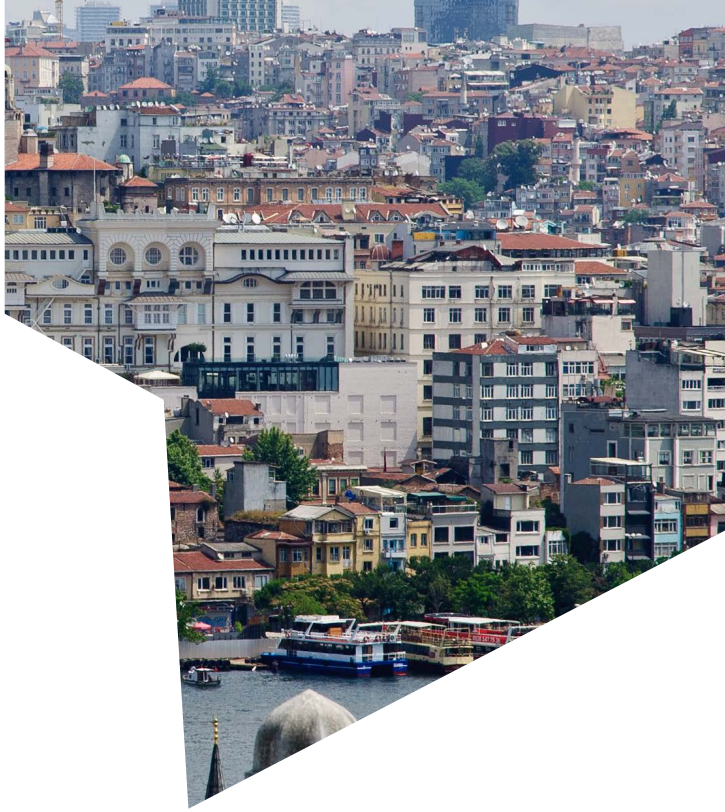
Most of the input to the CBA originates from this survey. Otherwise, international literature and analysis are used. Value of time saved is estimated using the IETT's passenger survey.

Results

EMBARQ's cost-benefit analysis concludes that the project's benefits heavily outweigh the costs, reflected in a cost-benefit ratio of 2.8 and a 65.8% internal rate of return.

The largest benefits are within travel time reductions, which is a combination of the high number of daily riders and high average travel time savings. This also reflects the design of the BRT as a highway-BRT bypassing the heavy congestion in the city. 64% of the benefits come from travel time reductions.

Reductions in vehicle operating costs are also significant, and account for 23% of the total benefits. This reflects that 9% of Metrobüs passengers changed from cars to BRT, which decreases costs associated with the operation of privately owned cars.



The value of increased traffic safety (avoided road fatalities and accidents) accounts for 9% of the projects calculated benefits. The dedicated lanes provide a high degree of traffic safety. The fact that most Metrobüs users would have otherwise used public transit or personal vehicles operating in general traffic lanes also adds to traffic safety benefits.

Finally, EMBARQ (2013) finds substantial benefits from increased physical activity and avoided CO_2 emissions (see table 4.2).

Internal rate of return (IRR) is the interest rate at which the net present value of all the cash flows (both positive and negative) from a project or investment equal zero. Internal rate of return is used to evaluate the attractiveness of a project or investment.

4.5 Lessons on BRT from research and other cities

Transportation, both public and private, is a well-developed area when it comes to assessing costs and benefits. Development of public transportation options often involves large investments and multiple stakeholders. The additional cost of investing in low-carbon, climate resilient urban infrastructure is often limited compared to the overall investment, and can lead to shorter travel time for inhabitants, reduced traffic congestion, reduced local air pollution and reduced greenhouse gas (GHG) emissions (OECD 2014).

There is a long history of using cost-benefit analysis in transportation projects supplemented by a socio-economic assessment, as opposed to a purely financial assessment. This makes public transportation one of the more advanced areas in cost and benefits assessment. Many countries also have public manuals with official figures to be used in calculations of larger projects.

EMBARQ has done extensive research concerning BRT costs and benefits, including wider environmental and social benefits. Along with Bogotá and Istanbul, which were covered

STEPS TO ASSESS BRT SYSTEMS

- List all potential benefits that accrue to users of the BRT system as well as other citizens that benefit from less congestion, cleaner air, etc.
- Prioritise benefits that are most important to your city and that you have or can obtain valid data for. Reductions in travel time are usually a key benefit and should be prioritised.
- Gather data on selected benefits and costs locally and from other studies/cities. If resources are limited, it is a good idea to use findings from other cities, especially in areas where benefits are expected to be less important.
- Adapt findings from other cities to local specifications, e.g., local prices, income levels, infrastructure, etc.
- Compare the present value of benefits to the present value of costs over a period. Some countries' transportation authorities have developed manuals that specifies the period. If this is not the case, then the length of this period may depend on project specifics such as the expected lifetime of the fleet and infrastructure.
- Report potential benefits that have not been quantified in non-monetised values, e.g., based on citizen surveys on improved community liveability.

above, they have also assessed the BRT in Mexico City and Johannesburg. All BRT systems have benefits that exceed costs, some more than others. Based on the available literature, all show positive net present benefits, but operate in very different circumstances and cannot be directly compared to one another. Mexico City and Istanbul both have BRTs of medium capacity, while the capacity of the BRT in Johannesburg is low-capacity, with fewer than 70,000 passengers daily. The BRT in Bogotá is one of the largest capacity BRT systems.

As there is a growing interest in BRT systems, EMBARQ created a database that gathers important information to show that use of BRTs can be an appropriate solution for many cities worldwide. Another very successful example of BRT implementation is in Guangzhou. The BRT of Guangzhou transports 843,000 passengers per day. BRT is growing in China, and there are already 18 BRT systems of varying sizes in cities across the country (BRTdata).

4.6 What to consider before undertaking a similar project

The cases presented here illustrate some of the benefits that should be included when assessing the costs and benefits of BRT systems and public infrastructure projects in general. These include:

- Reduced transit travel time
- Reduced transit operating cost
- Travel cost savings
- CO_2 emissions avoided
- Road safety impacts
- Changes in air pollutant exposure
- Physical activity benefits

DATA NEEDS AND SOURCES

Minimum local data needs typically include:

- Data for current and estimates for future ridership and use of private vehicles. Local transport authorities typically have useful data on current ridership, etc. and may also have developed transportation models to estimate future ridership and time savings. Alternatively, a number of consultancies specialise in developing transportation models that may be applied.
- Crash data and associated costs for the health sector and property damage may be gathered from local transport and health authorities.
- Data for walking minutes per trip by mode of transport is typically gathered via surveys.
- Data for CO_2 emissions and air pollutants may be collected from local environmental authorities or local studies.

TABLE 4.5 **COMPARABLE VARIABLES – BOGOTÁ & ISTANBUL**

Source of benefit	Bogatá	Istanbul
Reduced transit travel time	78 %	82 %
Road safety	13 %	11 %
Physical activities	4 %	5 %
CO_2 avoidance	5 %	2 %

Source: EMBARQ 2013.
Note: 12 % discount rate is used.

To evaluate whether a BRT system is a suitable public transportation choice, a cost-benefit analysis (CBA) in the form of an impact analysis is often used, as it is the most common method used in transportation analyses. A CBA provides policymakers and other stakeholders with valuable knowledge on the wider effects of an initiative, and estimates net present value in monetary terms, which is easy to understand and communicate.

The cases presented here shows that there are more ways to find data besides making calculations from scratch. This includes applying analyses made on other systems, using international data or by conducting a survey among users. The latter is a relatively simple way to gain insights and knowledge into aspects such as travel time savings and increased physical activity.

Before deciding on a BRT solution, it is useful to consider outside circumstances. Generally, this kind of project works best with high urban population densities, where there is a local institutional capacity for project planning and implementation already in place. Thus, not all cities are suited for BRT.

The importance of benefits may vary slightly across different cities. By selecting four comparable variables, we see that Istanbul gains slightly more from reduced travel time and physical activities, while Bogotá gains relatively more from road safety and CO_2 avoidance (see table 4.4). However, these variables only represent the comparable variables and not every type of benefit BRT offers.

It is also useful to consider the size of the BRT project; if large loans are required then financial institutions should be brought on board as early as possible in the planning process. Specialists and experts should also be included in the planning process, and an ongoing dialogue with the public and other relevant organisations is important.

Project costs vary significantly across systems depending on the required roadwork (bridge/tunnel, corridor capacity, bus lanes, station requirements etc.). Local costs of labour and capital are also important factors to consider. Despite variation in local circumstances, it can be beneficial to look at existing systems to define the expected range of costs for a BRT.

More information on Bogotá's TransMilenio

- www.transmilenio.gov.co/en

For more information on Istanbul's Metrobüs visit

- www.iett.gov.tr/

Or consult these resources:

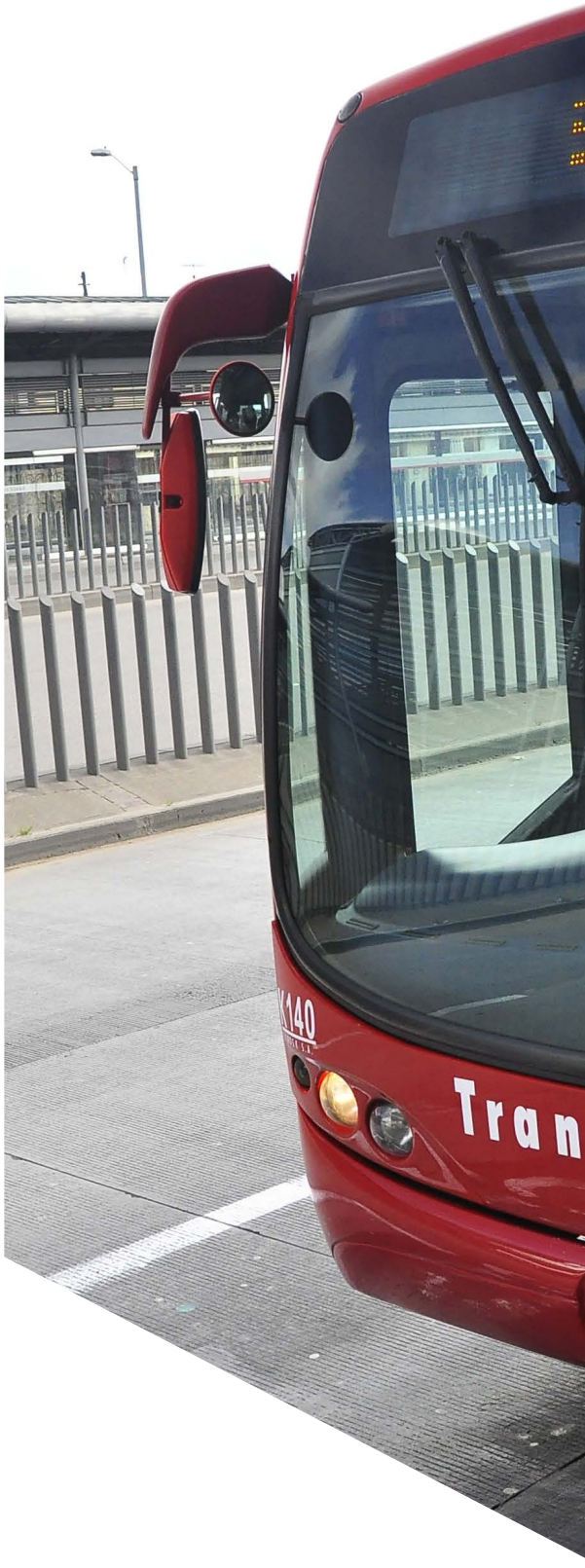
- EMBARQ (2013): Social Environmental and economic impact of BRT
- EMBARQ (2015) Cities at large
- World Bank (2013): Transforming cities with transit
- U.S. DOT (2009): Land Use Impacts of Bus Rapid Transit
- Suzuki et al (2010): Eco2 cities : Ecological Cities as Economic Cities
- Yazici, A et a (2013): A Bus Rapid Transit Line Case Study: Istanbul's Metrobüs System

For data visit

- www.brtdata.org

Other cities with BRT in place, for example:

- Mexico City
- Cape Town
- Jakarta
- Ahmedabad



5. Private transport

A LARGE SHARE OF TRAVELLED KILOMETRES IN CITIES IS DONE BY PRIVATE TRANSPORT MEANS SUCH AS WALKING AND CYCLING, OR DRIVING CARS, TAXIS, TRUCKS AND OTHER MOTORISED PRIVATE VEHICLES.

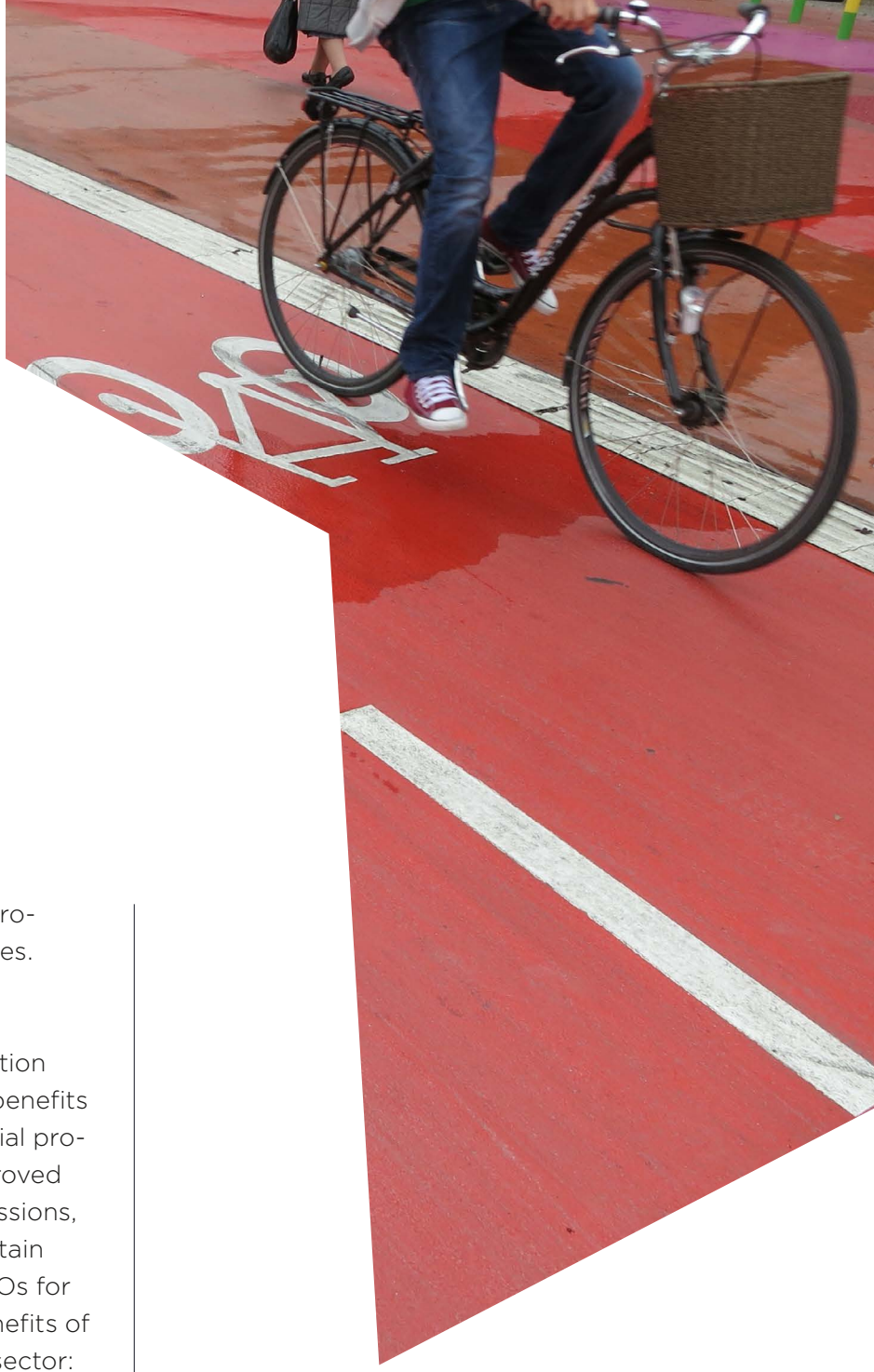
5.1 Characteristics of the sector

Transport forms an essential part of daily life in cities all over the world. Citizens use transport to commute to and from work and school. Businesses use transport to receive and deliver goods and services. Visitors access cities by various modes of transport. A large share of travelled kilometres in cities is done by private transport means such as walking and cycling, or driving cars, taxis, trucks and other motorised private vehicles. While walking and cycling are associated with zero emissions, private motorised vehicles have high relative emissions. According to the Climate Action in Megacities survey (CAM 2.0), private motorised vehicles account for less than a third of journeys travelled, but 72% of all transport related emissions in megacities. Private transport thus represents a key sector for climate action initiatives.

Climate action measures targeted at the private transport sector primarily relate to:

- Promoting the use of climate (and health) friendly private transport modes such as walking and cycling.
- Reducing the use of private vehicles, including actions to manage transport demand and promote vehicle sharing.
- Reducing the carbon intensity of private motorised vehicles, e.g., by requiring particle filters or promoting alternative fuel vehicles.

While some of these measures involve large-scale infrastructure investments and careful urban planning, measures to promote walking and cycling typically represent a less costly way to target climate action in the private transportation sector. According to CAM 2.0, measures to promote walking and cycling in



cities represent the most frequently introduced actions among the surveyed cities.

5.2 Sector benefits

Potential benefits of private transportation projects are large and numerous. Key benefits include travel time savings (and potential productivity gains) for urban citizens, improved urban air quality and reduced CO_2 emissions, improved population health and, in certain cases, reduced accidents (see, e.g., CEOs for cities (2007), WHO 2011: Health co-benefits of climate change mitigation – transport sector: Health in the green economy, City of Copenhagen (2010): City of cyclists – Bicycle account 2010, Cortright J., Impresa (2009): Walking the walk).

Even when substantial, the benefits of private transport projects are often challenging to predict and quantify. This is because measures

to reduce use or emission intensity of private vehicles often affect an entire urban populations' travel behaviours in different ways, depending on travelling purposes, alternative modes of transport available, income, residence, work location, etc.

Fortunately, many countries have a long tradition of using advanced traffic modelling and cost-benefit methods to quantify the most substantial benefits of private transportation projects.

These include, in particular, shorter and more reliable travel times for citizens who are dependent on their cars as other citizens choose alternative transport options. It also includes the associated benefits from reduced emissions and improved air quality, as fewer cars are on the roads and trips become more environmentally friendly due to, e.g., less congestion or cleaner modes of transport. While air quality tends to improve locally in cities marked by congestion problems, curbing emissions also has important climate mitigation effects. Lastly, projects in the private transportation sector often affect road safety – the number and types of accidents that are likely to occur – which implies saved lives.

Moreover, several countries are undertaking measurements of other important benefits, such as other health effects, wider economic benefits, etc. (see e.g. UK Department for Transport (2005)). Health effects occur not only from reduced pollutant exposure, but also due to increased physical activity from walking or cycling. One example of such documented health effects of cycling is a Copenhagen study in connection with major infrastructure improvements for cyclists, which demonstrated a health value of almost $1 (USD 2008) per cycled kilometre (City of Copenhagen (2010): City of cyclists – Bicycle account 2010). Altogether, when accounting for transport costs, security, comfort, branding/tourism, transport times and health, the study found a net social gain of approximately 25 cents per cycled kilometre compared to a net social loss of approximately 15 cents per kilometre driven by car. Wider economic benefits include, e.g., productivity gains from larger labour markets (because people can move across the city faster) and thus better matches between required job skills and competences, increased local competition, etc.




Dulwich Library
12
LTZ1433
LJ51 RMZ
TAXI
Big Bus Blue Tour

CASE 3

5.3 **CONGESTION CHARGES IN LONDON**

THIS CASE, BASED ON AN ASSESSMENT OF PUBLICALLY AVAILABLE DATA, DEMONSTRATES HOW INTRODUCTION OF A CONGESTION TAX IN LONDON YIELDED NET BENEFITS TO PRIVATE CAR DRIVERS, PRIVATE BUS RIDERS, GOVERNMENT AND SOCIETY AS A WHOLE.

The tax, introduced in 2003, represents the first congestion pricing programme in a major European city.

Political context and motivation – why has the city taken action?

Transport planners have recommended congestion charging as a tool to improve traffic conditions in London's city centre for many decades. A formal study of the potential benefits of road pricing in London was already conducted in 1973. In 1995, the London Congestion Research Programme concluded that a congestion taxing scheme would be beneficial to London. Central London was perceived as particularly suitable for congestion pricing due to:

- Limited road capacity
- Congestion caused by heavy travel demand
- Extensive and comprehensive travel alternatives, including walking, taxis, buses and subway services, which are used by most travellers

In 1997, future London mayors were given new powers to manage the city's transport system, implement levys and raise fares to fund transport improvements. Plans for implementing a London congestion scheme became reality with the election of Ken Livingstone in 2000, who supported congestion charging in London (see Litman 2011, Evans 2007).

Case facts

The London congestion charge is a fee charge on motorised vehicles operating within a charging zone covering central London between 7:00 a.m. and 6:00 p.m. Monday to Friday. A standard charge of £11.50 per day applies, irrespective of where or when you enter the zone. The standard charge has been regularly adjusted upwards from an initial £5 on an ad-hoc basis.

Discounts are available to residents living within or very close to the zone, users of automatic payment systems, businesses with six or more vehicles and greener vehicles (until 2013) while

CASE FACTS

Name: London Congestion Charge
City population: 8.4 million (Greater London)
Project inception: 2003

Congestion charge system: The system consists of a simple toll cordon around the inner city with a charge imposed 7:00 a.m. to 6:00 p.m. on weekdays. The charging zone, which is targeted at commercial rather than residential areas, covers about 2% of the citizens in Greater London.

The congestion charge system has:
- Reduced traffic volumes by 18%
- Reduced congestion by 30%

For a comprehensive overview of net benefits identified: see table 5.5.

Exemptions apply for:
- Emergency service vehicles
- The disabled

Discounts apply for:
- Residents living within or very close to the zone
- Users of automatic payment systems
- Businesses with six or more vehicles
- Greener vehicles (until 2013)

National Health Service vehicles, the disabled and fire fighters are exempt.

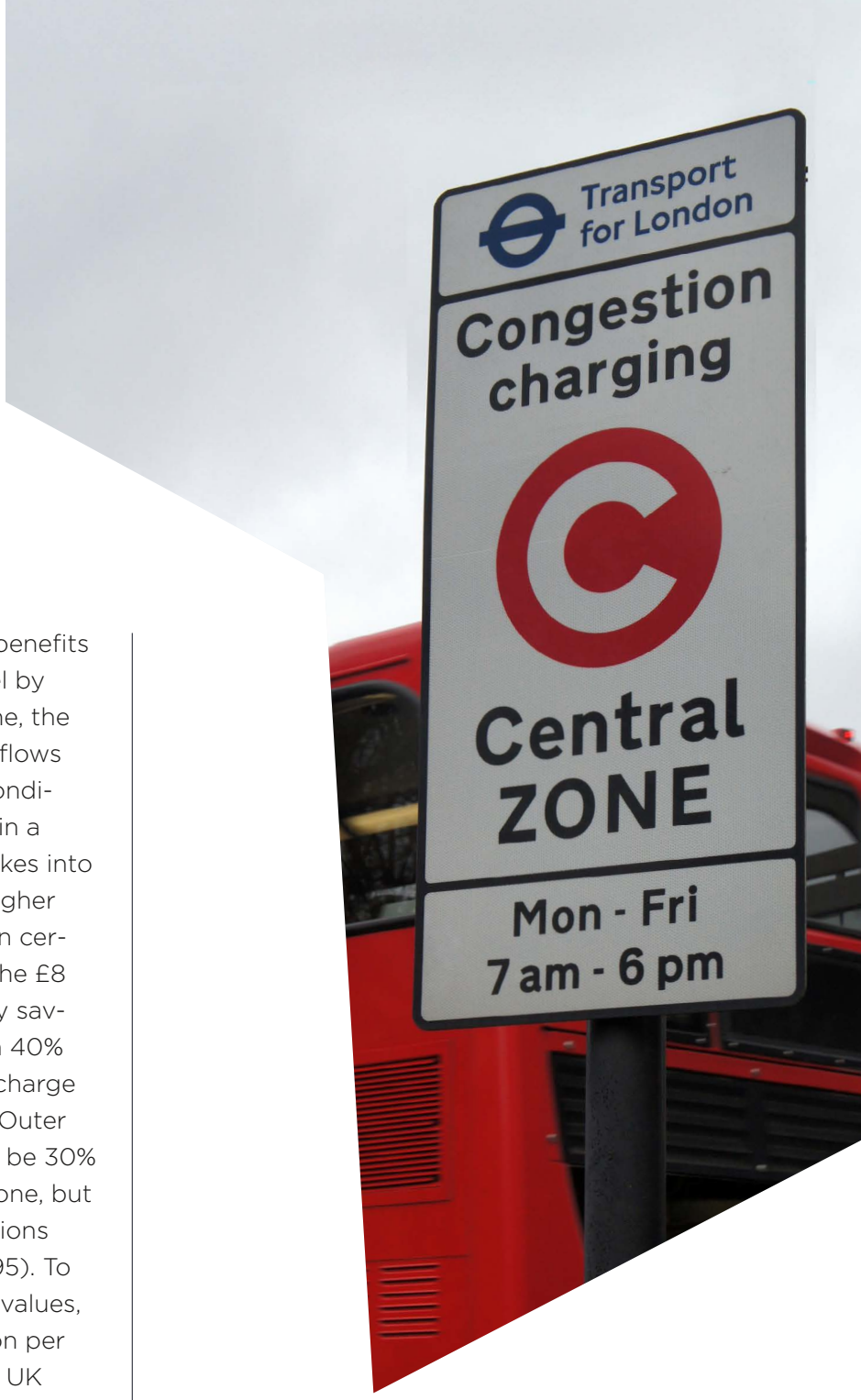
In 2007, the boundary of the charging zone was extended westwards, though the expansion was reversed in 2010.

How benefits have been measured

This case rests on a comprehensive evaluation of the impacts of the Central London Congestion Charge from 2007 (Evans 2007). The benefits calculated are thus based on the £8 charge applied from 2005-2011. It does not take into account the temporary expansion between 2007 and 2010.

Key benefits included in the analysis are:
- Charge payer benefits from shorter and more reliable travel times
- Benefits to public transport users from increased punctuality of public buses
- Government operating revenues
- Revenue benefits for private sector providers of bus services
- Society benefits from fewer accidents and reduced local air pollutants and CO_2 emissions

Benefits not considered in the analysis are changes in physical activity, benefits attached to an improved urban environment and potential long-term labour and housing market effects.



To calculate time saving and reliability benefits to individuals and businesses that travel by car inside and outside the charging zone, the study uses observed changes in traffic flows and speeds compared to pre-charge conditions (see Transport for London 2007) in a traffic assignment model. The model takes into account offsetting effects, e.g., when higher possible road speeds increased traffic in certain areas/time periods. On this basis, the £8 charge is estimated to yield a total daily savings of around 36,800 hours – of which 40% of the time savings arise in the central charge area – 44% in Inner London and 16% in Outer London. Reliability savings are taken to be 30% of travel time savings in the charging zone, but 0% elsewhere, based on earlier calculations (see Government Office for London 1995). To convert these estimates into monetary values, recommended values of time per person per hour for various types of drivers by the UK government are employed, scaled by 1,385 to reflect the higher average earnings in London compared to national averages. This yields an average value of time per person in the charging zone of 40 pence per minute, and an average value of time per person in the charging zone of 40 pence per minute.

Public transport benefits to bus users are estimated using the same procedure as for private vehicle users, but counting only half the observed changes in speeds and waiting times to account for other policies which impact bus speeds and reliability.

To measure societal benefits in the form of reduced accidents, reported personal injury statistics from 2001- 2004 were observed. These indicated a reduction of around 10% in central London and 4-5% in the rest of London, while reductions from previous years had been almost equal. To control for the fact that factors other than the congestion charge might impact accident numbers, an accident prediction model relating accidents by type and area to changes in flows of relevant vehicle/person types is used. This model indicates around a quarter to one third observed reduction in that year's accidents are attributable to congestion charges, which implies a total reduction of 254-307 accidents. This was converted using standard costs for various types of injuries.

Reduced CO_2 emissions are estimated using calculations from the reduced distance travelled and improved average vehicle speeds, which both impact fuel consumption. The scheme is estimated to reduce fuel consumption by about 3% from London's pre-charge fuel consumption, corresponding to approx. 48 million litres per year. Savings are calculated as costs of fuel consumption without the charge minus fuel consumption with the charge. The average CO_2 emission rate is assumed to be 2.5 kg per litre of fuel (weighted average of petrol and diesel). Using the official UK carbon valuation of £75/tonne, and knowing that carbon represents 6/22 of CO_2 by weight, this can be converted into a monetary value of

TABLE 5.1 **NET BENEFITS, CONGESTION IN LONDON**

Source of benefit	Loss/gain (million USD per year)
Private benefits	64
Travel time and reliability (charge payers)	473
Car operating savings (charge payers)	51
User charge and compliance costs (charge payers)	-464
Reduced crowding (bus passengers)	78
Deterred trips	-56
Private parking revenues	-18
Society benefits	31
Accidents	25
CO_2 emissions	4
NOx and PM (Particulate Matter)	2
Government benefits	85
Charging	231
Fuel duty	-49
VAT	-25
Additional buses	2
Infrastructure	-45
Parking revenues	-27
TOTAL	**180**

Source: Evans 2007

Note: Average currency exchange rate for 2005 has been used between British Pounds and US Dollars. The exchange rate was 0.55 GBP for 1 USD.

saved CO_2 emissions. Similarly, reduced vehicle driving and congestion reduces emission of air pollutants such as NOx and particulate matter. The reduction between 2002 and 2003 was measured to be 13.4%. The reduction is, however, not only attributable to traffic flow and speed changes brought about by the congestion charge, but changes in vehicle stock. Using observed traffic data and vehicle emissions relationships for different vehicle types, the study estimates that the congestion charge is responsible for emissions reduction of 8%. Later studies have attempted to estimate whether this impacted overall air quality in London (Kelly et al. 2011). Although the studies find that introduction of the charge is associated with changes in pollutant concentrations, they lack firm evidence that this is caused by the congestion charge alone.

Results

Table 5.1 shows the detailed distribution of net benefits (bold) across private users, government, and private non-users (society). Negative numbers indicate that negative effects outweigh positive effects for the particular population group in question (i.e., it is a cost).

Again, the value of the time gain to businesses and individuals (473 mil. USD/year) represents the single largest source of benefit. In the London case, it is higher than user charge and compliance costs, implying that even private charge-payers gain from the charging system. This is very impressive by international standards and indicates that London is particularly well-suited for congestion charging.

The society benefits relative to the charges paid, however, are relatively small compared to the Stockholm case (13% vs. 26%), which we will see in the next case. The benefits of reduced crowding on public buses are also quite significant and amount to 78 mil. USD/year.

Overall, when compared to identified costs, the benefits of the congestion charge exceed costs by a ratio of around 1.7:1 with an £8 charge for a typical year of operation.




Sheraton
Hotel

CASE 4

5.4 **CONGESTION TAX IN STOCKHOLM**

THIS CASE DEMONSTRATES HOW STOCKHOLM HAS SUCCESSFULLY INTRODUCED TAXES TO CURB CONGESTION PROBLEMS IN CENTRAL STOCKHOLM.

The system was first introduced in 2006 as a trial between 1 January and 31 July – the so-called Stockholm Trial – in spite of fierce public and political resistance. The congestion tax was permanently established by a referendum held in September 2006 where 53% of Stockholm's citizens voted for a continuation. The tax was permanently introduced on 1 August 2007. Stockholm was thus among the first capital cities to implement taxation as a means to manage traffic demand. Moreover, the case illustrates how a large-scale trial effectively changed public opinion towards an initially unpopular private transportation initiative.

Political context and motivation – why has the city taken action?

The primary motivation for introducing a congestion tax in Stockholm was to combat traffic jams and the associated pollution that plagued Stockholm prior to the trial.

Congestion on approach roads and in the inner city of Stockholm – especially during mornings and evenings – was costly for citizens and businesses. Moreover, though air quality in Stockholm was generally good, the air quality in several zones exceeded recommended pollution thresholds, and private motorised vehicles represented a prime source of pollution, accounting for 1/3 of all emissions in Stockholm (Stockholmsforsoket.se)

A number of analyses showed that expansion of the road network would be insufficient to alleviate the congestion problem. Therefore, testing an alternative and greener solution, through congestion charging combined with an expanded public transit system, was pushed by the Swedish Green Party as a condition for supporting a Social Democratic government.

Case facts

The Stockholm congestion tax system consists of a toll cordon surrounding the inner city. The toll is in effect on weekdays between 6.30 a.m. and 6.30 p.m. and a tax of 10 SEK is charged for vehicles entering or exiting the

CASE FACTS

Name: Trängselsskatt (Congestion tax)
City population: 0.88 million
Project inception: 2007

Congestion tax system: The system consists of a simple toll cordon around the inner city with a charge imposed 6.30-18.30 on weekdays. The charging zone covers:

- 34.5 km^2 or 18%. of Stockholm's land area
- 1/3 of the citizens in Stockholm city
- 60% of the city's jobs in which 71% of the employees live outside the charging zone

The congestion charge system has:

- Reduced traffic to/from the inner city by 20-25%
- Reduced queue times by 30-50% on all but one road
- Decreased emissions in the inner city by 14%

For a comprehensive overview of net benefits identified: see table 5.2.

Exemptions apply for, e.g., taxis, buses, and until 2009, alternative fuel vehicles, implying that about 30% of all passages were exempt in 2006. The passage made by alternative fuel vehicles increased from 3% during the trial in 2006 to 14% in 2009. This effect is not included in this analysis.

ESTABLISHED GOALS OF THE STOCKHOLM TRIAL

The pre-established goals by which the success of the Stockholm Trial was measured were:

- A reduction of car traffic to and from the city centre by 10-15 minutes during rush hour
- Improved traffic flow
- Reduced CO_2, NOx & particle emissions
- An improved urban environment for citizens

charging zone[2]. The prices double during rush hours (7.30-8.30 a.m. and 4.30-6.30 p.m.) and are 50% higher in shoulder periods (30 minutes before and after peak periods). There is a maximum daily charge of 60 SEK. Taxes are collected monthly based on registered vehicle owners.

An important supplement to the congestion tax, both during the trial period and after its permanent introduction, was an extension of public transport options, primarily through introduction of additional bus lines.

How benefits have been measured

Because of extensive traffic measurements made prior to and during the Stockholm Trial,

2 It has recently been decided to increase charges in 2016, which have remained constant since their introduction.

it is possible to measure the trial's achievement of goals. As indicated in the fact box to the left, the short term trial evaluations show all measurable project goals were more than satisfied.

Given potential alternative uses of resources, it is informative to base this assessment on a comprehensive evaluation of the total benefits of a permanent congestion charging system compared to the costs to determine whether the project has been beneficial to society as a whole.

Eliasson (2009) carried out a cost-benefit analysis of the Stockholm Congestion Charge based on traffic measurements from the Stockholm Trial, reviewed in table 5.2. The table provides an overview of the benefits included in the calculations.

These benefits are calculated by comparing the trial situation to the pre-trial situation. Benefits not considered in the analysis are impacts on the punctuality of public buses, physical activity, benefits attached to an improved urban environment and potential long-term labour market and housing market effects.

Travel time gains are estimated using observed changes in traveling patterns (traffic flows and travel times) during the experiment. These are measured using automatic travel time measurement systems. The value of time per vehicle was calculated using recommended Swedish values, except for the value for private car trips, which was taken from a stated preference study of Stockholm car drivers (which is considerably higher due to higher incomes, higher shares of working trips and a high share of public transit)

TABLE 5.2 **BENEFITS CONSIDERED**

Annual public operating revenues and increased public transit revenues
Private user benefits, including shorter travel times and more reliable travel times
Change in CO_2 emissions
Changes in exposure to local air pollutants
Road safety benefits

Source: Eliasson (2009)

among others. The shares of private trips, business trips, distribution of traffic and the number of persons per vehicle were taken from travel surveys.

The value of travel time variability can be estimated using information about the travel time, free-flow travel time and the standard deviation of travel time (for further details see Eliasson 2009).

Reduced car use is estimated to reduce emissions by 2.7% (42.5 kilotons) in Stockholm County and 10-14% in the city centre based on the traffic counts. Using the recommended Swedish valuations and calculation procedures (SIKA 2006), this can be converted into monetary benefits. This value also includes the health effects of improved air quality.

TABLE 5.3 **NET BENEFITS, CONGESTION IN STOCKHOLM**

Source of benefit	Loss/gain (million USD per year)
Total net private user benefits (consumer surplus)	-35
Shorter travel times	67
More reliable travel times	10
Loss for evicted car drivers, gain for new car drivers	-9
Paid congestion charges	-101
Increased transit crowding	-2
Total government costs and revenues	91
Paid congestion charges	101
Increased public transit revenues	17
Decreased revenues from fuel taxes	-7
Increased public transport capacity	-8
Operating costs incl. reinvestment and maintenance	-28
Marginal cost of public funds	23
Correction for indirect taxes	-8
Total non-user costs and benefits (externalities)	27
Reduced GHG emissions	8
Health and environmental effects	3
Increased traffic safety	16
Net annual social benfit, exl. Investment costs*	**83**

Source: Eliasson 2009
Note: Average currency exchange rate for 2009 has been used between Swedish Krona and US Dollars. The exchange rate was 7.958 SEK for 1 USD.

Savings due to reduced accidents amounts to an average annual reduction of 3.6% in accidents. The economic value of prevented traffic accidents is found by using recommended Swedish valuations of statistical lives, severe injuries and slight injuries.

Results

Table 5.3 shows the detailed distribution of net benefits (bold) across private users, government, and private non-users.

Negative numbers indicate that negative effects outweigh positive effects for the particular population group in question (i.e., it is a cost).

The table illustrates that the value of the time gain (67 mil. USD/year) represents the single largest source of benefit apart from the value of paid congestion taxes (which is not a benefit to society as a whole because it is just a transfer from private users to government, i.e., a cost to a benefit).

The travel time savings for car drivers that stay on the roads amounts to almost 70% of paid charges. This is very high by international standards, and is, among others, due to the large share of business travellers and positive effects for travellers that only travel inside or outside the charging zone (Eliasson 2009 p. 478).

In addition, there are important gains for non-users in the form of increased traffic-safety, reduced pollution and GHG- emissions and positive health effects. The reduction in traffic (taking into account increased driving speeds) is estimated to reduce the number of people killed and severely injured

by approximately 14 per year, while minor injuries are expected to fall by 50 per year. The corresponding monetary value is 16 mil. USD/year. The other health effects reflect an estimated five life-years saved per year in Stockholm County as a whole due to improved air quality. Certain medical studies indicate that this effect might be much higher and possibly 60 times as high (see Aga et al. 2003 for an overview).

Altogether, the analysis indicates that the congestion charges yield a net social benefit, including operating costs, but excluding investment costs, of 82 mil. USD per year. This annual societal surplus can be compared to the total investment cost of 239 mil. USD. Eliasson (2009) finds that public investments are paid off around 4 years.

Since maintenance costs are included in the analysis, the congestion tax has no obvious lifespan. Assuming a lifespan of 20 years, with constant costs and benefits and employing a recommended discount rate of 4%, the congestion tax systems' estimated net present value is 792 mil. USD. Taking into account an expected annual traffic growth of 1.5%, the net present value is 955 mil. USD. The net present value and benefit/cost ratio assuming a 20-year lifespan and traffic growth rates of 1.5% is shown in table 5.4 and 5.5.

Moreover, later analyses show that the measured observed effects during the trial remained for 9 years after the trial when controlling for external factors, such as demographic growth. The volume of traffic in and out of the zone during charging time has remained constant since the trial in spring 2006. There has been no increase

TABLE 5.4 **ANNUAL BENEFIT AND TOTAL INVESTMENT**

	USD million (2007)
Annual net social benefit	2
Total investment costs	239
Required life time for societal surplus	4 years

Source: Eliasson 2009
Note: Average currency exchange rate for 2009 has been used between Swedish Krona and US Dollars. The exchange rate was 7.958 SEK for 1 USD.

TABLE 5.5 **NET PRESENT VALUE AND BENEFIT/COST RATIO**

	USD million (2007)
Net present value	792
Benefit/Cost ratio	2.5

Source: Eliasson 2009
Note: 4 % discount rate has been used. Average currency exchange rate for 2009 has been used between Swedish Krona and US Dollars. The exchange rate was 7.958 SEK for 1 USD.

in car traffic despite the fact that the city has 100,000 more citizens (and the region 200,000 more citizens) in 2015 compared to 2006.

The national parliament has decided that from 1 January 2016 the tax will increase by 75% during rush hours, while remaining at its current level during off-peak hours, and a new tax will be charged on the present bypass. All the new revenue will be used for financing a huge extension of the metro line system in Stockholm. So far there has been no opposition to the tax increase – either in the media or among the public. This reflects recent opinion polls demonstrating 70% of the public support the congestion tax in Stockholm.

TABLE 5.6 **COMPARISON BETWEEN STOCKHOLM & LONDON**

Central areas for comparison	**Stockholm**	**London**
Private, government and society benefits (percent of total)		
Private benefits	-42%	-36%
Government benefits	110%	47%
Society benefits	32%	17%
Central areas of benefits and cost (percent of charges paid)		
Travel time benefits	76%	205%
Operating costs	28%	19%
Traffic safety benefits	16%	11%

Source: Eliasson 2009 & Evans 2007

For more information on London's Congestion Pricing, please visit:

http://www.tfl.gov.uk/modes/driving/congestion-charge

Or consult these resources:

- Litman: London Congestion Pricing – Implications for Other Cities (2011)
- Evans: Central London Congestion Charging Scheme: ex-post evaluation of the quantified impacts of the original scheme (2007)
- Transport for London: London's Congestion Charging Impacts Monitoring Fifth Annual Report (2007)

For more information on Stockholm's Trängselsskatt, please visit:

http://www.stockholmsforsoket.se/

Or consult these resources:

- Eliasson: A cost-benefit analysis of the Stockholm congestion charging system (2009)
- Börjesson et. al.: The Stockholm Congestion Charges – Five years on. Effects, acceptability and lessons (2011)



5.5 Lessons on Congestion Charges from research and other cities

It is well known that optimal road pricing on a congested road is beneficial to society as a whole. However, practical restrictions on the design of a charging system in the form of technical, physical, financial or political obstacles show that sometimes charging systems do more harm than good (see, e.g., Rich and Nielsen 2007 or Eliasson 2000 in Eliasson 2009). Some theorists have therefore doubted whether real-world congestion charging is feasible. The cases reviewed here illustrate that well-designed congestion charging schemes can yield significant economic, societal and environmental benefits.

On the other hand, the cases reviewed also illustrate that public opinion may be hostile prior to establishment. This is also confirmed by experiences of other cities considering introducing congestion charges, such as New York and Copenhagen.

The New York congestion pricing initiative

The New York Congestion pricing initiative was introduced as part of Mayor Bloomberg's sustainability plan "PlanNYC 2030" in 2007. In early 2008, the proposal was endorsed by the New York City Traffic Congestion Mitigation Commission – a committee charged with developing a solution to the severe traffic congestion problems in NYC.

The congestion pricing scheme entailed a daily fee for vehicles entering the Manhattan central business district of New York City between 6:00 a.m. and 6:00 p.m. It was estimated that the plan would reduce vehicle miles travelled in Manhattan by 6.8% and travel time by 30% in the charge zone and 20% in neighbouring areas. No comprehensive analysis of social and environmental costs and benefits was undertaken before project initiation, but the net revenues after operating expenses – earmarked to mass transit improvements – were projected to be $491 million per year.

The New York City Council approved the proposal, and polls indicated widespread public support by NYC and NY state voters (Quinnipiac University 2008). Moreover, the congestion tax programme was awarded a $354 million federal grant to support the launch phase and expansion of alternative public transport infrastructure.

In August 2008, however, the initiative was blocked in the New York State Legislature. Political opposition among Democratic representatives from the so-called outer boroughs – the areas that would be located outside the congestion charging zone – blocked the initiative from being put to vote.

A minority group of opponents eventually blocked the initiative and disputed, among others, whether the proposal would lead to the expected societal benefits and if the revenue would be used for necessary investments in mass transit improvements and alternative transport modes as a viable alternative to private cars (Schaller 2010).

The Copenhagen toll ring proposal

Increasing frustration with congestion in Copenhagen led left wing Danish opposition parties to promise the introduction of a Stockholm-type congestion tax, the so-called bompengering. The left wing parties estimated that traffic jams generated a societal loss of 7 billion DKR, equivalent with approximately 1.3 billion USD, annually (S-SF 2011).

After winning the election, the Copenhagen toll ring was thus set to become reality. The toll ring proposal, however, faced increasing hostility among opposition politicians, in the media and among mayors outside the charging zone. One of the major criticisms was that the proposed congestion charge had been estimated to yield an overall negative societal effect in earlier analyses by traffic economists and that experts were not sufficiently involved in designing a good model (See, e.g., Ingeniøren.dk 2012). Ultimately, the critique led the government to abandon the project in February 2012 after a 5-month vigorous defence, concluding that "nobody wants the congestion tax" (Politiken 2012).

General lessons

The general insight is that congestion taxing schemes are likely to face public hostility and risk being blocked in politics whether or not they are well-designed and expected to leave society better off.

In light of these experiences, it is important to note that research on road pricing and the cases reviewed here show that acceptability of (well-designed) congestion taxes and road pricing in general tend to increase with familiarity (Börjesson, M. et al. 2011). A number of reasons have been suggested for this finding, including:

- Uncertainty about the positive effects and the systems' ability to change behavioural patterns
- The costs in terms of fees and changes in travel behaviour are more palpable than benefits in terms of shorter travel times, less pollution, etc.
- Attitude and psychological factors such as general reluctance towards pricing of previously unpriced goods (road space) and preference for the known status quo, coupled with prolonged uncertainty about introduction of road pricing schemes, is likely to increase resistance (Frey 2003, Shade & Baum 2007 in Börjesson, M. et al. 2011).

Careful documentation of costs and benefits before project initiation, the use of trials and clear strategic communication is likely to



promote public acceptance in the challenging early phases (Börjesson, M. et al. 2011, Schaller 2010)

5.6 What to consider before introducing a congestion charge

The cases reviewed here point to the following key economic and environmental benefits of congestion charge projects:

- Travel time savings for businesses and private travellers
- More reliable travel times for businesses and private travellers
- Tax revenues and public transit revenues (government)
- Local pollution and health benefits
- Increased traffic safety
- Avoided GHG emissions

Although a congestion charging scheme might be successful for London and Stockholm, the conclusions are not directly transferrable to all cities.

Congestion charge systems can be expected to have positive socio-economic effects in cities where:

- Problems with congestion are extensive. Studies have shown, that the higher the level of congestion, the more gains can be achieved. Studies have shown that Copenhagen had half the levels of congestion of London prior to implementation of the congestion charge (Rich and Nielsen 2007).
- Alternative public transportation options exist. An integral part of the Stockholm Trial was a massive extension of public transit options to provide alternatives for car drivers. Failure to ensure sufficient alternative transportation options will entail huge social losses, as congestion will not be significantly reduced in spite of a schemes' huge investment and operating costs, crowding in public transit, etc.

Moreover, the design of the congestion charge zone is important. Different technical

solutions, geographical areas covered, differentiation in charges across location, time and transport modules need to be considered to ensure that the charges do indeed lead to the intended behavioural changes. If the charging scheme makes car drivers take longer routes to evade the charging zone or limits labour supply because sufficiently fast or cheap alternative transport options do not exist, it is likely a bad idea.

Comparing studies of the congestion tax in Stockholm and the congestion tax in London yields highly dissimilar results. In Stockholm, private firms and consumers lose, while the government and society benefit (see table 5.6). In London, however, consumers and private firms benefit from a congestion tax, particularly because of high travel time benefits. The operating costs as a fraction of total charges paid by consumers are higher in Stockholm compared to London, while benefits from reduced traffic accidents are higher in Stockholm.

Observed differences might be explained by different initial congestion levels, geographic properties, values of person hours, statistical values of life, etc.

For more information on the congestion price schemes reviewed here, see boxes in case sections.

Examples of other cities with congestion charge projects

- Singapore
- Milano

DATA NEEDS AND SOURCES

Data needs and useful sources typically include:

- Comprehensive city traffic data including number of vehicles on the road net, flow times at various times of the day and on different roads, number of passengers per vehicle, number of passengers in public transit systems, etc. These are usually obtained from automatic traffic measurements systems and traffic models.
- Traveller characteristics (business/private) and characteristics of vehicle fleet (petrol use per km). These can be obtained from commuting statistics and surveys.
- National Government shadow prices of person hours (private/business). If city salaries are considerably higher than national averages, shadow prices should be adjusted accordingly.
- Accident statistics and official statistical values of life.
- Fuel prices
- Local pollution level measurements from official measurement stations

It is thus essential to undertake a comprehensive cost-benefit analysis using traffic models to gauge whether congestion charging might be a good idea in your city. The box below reviews the most important steps to consider.

An important part of the data needed will have to be obtained from traffic measurement systems and models. Typical data needs and sources are summarised in the box below.

STEPS TO ASSESS CONGESTION CHARGING SYSTEMS

Assessing whether a congestion charging scheme is a good idea in your city is a comprehensive task.

Prior to undertaking an actual study, it is a good idea to consider the following:

- Is congestion is an extensive problem in your city? A good indication of the severity of congestion problems can be obtained by comparing average traffic speeds at daytime with night time flows. In London, the pre-charge difference was between 35-40% prior to congestion charging. In Copenhagen, where the toll ring was eventually abandoned, the corresponding number was 13 %.

- Does the city have extensive alternative public transportation options? If this is not the case, extending transit options would have to be part of the congestion charge project. This requires additional funds.

A comprehensive study will typically be undertaken by experts and include the following key steps:

- Estimation of changes in traffic speeds and traffic flows based on alternative congestion charge models

- Calculation of key net benefits across user groups affected by the scheme.

- For private users, net benefits calculated should as a minimum cover changes in time savings, travel reliability, operation expenses (petrol, car maintenance etc.) and compliance costs (congestion fees, etc.) for travellers using private and public transport.

- For the public, net benefits should as a minimum include revenues from congestion charges, changes in revenues from public transport and other revenue sources (e.g., petrol taxes, VAT, parking) and infrastructure investment and maintenance costs.

- For the city as a whole, it is important to calculate broader benefits including e.g. reduced pollution levels, reduced emissions, changes in accident numbers and other potential health impacts.

6. Energy efficiency

ABOUT 80% OF THE WORLD'S ENERGY IS BASED ON COMBUSTION OF FOSSIL FUELS THAT RELEASE GREENHOUSE GASES AND OTHER POLLUTANTS.

6.1 Characteristics of the sector

About 80% of the world's energy is based on combustion of fossil fuels that release greenhouse gases and other pollutants. Meanwhile, energy demand increases as living conditions improve around the world (UN 2014). Energy efficiency measures aim to reduce the amount of energy required to provide the products and services that citizens across the world demand, and it is important to curb emissions to provide a more sustainable future.

For cities, energy efficiency actions can be taken at two levels:

- Promoting more energy-efficient choices in the urban population through policy, regulation, or financial incentives/disincentives
- Improving energy efficiency in municipal services including lighting, transport, buildings power, heat, water and waste.

Energy efficiency measures span multiple sectors, as any action or implementation of technology resulting in reduced energy consumption belongs to this group of climate action initiatives. While changes to the entire energy infrastructure will often be based on national decisions, cities have an important role in promoting efficient use of energy to light, heat and power buildings and public space. The buildings sector is particularly important (CAM 2.0 data indicates that more than 1/5 of all climate actions taken by C40 cities target this sector). This discussion focuses on other energy efficiency measures with greater potential for urban action. One of these is improved energy efficiency in outdoor lighting, notably street lights and traffic lights. In the CAM 2.0 survey, 90% of responding cities were taking action on outdoor lighting.

6.2 Sector benefits

An important tangible benefit of actions targeted at energy efficiency is reduced energy costs. Thus, not only do energy-efficiency measures benefit society and city inhabitants via reduced emissions, cleaner air etc., but they also directly translate into savings for



city authorities on financial bottom lines. One example is the Turkish city Gaziantep, where the World Bank identified potential annual savings of more than US$50 million from energy efficiency measures targeted at improving the potable water system (pumps), the city's street lighting, etc. Even if initial investment costs in improved technologies might seem substantial, the investments are usually recovered quickly.

When measuring benefits and making the case for new energy-efficient technologies in various sectors, it is essential to conduct life-cycle cost-assessments (see guideline in the appendix).

Purchasing energy efficient technologies will often be more expensive than less energy efficient choices. To make an informed decision, cities have to look at the total cost over the technology's lifetime – including operation and maintenance costs.

Beyond financial benefits, energy efficiency actions may contribute to a number of other environmental and social benefits depending on the sector in question. Reduction of carbon emissions and thus climate mitigation are common for most measures, given that cities account for approximately 2/3 of global energy consumption (World Bank 2014).

Other common benefits are short term job creation, as the installation of new technologies is often labour intensive, enhanced public health and community liveability (see also chapter 8 on buildings).

Improved energy efficiency of street lighting represents an example where there are not only major cost saving and opportunities to significantly reduce energy consumption but also additional benefits associated with phasing out environmentally harmful technologies. Moreover, major street light retrofit projects are likely to contribute to short-term job creation, better street lighting, increased perception of street safety and potential additional effects on other factors like traffic accidents and crime.



CASE 5

6.3 **LED STREET LIGHTS IN LOS ANGELES**

THIS CASE DEMONSTRATES HOW LOS ANGELES HAS SUCCESSFULLY LAUNCHED THE LARGEST LED (LIGHT EMITTING DIODE) RETROFITTING PROGRAMME EVER UNDERTAKEN.

The programme has already resulted in significant cost savings, carbon emission reductions, less hazardous waste, local job creation, reduced light pollution and increased community liability (ESMAP 2011).

Political context and motivation – why has the city taken action?

The street light conversion in Los Angeles was an important platform in LA's ambitious 'Green LA: An Action Plan to Lead the Nation in Fighting Global Warming' from 2007. The goal is to reduce LA's greenhouse gas emissions to 35% below 1990 levels by 2030 – i.e., beyond the Kyoto targets. It represents one of the most ambitious goals of any large U.S. City (C40 – City Climate Leadership Awards).

LA's public lighting system was seen as an area with both cost and emission saving potential. Prior to the project, LA's annual electricity bill accounted for almost 1/3 of the city's annual operating budget, and lighting system maintenance costs were increasing (ESMAP 2011).

Subsequent to a comprehensive testing and cost-benefit analysis of new street light technologies before project initiation, the LED Street Lighting Retrofit Program was approved in 2008 by Mayor Antonio Villaraigosa and initiated in 2009.

Case facts

The LA LED Street Lighting Retrofit project consisted of a mass conversion of 140,000 street lights – amounting to approximately 2/3 of all street lights in LA – over a period of 5 years. The project focused on replacing high-pressure sodium vapour (HPSV) 'cobra-head' street light fixtures, mainly in residential areas.

CASE FACTS

Name: LED Street Lighting Retrofit project
City population: 13.1 million (metropolitan area)
Project inception: 2009

Key project facts of the Los Angeles LED Street Lighting Retrofit Program:

- Number of street lights replaced: 140,000 – or 2/3 of the LAs more than 209,000 street lights
- Actual phase in period: 3 years (5 years planned)
- Initial program cost: $57 million
- Payback period: 7 years

Key benefits of the project by 2012 included:

- 63.1% reduction of city energy use
- Carbon emissions reduction by 47,583 metric tonnes per year

For a comprehensive list of identified benefits, see the results section.

The key project targets were (C40 Cities and Clinton Climate Initiative 2011):

- Minimum 40% energy savings
- Reduction of minimum 40,500 tonnes of CO_2 emissions/year
- $10 million annual savings in energy and maintenance costs upon full implementation
- Project completion: 5 years
- Project payback within 7 years

In summer 2012, two years ahead of the initial plan, Mayor Villaraigosa announced the completion of the programme, with a total installation of 141,089 street lights with LED bulbs (LA Mayor's Office 2012).

How benefits have been measured

Using a life-cycle cost assessment approach, the total cost of using LED compared to traditional bulbs was analysed. This method is used to calculate all the costs that are expected throughout the lifetime of LED street lights compared to conventional street lights. Such an assessment can accurately gauge the full financial and environmental impacts of any lighting technology. Relevant data was collected from manufacturers, but verified through a number of trials in the early project phase (ESMAP 2011) and measure pre- and post-project implementation, maintenance costs, etc. Based on this data, cost-savings over the lifetime of the LED street lights was calculated.

The conducted life-cycle cost assessment only takes into account economic facts, leaving out other potential benefits to the public. Knowing the CO_2 contribution of the technology used, the contribution to carbon emission reduction goals can be calculated – although in this study they were not converted into monetary values.

Information on other benefits, such as jobs and community liveability, were collected through surveys among citizens and manufacturers, and results were reported directly along with cost-savings estimates.

Results

Cost savings from the new lights have exceeded initial programme goals. Energy

use has been reduced by 63.1% compared to the expected 40%. The project has cut LA's energy use by more than two thirds. In addition to annual cost savings, LA experienced a drastic decrease in maintenance costs with the installation of LED street lights. Thus, by 2012, LA recorded 46,300 maintenance and repair occasions compared to 70,000 in 2008. By summer 2012, the project had saved LA more than $7 million dollars per year, a number that is expected to increase to $10 million dollars per year upon loan repayment (LA Mayor's Office 2012). Comparing cost savings alone with initial project investments, the project has yielded an even higher internal rate of return than the initially projected 10% (ESMAP 2011).

Regarding carbon emissions, the project also exceeded expectations, recording reduced annual CO_2 emissions by 47,583 metric tonnes i.e. a reduction of 43%, compared to pre-project emissions of 110,000 metric tonnes. This corresponds to taking 10,500 cars off the road and providing electricity to 6,800 homes (C40 – City Climate Leadership Awards 2014). Overall, the project highly contributed to achievement of the City' GHG emission reduction targets under the Green LA plan.

Additional recorded benefits by 2011 were job creation, consisting of 11 new jobs at the LA Bureau of Street Lighting and an estimated 300 jobs for the manufacturers of LED street lighting products, according to information provided by the manufacturers (ESMAP 2011).

Moreover, light quality has improved community liveability through lower failure rates and higher optical efficiency, with a reduction of failure rates from 10% to only 0.02% and improved optical efficiency from 65 to 80%.



LED lights provide clearer and more illuminated vision than traditional street lights, drastically improving conditions for drivers, cyclists and pedestrians, and makes lighting services more reliable. The Los Angeles Police Department has even claimed that the project has been associated with improved safety across neighbourhoods, e.g., assisting helicopter operators at night, and contributed to improved crime statistics from 2009 to 2013 (C40 – City Climate Leadership Awards). Such statistics might, however, reflect developments other than improved lighting on LA streets.



CASE 6

6.4 **LED STREET LIGHTS IN SYDNEY**

THIS CASE DEMONSTRATES HOW SYDNEY HAS DEALT WITH ENERGY EFFICIENCY IN THE FORM OF CHANGING STREET LIGHTS TO MORE EXPENSIVE, THOUGH ENERGY EFFICIENT, LED LIGHTS.

Political context and motivation – why has the city taken action?

With the adoption of the plan "Sustainable Sydney 2030", the City of Sydney formulated and endorsed a set of energy related targets and goals. These include 70% emissions reduction by 2030 compared to 2006 levels.

Improving the energy efficiency of Sydney's street lighting was perceived as an important instrument for achieving these goals. Public lighting accounted for one-third of the City's annual electricity bill and a large contributor to the city's greenhouse gas emissions (The Climate Group 2013). One solution was to replace conventional lighting technologies with more energy efficient LED light technology.

Before embarking on the LED programme, the city conducted a real-life trial experiment to serve as the basis for an analysis of costs and benefits, testing in particular expected savings, quality of lighting, citizen support and potential unplanned costs (IRENA 2013).

Case facts

Based on the successful trial results, the city embarked on an ambitious LED light programme with a 7 million AUD guaranteed energy performance contract, equivalent with approximately 6.9 million USD[3] (City of Sydney 2012). The programme aimed at replacing a total of 6,448 conventional lights with new LED lights over a 3-year period from 2012-15. This corresponds to approximately 30% of the total number of street lights in Sydney and more than of the lights controlled by the City of Sydney (13,500 lights are maintained by Ausgrid). The programme made Sydney the first city in Australia to roll out new energy-efficient LED lights in streets and parks. Moreover, lighting hours were extended until 10 p.m. in major parks to improve evening usage for picnics and other low-level activities (City of Sydney 2013).

3 Based on average annual exchange rate between AUD and USD in 2012.

CASE FACTS

Name: City of Sydney's LED light programme
City of Sydney population: 187,000 (2012)
Project inception: 2012

Key aims of Sydney's LED Light Programme :

- Number of street lights to be replaced: 6,448 street lights – or 30% of City of Sydney's approximately 22,000 street lights
- Programme initiation: March 2012
- Expected payback period: 10 years

This case study is based on an extensive 18 month trial between 2010-2012, with reported results in February 2015.

For a comprehensive review of identified benefits, see the results section.

As of February 2015, more than 5,700 LED lights have been installed in streets and parks across Sydney (City of Sydney 2015).

This case rests on reported results carried out over an 18-month trial period between 2010-2012 using multiple LED lighting types and providers in various locations throughout the city (IRENA 2013 and City of Sydney 2015).

How benefits have been measured

During the trial, various types of LED bulbs were tested against conventional metal halide street lights. The City of Sydney received technical support from the Climate Group, an international environmental organisation, for carrying out technical data measurements, e.g., lighting properties, energy use and maintenance properties (The Climate Group). Measurements indicated that LEDs achieved 50-70% energy savings and that up to 80% savings could be achieved when coupled with smart controls. Moreover, the failure rate of the LED lights was very low relative to conventional failure rates. The City of Sydney has since undertaken recurrent measurements of energy use and calculated annual energy savings (City of Sydney 2015 and IRENA 2013).

Knowing carbon intensity of relevant energy sources, these numbers can be used to calculate annual reductions of CO_2.

Lastly, a survey among citizens was undertaken to assess how LED lights contributed to community liveability through improved visibility, reduced glare, natural luminosity, perception of safety, etc. The results were reported directly and not translated into monetary values.

Results

In terms of energy cost savings and corresponding reductions in GHG-emissions, by February 2015, the City of Sydney reported reduced energy use by more than 46% since March 2012, amounting to savings of almost 370,000 AUD from the 5,700 energy efficient LED lights already implemented.

Based on trial results the city expects (City of Sydney 2013):

- Reduced city electricity consumption in City owned street lights by 51% and savings in annual electricity bills and maintenance costs of nearly $800,000 a year.
- Reduction of GHG emissions by 2,861 tonnes a year, corresponding to 1/5 of the city's annual level from street lighting of 14,017 tonnes of GHG emissions (IRENA 2013 and City of Sydney 2014).
- An estimated payback period of 10 years

As to other benefits such as community liveability, the pilot phase survey showed that more than 90% of people surveyed found the new lights appealing and three-quarters said the LEDs improved visibility. Furthermore, the extended lighting hours in major parks are expected to improve evening usage for picnics and other low-level activities. Thus, there might be additional benefits for, e.g., physical activity, which have yet to be included in a more thorough analysis (City of Sydney 2015).



6.5 Lessons on LED lights from research and other cities

The cases reviewed here as well as multiple trials conducted worldwide (see, e.g., The Climate Group), illustrate that LEDs have reached technical maturity and large scale trials are no longer necessary (The Climate Group 2013). However, the extensive piloting also indicates that performance varies across various manufacturers and relative performance should be carefully verified and assessed based on independent sources.

Once the right technology is chosen and in place, the trials show that even when ignoring broader societal benefits such as improved community liveability or job creation, LED projects pay off within a relatively short period, and in some cases, in less than 5 years (LA Mayor's Office 2012). The literature within outdoor LED lighting is very much borne by the manufactures and developers themselves. However, many cities have engaged in testing various types of lighting, showing LEDs to be a very safe investment. This might also be the reason that energy efficient lighting systems are one of IEA's 25 energy efficiency recommendations.

The studies reviewed also indicate that well-functioning public lighting can improve quality of life in a city by contributing to increased road safety, improving sense of safety and allowing for longer use of public spaces for recreational and economic activities, etc. When comparing alternative green investment opportunities, it is still important to be able to measure all potential benefits of alternative projects to make an informed choice on optimal investment opportunities for the city in question. Further research on societal effects of LED lighting projects can thus be beneficial. Overall, the most important obstacle for this type of sustainable city project is the initial investment, which is quite substantial.

TABLE 6.1 **COMPARABLE VARIABLES**

Source of benefit	LA	Sydney (expected)
Number of LED lights	141,089	6,448
Energy and maintenance savings per light bulb	$71	$124
CO_2 reduction per light (kilo)	444	337
Community livability	+	+

Source: City of Sydney 2013 & LA Mayor's Office 2012.
Note: Average annual exchange rate for 2012 between AUD and USD has been used for calculating benefits in Sydney.

6.6 What to consider before undertaking a similar project

The studies above reveal that LED street light projects usually contribute positively to municipal financial bottom lines over short time horizons.

The cases reviewed here indicate the following documented benefits from sustainable street light projects:

- Cost savings from reduced energy use
- Cost savings from reduced maintenance and longer life times

- Carbon emission reductions
- Less hazardous waste
- Local jobs
- Reduced light pollution
- Increased community liveability

Moreover, improved street lighting might contribute to other benefits, for example:

- Increased traffic safety
- Increased physical activity among residents due to better lighting infrastructure.

Before undertaking a similar project, the following things are important to consider:

Large-scale trials of street lighting projects prior to investment might no longer be necessary, but it is important to carefully choose the most fitting lighting technology, which might depend on current technology in place, demand for more decorative fixtures, etc.

Even if LED technology has proven effective, it is a field under constant development, and it is important always to consider alternatives such as these based on renewable energy.

Even if LED projects seem financially viable, it is important to consider whether alternative projects might be even more beneficial when taking into account all potential economic, environmental and societal benefits

The studies from Los Angeles and Sydney indicate that benefits may differ by city. As is illustrated in table 6.1, both energy and maintenance cost savings and CO_2 reduction are expected to be higher in Sydney than in Los Angeles. This variance in benefits likely stems from infrastructure differences, the specific LED technology chosen, cost of electricity, etc. At the same time, both studies claim that community livability has been improved.



STEPS TO ASSESS STREET LIGHTING PROJECTS

- Collect data on the city's current street lighting technology and expenses
- Identify potential alternative street lighting technologies
- Pilot test the most promising alternative street lighting options for an independent assessment of properties such as installation costs, reliability, lighting properties and technical properties in you city.
- Make a list of all potential benefits across private and public actors, including wider benefits such as increased traffic safety, community liveability, etc.
- To identify relevant benefits, inspiration can be found in the introductory section of this subchapter (6.6).
- Quantify the benefits on which you have already gathered data in the pilot phase. This will typically include energy use, the carbon intensity of city energy sources, lighting properties, the investment costs. For illustrations of the specific calculations, see "how benefits have been measured sections".
- Compare the net present value of quantified benefits to installation costs over the lifetime of the alternative technology.
- Remember to compare over a life cycle scenario, including estimates of potential savings on maintenance and reductions of hazardous waste. It is a advised to compare manufacturer estimates with findings from similar projects in other cities.
- Report potential benefits that have not been quantified in non-monetised values, e.g., based on citizen surveys on improved community liveability.

Key steps to analyse whether a street lighting project would be beneficial to your city are summarised in the box above.

The following box indicates some minimum local data needs and where such data can often be found.

Overall, the cases reviewed illustrate that a limited amount of fairly accessible data is necessary to make the case for a sustainable city project within lighting. The key challenge consists in securing large scale, up-front infrastructure investments.

DATA NEEDS AND SOURCES

Minimum local data needs typically include:

- Data on the city's current street lighting technology including the number and types of street lights across the city
- Data on current city energy use for street lighting
- Data on maintenance costs of current street lighting
- CO_2 emissions of energy used
- Energy costs
- Information on alternative lighting technologies available
- Characteristics of alternative lighting technologies (installation costs, energy use, maintenance costs, lighting properties, life time, etc.).

Useful data sources may include:

- Municipal data sources and suppliers of energy
- National energy price statistics or municipal electricity bills
- For initial pre-project research, manufacturers specification of lighting technology can be used.
- For final technology choice primary data source should be independent assessments of major benefit and cost categories preferably in own city

For more information on the Los Angeles initiative, please visit:
http://bsl.lacity.org/

For more information on the Sydney case, please visit:
http://www.cityofsydney.nsw.gov.au

Or consult these resources:

- Navigant Consulting: Life Cycle Assessment of Energy and Environmental Impacts of LED lighting Products, 2012
- Climate Group, Phillips: Lighting the clean revolution – the rise of LEDs and what it means for cities
- Climate Group: Sydney LED trial: Final report
- Silver Spring Networkts, The business case for Smart Street lights, 2013

Other cities with LED street light projects, for example:

- Ann Arbour
- New York

7. **Community scale development**

AS CITIES CONTINUE TO GROW, THEY MUST CREATE ECONOMIC OPPORTUNITIES FOR THEIR CITIZENS IN AN INCLUSIVE, SUSTAINABLE, AND RESOURCE-EFFICIENT WAY

7.1 Characteristics of the sector

As cities continue to grow, they must create economic opportunities for their citizens in an inclusive, sustainable, and resource-efficient way, which fully harnesses the benefits of ecological systems and protects and nurtures these assets for future generations. Cities create value and opportunities for citizens, businesses and society by efficiently using all tangible and intangible assets to enable productive, inclusive and sustainable economic activity, while also protecting and nurturing local ecology and global public goods, such as the environment, for future generations (World Bank, 2010).

Community scale development is one of the most established sectors within green climate actions. A survey among 47 global megacities show that 66% employ community-scale development actions that are either citywide or across most of the city (CAM 2.0).

Community scale development can be split into three categories (CAM 2.0):

- Sustainable community development: actions that encourage 'compact city' and eco-district development strategies, for example, low-carbon industries.
- Land use & the environment: Actions facilitating urban agriculture and increasing green space.
- Standards for the built environment: Actions that establish building codes and/or standards for new commercial and industrial buildings and new houses.

7.2 Sector benefits

Community scale development covers many different types of actions with benefits depending on the specifics of the project. Here, some of the key benefits are highlighted with respect to increasing green spaces in the cities.



Projects, such as establishment of green areas, have a positive effect on the attractiveness of the surrounding area, which increases property values in the area. Proximity to parks or coastlines is shown to increase property value by 10-30%. Properties near train stations or metro stations also have a higher value than similar properties elsewhere (Lundhede et. al., 2013 and Panduro et. al., 2014).

Community scale development also creates value for citizens, who can use green areas for social and/or sport activities. Increased physical activity has a positive health effect by decreasing the number of lifestyle diseases connected with inactivity.

Furthermore, community scale development projects can help create jobs, attract tourism, contribute to heat reduction, reduce noise and air pollution and may be used to store water and thereby help better manage rainwater.


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CASE 7

7.3 **GREEN AREAS IN COPENHAGEN**

THIS CASE DEMONSTRATES HOW A CENTRAL TRAFFIC CORRIDOR WAS REBUILT INTO A PARK WITH MANY BENEFITS FOR THE CITIZENS IN THE RELEVANT PARTS OF THE CITY.

Copenhagen has used experiences from the recently established park to develop methods to calculate the economic value of green areas. This has been done to build a strong argument for the establishment of publicly accessible green spaces in urban areas and prevent reduction of existing green areas. The case builds on the report from this evaluation: The City of Copenhagen, 2014.

CASE FACTS

Name: City park of Sønder Boulevard
City population: 1.2 million (2014)
Project inception: 2007
Park size: 1.6 ha

The park includes a perennial garden, a playground for toddlers, a playing field for soccer and basketball, a track for BMX bikes and seating areas.

Political context and motivation – why has the city taken action?

The population of Copenhagen is predicted to increase by 100,000 by 2025. The city currently has approximately 1.2 million citizens. The increased population requires additional housing, new business areas and new infrastructure, which all requires space, a scarce resource in the city. It is therefore challenging to find space for green areas, and even more so because the value of green areas is often considered to be subjective, value-based and to some degree undocumented (The City of Copenhagen, 2014).

Sønder Boulevard was a central traffic corridor in Copenhagen. The area's attractiveness had experienced a decline, which was worsened when the boulevard's elm trees died. As part of a general renewal of the area, it was decided to transform the boulevard's broad central reserve into a park with various facilities.

Case facts

The city of Copenhagen spent approx. $2.5 million constructing the park, which was completed in 2007. Trees, pavement and grass were used to create a so-called "strip park" with a perennial garden, a playground for toddlers, a playing field, a track for BMX bikes and seating areas with different ambiances. The layout of the boulevard was designed to not favour one activity over another.

As Sønder Boulevard is no longer a traffic corridor, speed limits have been lowered to 30 km/h and 40 km/h to encourage the area's attractiveness.

How benefits have been measured

There is limited available data to measure the value created by the park. The report therefore applies economic estimation techniques with detailed data collected from various public sources and from specially designed surveys aimed at the users of the park. The report focuses on following four aspects of the park's value:

- Property value
- The value created for service and trading companies
- The value of park activities
- Health value due to increased physical activity

Property value

Parks increase the attractiveness of an area, and by extension the values of properties near the park. This increase in property value can be estimated with a hedonic pricing method, (see the description in the glossary) where the actual sale price of flats in the period 2010-2013 is compared with an estimated sale price based on detailed data for all flats sold in Copenhagen in the period.

Data includes the sale prices as well as a range of characteristics for the flats such as size, age, etc. The difference between the actual sale price and the estimated sale price for flats in the proximity of Sønder Boulevard is attributed to the attractiveness of the park.

The calculations also include changes in property taxes as a result of increased property values.

Value created for service and trading companies

It is hypothesised that attractive green areas attract more people and potential customers. This will be reflected in the number of companies, increasing contribution margins and more employees.

The analysis is based on company lists from the Danish Central Business Register (DCBR) for firms in selected industries such as trade. There is limited publicly available information for company performance, which is a challenge. Proff.dk is a privately operated database with information on contribution margins for individual firms in Denmark. This information has been web scraped and combined with company data from DCBR.

The analysis seeks to demonstrate a correlation between commercial activities and distance to Sønder Boulevard.

The value of park activities

The value of park activities is measured by applying the travel cost method (see guidelines in appendix). Thus, when a person



chooses to visit the park, the person opts out of other activities, such as spending time at work. In other words, there is a so-called opportunity cost in spending time at the park. The person will only spend time in the park if the value derived for this individual is higher than the opportunity cost.

The opportunity cost is calculated in monetary terms by using transport economic unit prices from the Danish Ministry of Transportation's calculation tool for socio-economic analyses, TERESA (homepage is in Danish). This information is applied to knowledge on how much time the visitors spend in the park including transport to and from the park. This knowledge was collected through a survey of the park's visitors.

Health value due to increased physical activity

The survey also gathered data on how visitors use the park, for example actively (ball games, running etc.), or inactively (social events, sitting on a bench etc.). The respondents were also asked about physical activities outside the park. The survey makes it possible to identify individuals for whom physical activity at Sønder Boulevard changed inactivity to activity.

The effect of exercise on the risk of lifestyle diseases and consequently health costs and losses due to reduction of production is calculated in the report "Cycling, health and economy" by Trafitec, 2007.

Results

The report estimates that proximity and access to the green area Sønder Boulevard has increased the value for proximal properties by USD 63 million[4]. This corresponds to almost 1% of the total value of properties

4 The average exchange rate in 2013 was 5.61 DKK/USD.

within 1,000 meters walking distance of Sønder Boulevard.

The increase in property value also leads to increased tax revenues of USD 2.2 million each year.

The analysis could not detect a relationship between the boulevard and performance in service and trade businesses. The authors hypothesise this may be due to limited data on firm performance and the influence of other factors in the area, such as the effect of Kødbyen, the former meatpacking district, now home to a large number of restaurants, bars and cafes.

The survey finds that 600,000 people visit the boulevard each year and spend 129.5 minutes on average in the park and 14.9 minutes per visit on travelling. It is calculated that the value of all park activities is USD 22.5 million.

Finally, the analysis finds the park has a modest health effect, corresponding to an annual value of USD 0.3 million. The effect on health is limited, as the park is primarily a leisure rather than sports park.

The results are summarised in the table 7.1.

7.4 Lessons on green areas from research and other cities.

Even though the above mentioned analysis does not find a positive effect on service and trade business, other studies indicate a positive effect of green areas as well as good infrastructure. A Danish study of rental prices of commercial leases shows that proximity to parks, coastlines, etc. increases rental prices 30-40% (Panduro et. al., 2014).

TABLE 7.1 **RESULTS, GREEN AREA IN COPENHAGEN**

Source of benefit	Value (1,000 USD)
Effect on property value	65,171
Increase in property value	63,016
Annual increase in tax revenues	2,154
Service and trade business	No clear conclusion
Park activities (annual value)	22,496
Health value	287
Reduction of direct healthcare related cost	72
Reduction of production loss	215

Source: The City of Copenhagen, 2014
Note: Average currency exchange rate for 2009 has been used between Danish Kroner and US Dollars. The exchange rate was 5.57 DKK for 1 USD

Analytical tools have not yet been developed to quantify every aspect of green areas. There is, for instance, no agreed-upon methodology for valuing the carbon sequestration value of a city park (Harnik and Welle, 2009). To build arguments in favour of these effects, it may be necessary to use case studies and references to other research.

The effects of green areas on property values, private activities, business activities, health and clean water and air are thoroughly described in the literature, and well accepted methods to

STEPS TO ASSESS GREEN AREAS

- List all potential benefits that accrue to users of the green area as well as other citizens that benefit from the park's attractiveness.
- Prioritise benefits that are most important to your city and you have or can get valid data for. If, for example, the project focuses on establishing ball courts, skate ramps, etc., then health benefits may be more relevant to assess.
- Gather data on selected benefits and costs locally and from other studies/ cities. If resources are limited or the project scope relatively small, it is a good idea to use findings from other cities, especially in areas where benefits are expected to be less important.
- Adapt findings from other cities to local specifications, e.g., local prices, income levels, infrastructure etc.
- Report potential benefits that have not been quantified in non-monetised values, e.g., based on citizen surveys on improved community liveability.

quantify the effects have been developed. For example, Harnik and Welle (2009) reference more than 30 studies that show parks have a positive impact on property values, which can be measured up for to 2,000 feet (600 meters).

Evaluations of these effects are often hampered by lack of data. Only a few cities have data for park visitation and visitor origin. This makes it difficult to estimate, for example, the degree parks help attract tourists who patronise regional businesses.

7.5 What to consider before undertaking a similar project

Sønder Boulevard in Copenhagen has significant benefits for its users and on the value of properties near the park. Evaluations of other parks in other cities and climates find further benefits. Below is a list of some of the general benefits parks give to cities:

- Increased property value
- Benefits for service and trade businesses
- The value of park activities (the enjoyment people experience when using the park)
- Health benefits due to increased physical activity
- Urban cooling
- Slowing rainfall run-off
- Air filtration (and improving health)

The analysis referred to in the case above focuses on an area in Copenhagen and is specific to local conditions. The analysis may not be directly applicable to other geographic areas. For example, evaluations of other green areas may find significant effects on businesses performance.

DATA NEEDS AND SOURCES

Minimum local data needs typically include:

- The expected impact on property values may be estimated by applying percentage increases found in existing literature (preferably local studies) to data for property values usually found at statistical bureaus and/or financial institutions.
- To estimate the value of park activities and the health benefits from increased physical activities, start with surveys of users of existing similar parks in the city. The value attributed to the user's time-usage of the park can be derived from transport analysis manuals made by the local ministry of transportation (see also the cases with BRT systems in Bogotá and Istanbul). The health benefits linked to increased physical benefits may be found in existing research such as the above mentioned case.
- Data for current city temperatures and rainfall may be found at local meteorological institutes.
- Data for the city's air quality is usually available at local environmental agencies.

Some benefits could vary, if e.g. weather conditions are more extreme, people use parks less. This will have a negative effect on personal health benefits.

In most cities, green areas have value. The value relies on, e.g., the proximity to other green areas, the general development in the area etc. The added value of establishing a green area is higher if there are no or only a few other nearby green areas.

In some cases where there appears to be a link between green infrastructure and societal benefit, the scientific basis necessary to enable quantification and/or monetisation is not sufficiently robust.

The box on the previous page reviews the most important steps to consider when assessing the value of green areas.

There seem to be few, if any, proper methodological models that predict the usage and value of new green areas. Analysts that wish to evaluate new green areas often rely on results from existing literature combined with surveys of citizens and users of the city's other green areas. The box above indicates some minimum local data needs and where such data can often be found.



FOR MORE INFORMATION ON THE SØNDER BOULEVARD CASE, PLEASE VISIT:

The City of Copenhagen: Economic Valuation of the Green Areas in Copenhagen, 2014

Or consult some of these resources:

- OECD: Cities and Green Growth: A Conceptual Framework, 2011.
- The World Bank: Eco2 Cities – Ecological Cities as Economic Cities, 2010.
- LSECities: How Cities are leading the next economy, 2013.
- Harnik, Peter and Ben Welle: Measuring the economic value of a city park system, 2009.

Examples of other urban green projects:

- Ropner Park, Stocktion-on-Tees, England
- Knowledge Quarter (LKQ), Liverpool
- Hamburg Green Network

8. **Buildings**

THE BUILDINGS SECTOR ACCOUNTS FOR 1/3 OF GLOBAL ENERGY USE AND 1/5 OF ALL CO_2 EMISSIONS. IT IS THEREFORE A VERY IMPORTANT SECTOR IN THE URBAN TRANSITION TOWARDS SUSTAINABILITY AND CLIMATE RESILIENCE.

8.1 Characteristics of the sector

The buildings sector accounts for 1/3 of global energy use and 1/5 of all CO_2 emissions. It is therefore a very important sector in the urban transition towards sustainability and climate resilience. Widespread implementation of best practices can lead to a stabilisation or even reduction in energy use in buildings by 2050. Moreover, buildings offer near-term, highly cost-effective opportunities to limit energy demand growth rates (IPCC 2014).

It is therefore not surprising that the buildings sector is a focal point of city climate action efforts. Based on a survey of 59 global megacities, it is the sector with highest number of initiated climate actions and expected future actions (CAM 2.0).

In general, climate actions targeting both new and existing buildings (retrofitting) can be divided into two areas:

- Reducing energy use in buildings through the introduction of new technologies that reduce energy demand (e.g., improved isolation, more efficient heating and cooling systems, etc.)
- Integrating technologies into the building that deliver cleaner energy (e.g., solar panels or small wind turbines)

8.2 Sector benefits

Urban climate actions in the buildings sector serve a multitude of objectives. Projects often do not only benefit owners and tenants, but also serve more general purposes such as (storm) water management and adaptation or mitigation, depending on the type of project.

Two key benefits of sustainable city projects relating to buildings are the reduction of carbon emissions and energy costs. Reduced emissions are a natural consequence of initiatives aimed at reducing building energy consumption or switching building energy consumption to cleaner energy sources. Indeed, given the high share of global energy use by the buildings sector, it may have significant climate mitigation effects. The IPCC argues that global greenhouse gas emissions could be cut by a third through better design and operation of commercial and residential buildings.



Similarly, such building projects often entail significant reductions in energy costs for owners or tenants. Examples are large scale building retrofit initiatives, like London's RE: FIT programme, which reduced energy consumption in retrofitted buildings by 28%. To date, by retrofitting over 400 of London's public sector buildings, the programme has generated estimated annual CO_2 savings of 30,000 tonnes (RE:FIT 2015). These benefits are also the focus of most economic assessments of sustainable building projects, for example, Oslo city's Climate and Energy Fund, which has subsidised energy efficient retrofitting of Oslo buildings since 1982.

There are a number of other potential benefits of green buildings projects. One of these is the creation of local jobs. Retrofitting of buildings is usually labour intensive, and can thus result in important short-term job creation. Examples are the City of Toronto's Better Building Partnership, which through refitting an area 525 mil. ft^2 (corresponding to approximately 7,000 soccer fields) is estimated to have generated 31,250 jobs.

Lastly, certain types of building projects contribute to climate adaptation, public health and even community liveability. Climate adaptation occurs when building projects, e.g., improve building resilience and resistance or (storm) water retention. Public health benefits typically occur when building projects improve urban air quality or indoor climate. Finally, community liveability typically occurs when building projects improve aesthetics (Portland 2008, 2010). Such benefits are less frequently included in assessments of sustainable city projects and require sophisticated economic methods to assess their economic value. For example, one method to capture increased community liveability is to look at the development of property prices (all else equal).

One type of climate action in the buildings sector that serves multiple purposes is ecoroofs. Ecoroofs are generally installed to respond to two primary climate drivers: precipitation and temperature, and can be green (vegetated), white (cooling), or blue (water managing). As the following case study illustrates, green roofs are particularly interesting, as they entail a large variety of potential benefits.



CASE 8

8.3 **ECOROOFS IN PORTLAND**

THIS CASE DEMONSTRATES HOW PORTLAND, AS PART OF A ITS GREY TO GREEN INFRASTRUCTURE PLAN (PORTLAND 2008), HAS USED EXTENSIVE GREEN ROOFS (ALSO CALLED ECOROOFS) TO GENERATE A WIDE VARIETY OF BENEFITS.

These benefits, include storm water management through reduction of rooftop runoff, reduced energy demand through better insulation, reduced urban heat island by reducing rooftop temperatures, improved local air quality through plant photosynthesis, and the creation of natural habitats and improved community liveability through aesthetics and green spaces (Portland 2010).

Political context and motivation – why has the city taken action?

In Portland, average annual rainfall generates approximately ten billion gallons of storm water runoff. This challenge has traditionally been managed through so-called 'grey' storm water infrastructure, which moves storm water from points of collection to a centralised treatment area. Increasingly, Portland has sought sustainable storm water management solutions that make use of systems that mimic natural processes.

Central to this strategy is the Portland Ecoroof Program. Portland has worked with ecoroofing since 1996. From 1999 onwards, ecoroofs have been included in the city's storm water management manual as a preferred best management practice for reducing storm water runoff. Based on these initial positive experiences, Portland has promoted development of ecoroofs through a number of incentive schemes using regulatory, administrative and financial tools. An important step was the adoption of the "Grey to Green" strategy in 2008, which provided significant funding for the programme and accelerated ecoroof development.

Case facts

Ecoroofs replace conventional roofing with a living, breathing, vegetated roof system.

The Portland Ecoroof Program has promoted ecoroofing of Portland rooftops since 1999.

CASE FACTS

Name: Portland Ecoroof Program
City population: Approx. 0.6 million (2.3 metropolitan)
Project inception: 1999
Number of ecoroofs: 344 ecoroofs and 138 roof gardens covering 33 acres (2013), representing 0.3% of Portland's 12,500 acres of roof space.

Ecoroofs replace conventional roofing with a living, breathing, vegetated roof system. An ecoroof consists of a layer of vegetation over a growing medium on top of a synthetic, waterproof membrane.

The central aim of the Portland Ecooroof program is to
decrease storm water runoff and restore healthy watersheds.

It is estimated that Portland ecoroofs retain and evaporate 55% of annual rainfall, implying a storm water runoff reduction of 18.2 million gallons.

In 2013, there were 344 ecoroofs and 138 roof gardens in Portland covering 33 acres and comprising 0.3% of an estimated 12,500 acres of rooftop space in Portland.

The main aim of the program has been to decrease storm water runoff and restore healthy watersheds. Additional benefits based on economic analyses in 2008 and 2010 include energy savings, reduction of pollution and erosion, cooling of urban heat islands, increased habitat for birds and insects and green space for the urban population (Portland 2008, 2010).

This case rests on two economic analyses carried out by the Portland Bureau of Environmental Services (BES) in 2008 and 2010, with the purpose of assessing whether the benefits of Portland Ecoroofs exceed costs and thus warrant further funding.

How benefits have been measured

To conduct a lifetime cost-benefit analysis, monetised values of the costs and benefits associated with the roofs over their full lifetime need to be obtained. While it is relatively easy to identify costs associated with ecoroofs (increase roof construction, operations and management costs), it is not easy to quantify the costs because each ecoroof is unique. There are a variety of potential benefits that are also difficult to assign economic values to.

Taking a comprehensive list of potential benefits associated with ecoroofs across private and public sectors as a starting point, BES adopted a two-step data collection strategy. First, a comprehensive literature review was carried out to gather evidence on key benefits and costs from other studies. Secondly, the identified benefits and costs were converted to Portland-area specifics.

Table 8.1 contains an overview of the potential benefits included in the analysis.

One important limitation to this study is that only costs and benefits included in other

TABLE 8.1 **BENEFITS INCLUDED IN THE ASSESSMENT**

Storm water management

- Reduced storm water quantity (public)
- Avoided storm water infrastructure (public)
- Reduced system management costs (public)
- Reduced storm water fees (private)
- Reduced infrastructure costs (private)

Energy and Climate

- Reduced energy demand (private)
- Reduced Heating, Ventilation and AC equipment size (private)
- Reduced energy costs (private)
- Reduced carbon emissions (public)
- Improved air quality (public)

Habitat

- Enhanced habitat (public)

Building development

- Improved roof durability (private)
- Increased floor area ratio (FAR) (private)
- Reduced operations & management (private)

Source: City of Portland 2008

studies are part of the analysis. In fact, a number of potential benefits, including improved watershed, reduced basement flooding, reduced urban heat island effects, enhanced carbon sequestration, enhanced aesthetics, increased property value and reduced building insulation have not been quantified as part of the study.

To estimate the benefits of a Portland ecoroof, data and evidence from other studies was converted to a comparable unit of measurement and adapted to Portland's context. To do so, the city defined attributes of a typical ecoroof appropriate for Portland's climate and adjusted identified benefits accordingly.

Looking at the calculated energy savings illustrates the applied methodology. Energy savings in the Portland case were primarily expected to result from reduced pumping in the combined sewer system. Therefore, it was necessary to estimate the proportion of ecoroofs located in the combined sewer area. Portland BES estimated that 80% of the ecoroofs would be located in the combined sewer area. This indicated that every acre of ecoroof resulted, on average, in the reduction of approximately 442,100 gallons of storm water annually from the combined sewer system. Using the BES estimate of $0.0002 of electricity cost per gallon on combined sewer storm water and an energy price of $0.06 per kilowatt hour (kWh), there is an estimated annual energy savings per ecoroof acre of 1,470 kWh (Portland 2010).

Assuming that all buildings with ecoroofs are heated and cooled throughout the year, the total annual energy savings of an ecoroof per square foot is 0.156 kWh, and the annual

TABLE 8.2 **OVERVIEW OF ANNUAL ENERGY SAVINGS**

Storm water	UHI	Insulation/Shade	Total
1,470 kWh/Acre	Relationship: Positive mitigation	6,800 kWh/Acre	8270+ kWh/Acre

Source: Portland 2010

energy savings from insulation per acre of ecoroof is estimated at 6,800 kWh (see table 8.2).

Generally, the City of Portland BES found ecoroofs were associated with improved physical and mental health beyond air quality effects. However, BES found that few studies have been able to demonstrate a clear quantitative relationship between green roofs and improved health. Therefore, a qualitative description of potential health effects is included (Portland 2010).

Results

Employing the methodology described above, Portland estimated the value of various benefits to private and public actors associated with a typical Portland Ecoroof with a lifetime of about 40 years.

As table 8.3 illustrates, Portland found that the largest benefits for private citizens consist of the one-off value of increased roof longevity and recurrent annual benefits of stormwater management and reduced energy demand.

For public actors, the most important benefits consist of a one-off savings on stormwater management infrastructure and the value of improved air quality over the roofs' lifetime.

Comparing the value of these benefits to the value of private and public construction, operations and management costs, the city of Portland found that construction of ecoroofs imparts immediate and long-term benefits for the public and positive net benefits for building owners from year 20. Since the assumed lifespan of an ecoroof in Portland is about 40 years, the analysis shows that although ecoroofs initially cost more than conventional roofs, they are competitive on a life-cycle basis for private owners. Over an ecoroof's lifetime, benefits exceed costs by approximately $700,000, due to longevity. For private building owners, benefits will not exceed costs until year 20, which might be the root of initial reluctance to make the investment.

Moreover, in the 2010 analysis, the city of Portland identified a number of additional benefits that were not converted into monetary values and thus are excluded from the

TABLE 8.3 **VALUE OF BENEFITS (USD 2008) – PORTLAND ECOROOF**

Source of benefit	One time	Annual
Total private benefits	**$690,000**	**$2,810**
Stormwater management	-	$1,330
Energy demand (cooling and heating)	-	$1,480
Avoided stormwater facility cost	$69,000	-
Roof longevity	$600,000	-
Heath, Ventilation and AC equipment sizing	$21,000	-
Total Public benefits	**$86,000**	**$3,053**
Stormwater management	$60,700	
Carbon reduction	-	$29
Improved air quality	-	$3,024
Habitat creation	$25,300	-

Source: Portland 2008. Note: The distinction between one time i-e. initial and annual i.e. recurrent benefits allow calculating benefits over the full investment horizon, that the investor is willing to consider.

TABLE 8.4 **DOCUMENTED NON-MONETISED BENEFITS**

Source of benefit		Effects
Health	Increased greenness	Associated with improved physical and mental health
Energy	CO_2 reduced emissions	7.1 metric tonnes/acre/year
Community Liveability	Amenity/ aesthetics	Possible positive effect on property prices
	Community cohesion	Possible positive effect on social capital, unknown effect on crime
	Environmental equity	Possible positive effect, depends on rooftop location
	Access to nature	Magnitude depends on number of people with views of or access to ecoroofs

Source: Portland 2010

above analysis. This implies that the social benefits of Portland's ecoroofs are expected to be even higher. Table 8.4 provides an overview of the additional effects.

8.4 Lessons on ecoroofs from research and other cities

Ecoroofs have drawn political attention in many cities due to their numerous advantages. Multiple cities have policies and guidelines for when ecoroofs have to be installed, for example. Some cities prefer a specific type of roof, e.g. white roofs, if their challenge is mostly in relation to heat, whereas other cities have regulations in place that ensure installation of green roofs for stormwater management.

The C40 CAM 2.0 report shows that heat risk, i.e., more hot days, increased urban heat island effects, hotter summers are considered to be extremely serious and pose an acute risk to a majority of reporting C40 cities. 57% of these cities have green roof initiatives to address these risks.

Toronto's Eco-Roof Incentive Program

Since 2009, the City of Toronto has provided financial support for green and cool (white) roof projects of $75/ and $2-5 per square metre respectively (within certain maximum limits). The program is seen as a key element of the City's Climate Change Action Plan, which aims at reducing Toronto's greenhouse gas emissions by 80% by 2050. To date, the program has helped fund the installation of more than 100 green and cool roofs. To our knowledge, no comprehensive evaluations of the programme have been undertaken based on actual observed data. A cost-benefit analysis undertaken before the programme was initiated, however, indicated that widespread implementation of green roofs in Toronto would provide significant economic benefits, particularly in the form of stormwater management and urban heat island and energy reduction. Other benefits included improved air quality and reduced emissions.

Greening of London's central business district

As part of the Mayor's climate change adaptation strategy, Managing Risks and Increasing Resilience, London supports green roofs, green walls and local green spaces in London's business districts, providing best practice guidance and project audits (City of London 2015). It is estimated that there are around 700 green roofs in central London covering an area of over 175,000 m^2 or approximately 25 football pitches. To our knowledge, there are no large-scale assessments of the economic or environmental benefits of London's green roofs. However, numerous case studies of individual roof projects can be found.

General lessons

Political attention to ecoroofs has also generated some detailed studies of the cost and benefits of ecoroofs. When drawing insights from these studies, it is important to consider the local context and climate. Policymakers interested in the benefits of ecoroofs for their city therefore often have to launch studies of their own, in which city-specific benefits are either estimated directly or derived from other cities and adjusted to local climate and context.

Another challenge when assessing ecoroofs is that the total lifetime of an ecoroof is not



agreed upon, which makes the conclusion that ecoroofs are a sound investment debateable. An estimate of the lifetime of ecoroof alternatives (notably conventional roofs) is equally important. There are many different suppliers of different types of ecoroofs, and green roofs use slightly or substantially different technologies. Combined with differences in climate and other conditions, many factors can impact the results of the analysis.

According to one assessment (CCAP 2011), the life cycle net present value of green roofs is as much as 40% higher than a conventional roof, taking into account storm water management, reduced electricity cost and air quality benefits. Without air quality benefits, the average is 20-25% higher for green roofs compared to conventional roofs.
Even though green roofs are more expensive to install than conventional roofs, the benefits can make them cost-effective to install, especially if costs and benefits can be aggregated across many installed roofs covering larger urban areas.

There is a strand of literature looking at conditions for which different types of ecoroofs are more appropriate (e.g. Sproul et al. 2014, CCAP 2011) Green roofs are typically preferred to white or blue ecoroofs because they have a wider range of environmental benefits, including stormwater management and energy savings. From a public perspective, green roofs are thus often the most interesting.

8.5 What to consider before undertaking a similar project

The case presented here illustrates some of the benefits that should be included when assessing the costs and benefits of an ecoroof. These include:

- Stormwater management savings
- Energy demand reduction (heating and cooling)
- Roof longevity
- Carbon emissions reduction/carbon sequestration
- Improved air quality and associated health effects
- Habitat creation
- Community liveability and aesthetics

The Portland ecoroof case indicates that stormwater management savings and energy demand reduction represent the most important economic benefits of ecoroof installation.

It is important to note that the benefits presented are representative for Portland ecoroofs, and may therefore not be directly applicable to other cities or geographic areas. The stormwater fee for all commercial buildings in Portland is an example of Portland-specific private gains. This is illustrated in the comparison of selected documented benefits from ecoroof projects in Toronto and Portland in table 8.5. Measured per square foot of ecoroofs, there are large differences in the benefits from stormwater avoidance and improved air quality between the two studies, while benefits from private energy savings are similar.

There are numerous reasons why these differences are observed. Different climate, rainfall, or the type of ecoroof installed impacts the benefits reaped. More technical aspects, such as different discount rates or measurement methods also impact results. When comparing the Toronto and Portland studies, the data the results are contingent on comes from very different sources. The Toronto study is based on a large implementation of 5,000 hectares of ecoroofs, equivalent to more than 538 million square feet, while the Portland study is based on an example of a 40,000 sq. feet ecoroof.

The case reviewed here illustrates some key steps in undertaking a cost-benefit analysis of your own, summarised in the box below.

TABLE 8.5 **SELECTED BENEFITS IN USD 2008 – TORONTO & PORTLAND**

Time discounted benefits per ft²	Toronto	Portland
Stormwater avoidance	0.19	4.39
Private energy savings	1.03	1.09
Air quality improvement	0.12	2.61

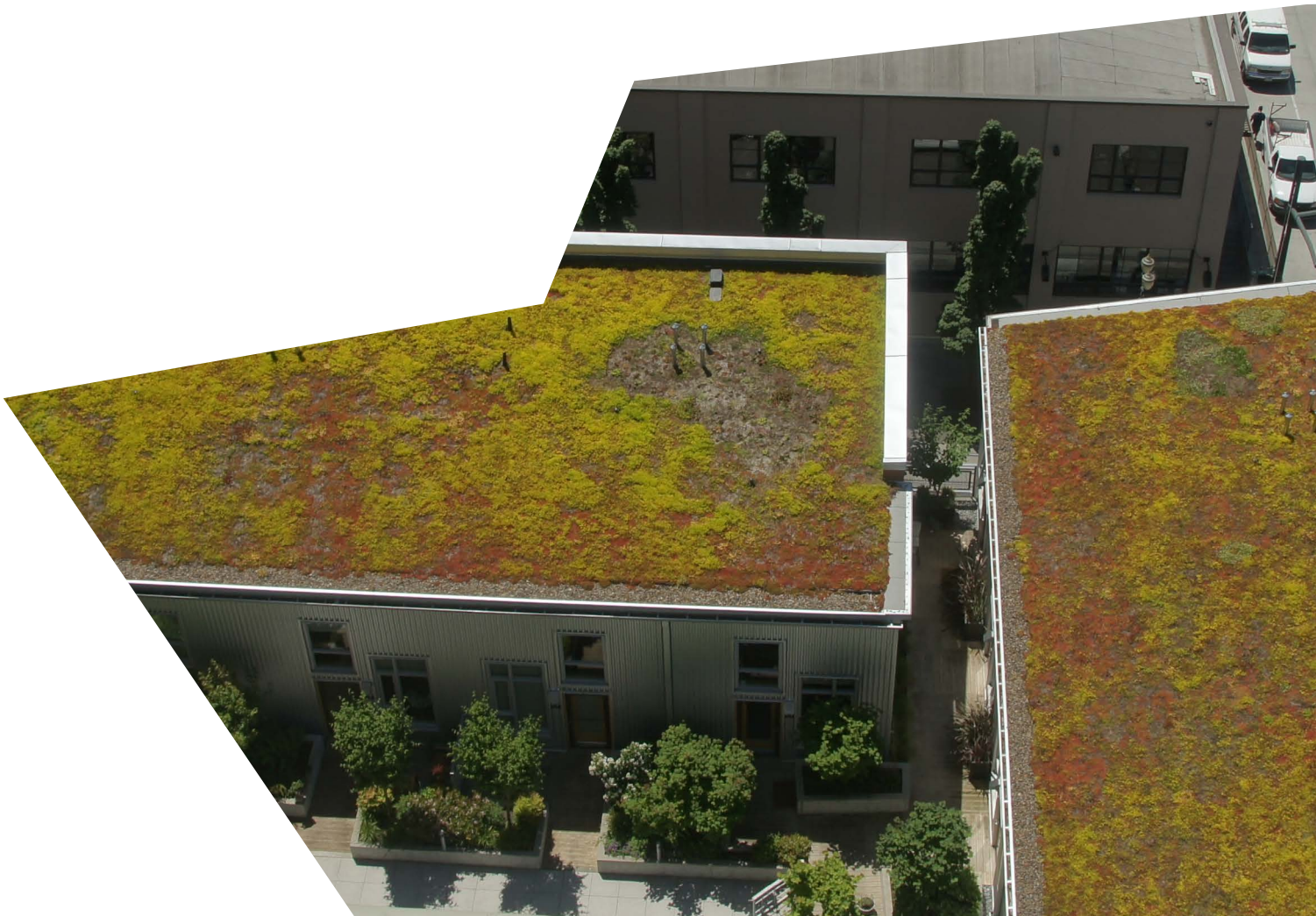
Source: City of Toronto & Portland 2008
Note: CPI for Canada between 2005 and 2008 has been used for Toronto. An average exchange rate in 2005 between Canadian Dollars and US Dollars has been used. A discount rate of 1.5% for annual savings in the Toronto study has been used because this is used in the Portland case.

As illustrated, it is possible to adapt findings from other studies rather than gather all data locally and carry out estimations from scratch.

It should be noted that the benefits of a given ecoroof are dependent on local conditions, and costs and benefits need to be correspondingly adapted. The box on the next page indicates some minimum local data needs and where such data can often be found.

Other aspects to be considered in connection with ecoroof projects are related to the project's timing. For a new building project, the best time to consider an ecoroof is during the initial concept/schematic design phase. The best time to consider an ecoroof for an existing building is when the roof needs repair or replacement, or when considering seismic upgrades, remodelling or retrofitting.

Lastly, the experience from Portland is that calculating the costs and benefits of ecoroofs and make them publicly available is important to promote ecoroof development. A significant driver in convincing the construction industry, developers, etc. of the benefits of ecoroofs is their extended lifetime (20 years longer than conventional roofs).



STEPS TO ASSESS ECOROOFS:

- Make a list of all potential benefits across private and public actors, including wider benefits such as habitat creation, aesthetics, etc.
- To identify benefits, table 8.1 and 8.3 list benefits that have been assessed in the Portland case, while table 8.4 contains an overview of potential wider benefits.
- Prioritise benefits that are expected to be most important to your city. In cities where rainfall is important, this is likely to be storm water management.
- Gather data on selected benefits and costs locally and from other studies/cities. If resources are limited, it is a good idea to use findings from other cities, especially in areas with less expected benefits.
- Adapt findings from other cities to local specifications, e.g., local energy costs, local weather conditions such as rainfall and temperature, construction costs and local building conditions.
- Compare the present value of benefits to the present value of costs over the lifetime of an ecoroof.
- Report potential benefits that have not been quantified in non-monetised values, e.g., based on citizen surveys on improved community liveability.

DATA NEEDS AND SOURCES

Minimum local data needs typically include:

- Local weather conditions, including temperature and rainfall
- Total cost of installation of ecoroof vs. costs of conventional roofs
- Characteristics of available local ecoroofs vs. conventional roofs (maintenance, lifetime etc.)
- Current energy use for stormwater facilities, heating and cooling
- Energy costs
- CO_2 emissions of energy used

Useful data sources may include:

- Weather statistics from national weather services
- National building construction cost indexes for labour and material for various construction works.
- Local manufacturers can often supply more specific estimates of expected ecoroof costs and life times.
- National energy price statistics or municipal electricity bills
- National governments often provide national energy statistics including CO_2 emissions per Kwh of various energy sources.

FOR MORE INFORMATION ON THE PORTLAND INITIATIVE, PLEASE VISIT:

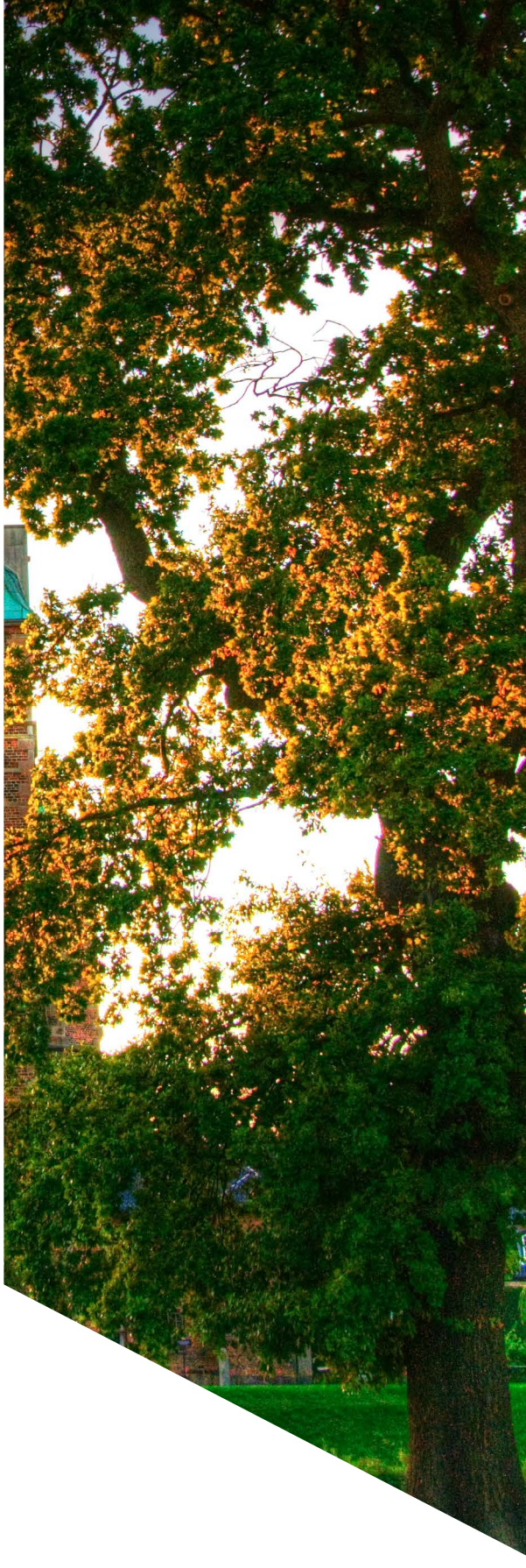
https://www.portlandoregon.gov/bes/44422

Or consult some of these resources:

- CCAP: The value of Green Infrastructure (2011)
- EPA: Case studies Analysing the Economic Benefits of Low Impact development and Green infrastructure (2013)
- Portland: Cost-benefit Evaluation of Ecoroofs (2008)
- Portland: Eco benefits of G2G program (2010)
- Doshi, H & S. Peck: Methods for Estimating Economic Public Benefits from Regional Implementation of Green Roof Technology
- Toronto and Region Conservation: An economic analysis of green roofs (2007)
- Gilardi, E: Cubiertas Verdes in Buenos Aires
- Hess, D: Sustainable City Projects

Examples of other cities with green roof projects

- Toronto
- London
- Oslo
- Berlin
- New York



9. **Appendix: Best practice guide**

Methods and analytical frameworks

This guide has been developed as part of a C40 project exploring the challenges of estimating the economic benefits of sustainable city projects.

This projects hopes to foster green and sustainable cities by focusing on the intersection between society, the environment, and the economy to find common ground in advancing social, environmental and economic goals.

C40 focuses on green and sustainable growth in cities, because cities are a critical part of the global green transition. The majority of the world's population lives in urban areas, and cities are both the main drivers of growth and innovation and major users of natural resources. Many interesting projects and actions are already taking place in cities worldwide, and further sharing of knowledge and possibilities is beneficial.

With this overview and easy-to-use guide, cities are better able to make broader economic evaluations of city projects. This will form the basis for bringing forth sound economic arguments for sustainable initiatives and assist in navigating the myriad of methods for assessing the value of sustainability. The guide focuses on commonly used methods for urban sectors of interest.

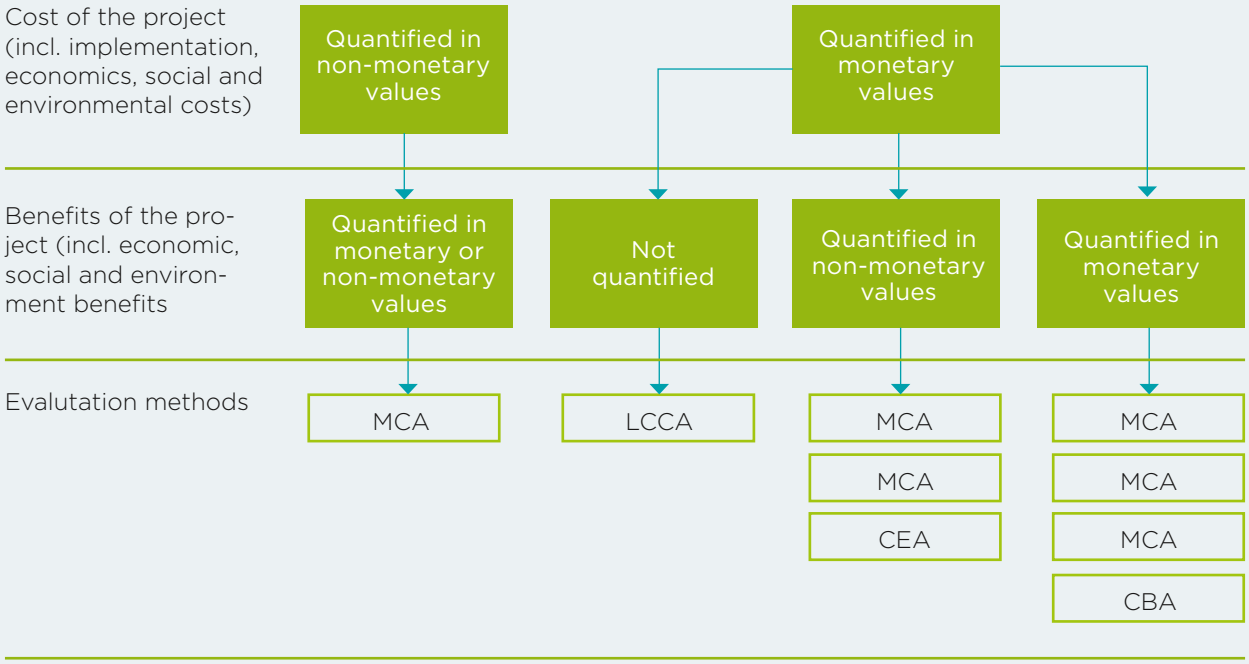
Numerous methods and analytical frameworks to assess the benefits of sustainable urban initiatives exist. In the following, methods most commonly used in city projects are presented. These are by no means exclusive. Generally, the overall aim of the methods is to internalise the externalities from environmental and social costs and benefits so they are included in the decision-making process.

9.1 Overview of methods

To estimate the positive and negative effects of city projects, it is necessary to find a suitable method of comparison. A common method is to compare cost and benefits, valuated in monetary terms. However, it is not always possible to attach monetary value either practically or cost–effectively.

The methods covered in the following are: multi-criteria analysis, life cycle cost assessments, cost- effectiveness analysis and cost-benefit analysis. These methods are widely used and approach the valuation of project benefits

FIGURE 9.1 **DECISION TREE**



Source: DAMVAD 2014. Note: Simplified. MCA – Multi Criteria Analysis, LCCA – Life Cycle Cost Analysis, CEA – Cost Effectiveness Analysis, CBA – Cost-Benefit Analysis

from different perspectives. Using other information as a proxy for impact measurement is also touched upon.

Decision tree

Figure 9.1 is meant to help navigate how to identify the available method for a project, given the project or city specific circumstances such as size, political objective, or data availability. The methods included in the figure are covered in detail in this guide, whereas the methods briefly described in the section "other" are omitted.

Before using the decision tree, have a specific project or programme in mind. If the project costs, including indirect project costs, can be quantified in non-monetary value, use the simple Multi-Criteria Analysis (MCA). If you have quantified the cost and indirect cost in monetary values, you should then look at the benefits of the project. If they are not quantified, Life Cycle Cost Analysis (LCCA) is an obvious option. If the benefits are quantified, but in non-monetary values, there are several options: MCA, LCCA or Cost Effectiveness Analysis (CEA).

If benefits are quantified in monetary values you can still use the MCA, LCCA and CEA to evaluate your project, but you can also use the Cost-Benefit Analysis, which is the most economically exact.

Cost and benefit assessment in general

To evaluate costs and benefits, it is useful to distinguish between cases in which a market for the goods concerned exists and cases in which no markets exists. This is because economists view impacts from a resource perspective; if a resource is spent on a particular project, it cannot be spent on another. For example, if a person spends time in congestion that time cannot be spent working. This implies that the value of a resource used or saved due to a green project is equal to the value of the affected resource's second-best use. When a market exists (assuming markets function reasonably well), the value is simply the market price. The value of an hour saved by a business traveller is thus his hourly wage.

When no market exists, and cost and benefits are assessed in non-monetary values, they should be either converted to a monetary value or treated in another way. Regardless of format, the results should be included in the final project assessment and in decision processes.

The level of complexity is illustrated in figure 9.2.

Which method proves most suitable depends on the level of details provided for the costs and benefits of the project or action, and the amount of time and resources available to obtain this data.

Short introduction to methods

Using proxy indicators

The simplest way to evaluate potential benefits from sustainable city projects, without collecting data or detailed knowledge of all benefits, is through proxy data. Here, standard values are used as indicative values where specific information is unavailable. A proxy could be, for instance, the average life years as a proxy for quality of life.

It is also possible to use data from experienced benefits in similar projects – the benefit transfer method – where benefits from similar projects are used as a proxy for another project. As there are many differences between geographical areas, economies, etc., the output of this should be valued with extreme caution. This approach can be used in all sectors, and is included to highlight the easiest way to get started in assessing a project's sustainability (UNEP-DHI 2014, LSE 2013).

Multi-criteria analysis – MCA

An MCA establishes a preference between options for a given project by referring to a set of objectives. In MCAs, the possibility of multiple as well as conflicting objectives is accommodated by assigning the objectives weights that reflect their relative importance. MCAs can thereby assist decision-making when objectives cannot easily be expressed in monetary values or when the monetary value is misleading (Demetriou et al. 2012, DCLG 2009).

Life cycle cost analysis (LCCA)

The LCCA assesses the total cost of acquiring, owning, and disposing a product, to assess which alternatives have the lowest lifetime costs. It is used in sectors like road infrastructure, buildings and construction. This evaluation type takes into account the user and maintenance costs, such as water use and energy costs. When evaluated over a long time period or throughout a product's lifetime, more expensive, effective solutions will prove better than less expensive solutions with higher costs of use (EC 2007, State of California 2013).

FIGURE 9.2 **SELECTED METHODS**



Note: simplified illustration

Cost effectiveness analysis (CEA)

The CEA assesses how a given (environmental) objective is reached as cost-efficiently as possible. CEAs also give an overview of the consequences of different paths towards the same goal. The cost of the project/program is evaluated in monetary values, whereas the benefits are assessed in physical units, e.g., reduced tons of CO_2 or the number of lives saved. CEAs are used to assist decision-making in public policies and programs, as well as in public and private investments. It is used in, for example, health, education, environment, employment and road safety. As a starting point, a CEA is slightly simpler than a CBA, which can be more complex and time-consuming (WHO, 2003; WHO 2011).

Cost-benefit analysis

With a CBA, all expected benefits and costs associated with a particular project are identified and evaluated before assessing if benefits exceed costs. As long as benefits exceed costs, the project is beneficial. In practice, however, a number of challenges arise, including, e.g., how to identify relevant impacts, how to measure the value of, e.g., air quality or the aesthetics of a green park and how to account for the fact that projects have both immediate and future impacts, (OECD 2006, EU 2008).

Other methods

There are numerous other methods that can be used to assess the effects of sustainable city projects. Some are described here in brief and will not be covered in detail. This list is not exclusive.

Footprint analysis can assess the value of sustainable city projects by giving insight into the entire use of a resource throughout the value-chain, for example, a CO_2 footprint, a water footprint, etc. Footprint analysis can be based on multiple footprints, covering more units, to capture an entire eco-footprint and make it possible to track the green impact of a project compared to alternatives.

This type of analysis can be used as a decision-making tool for choosing projects with the smallest footprint. However, often these types of estimations are very difficult and time consuming to make, as they require a comprehensive knowledge of the entire value chain of a project or risk being overly simplistic. General

footprint analysis allow cities to track their demand for natural resources and compare it to the amount of available natural capital. One advantage of this type of analysis is that it is very easy to communicate and understand, (US EPA 2013, Global Footprint Network).

A life-cycle analysis (LCA) takes a life-cycle approach and weighs costs and benefits of a project from cradle to grave, i.e., over the entire lifetime. In an LCA, it is possible to define costs and benefits more narrowly, and thus this model is easier to use than footprint analysis. LCAs include the environmental sustainability of a product in its entire lifetime, from manufacture, distribution, use, reuse and recycling (US EPA 2013).

With a sustainable production perspective, Eco-Efficiency analysis (EEA) is a possible method to estimate the best solution. It aims to increase resource efficiency, and therefore is relevant from a business perspective. EEA looks at environmental impacts in proportion to a product's cost-effectiveness, i.e., the ratio of total value of goods and services produced to the sum of environmental pressure created by the production of those goods and services. EEA does not attach monetary value to benefits. (US EPA 2013)

For all methods, a sensitivity analyses is a valuable tool to assess how sensitive the conclusions are to changes in parameters.
In the following, a step-by-step guide for how to proceed with the different methods is presented.

9.2 Proxy indicators

Using proxy indicators is a way to overcome lack of data on project-specific environmental and social effects. For example, good transport accessibility suggests a high level of integration in urban development and public transport infrastructure.

A proxy can be used in order to get as close as possible to a reliable description of effects. Life expectancy, for example, is a proxy of quality of life. When evaluating the performance and benefits of projects, it is possible to use a range of technological, managerial and institutional indicators, etc., as proxies for environmental and social effects. Proxies can be from international standard tables.
This approach can be a useful way to begin attaching value to benefits, but should be used with caution. Large transfer errors can occur,

EXAMPLE OF USE: PORTLAND

The City of Portland has worked to promote the green building sector since 1999, with a focus on reducing energy use and CO_2 emissions. This focus is ongoing today. Other initiatives have focused on energy savings in private households.

Portland has reduced GHG emissions in the buildings sector by 27% from 6,6 tCO_2e to 4,8 tCO_2e per person. The reduction took place in both residential sectors (2%) and in commercial sectors (28%). In part, this is due to the green buildings program.

Source: LSE (2013)

since two contexts are seldom comparable. Thus, the potential for sizeable errors in estimation is large, which should be taken into account when a decision process is based on this type of analysis (LSE 2013; CCAP 2012).

EXAMPLE OF USE: INTEGRATED PLANNING FOR GREEN GROWTH IN COPENHAGEN

Copenhagen has a goal of becoming carbon neutral by 2025 and therefore integrated transport and land-use strategies are key. There is a target for 75% of all trips to be by foot/bicycle or public transportation by 2025.

To assess the environmental impact, some proxy indicators are used. For example, Transport accessibility is a proxy for good urban development and public transport infrastructure. In the Copenhagen area, 56 % of the residential population and 61% of all jobs are within 1 km of a railway station. Partly because of this, car use for commuting into the city is low and has decreased from 42% in 1996 to 26 % in 2004. The amount of people commuting by bicycle is relatively high (36%) compared to London (2%) and Stockholm (7%). Per capita CO_2 emissions from transport in Copenhagen have declined by 9% between 1991-2011

Source: LSE (2013)

Selected literature

- LSE Cities, ICLEA, GGGI (2013): Going Green – How Cities are leading the next economy
- CCAP, Center for Clean Air Policy (2012): The Value of Green Infrastructure for Urban Climate Adaptation
- UNEP-DHI Group: Green Infrastructure – guide for water management

9.3 Multi-Criteria Analysis (MCA)

Conducting a multi-criteria analysis includes the following steps:

- Establish the decision context
- Identify the relevant performance criteria
- Measure the performance of options: assign each option with scores measuring how well each performance criteria is fulfilled, and assign each objective a weight reflecting its relative importance to the decision.
- Derive an overall value for each option by combining weights and scores and evaluate the options.
- Conduct a sensitivity analysis

USING MCA IN PRACTICE

In practice, MCA techniques can be used to identify a single preferred option among several options, to short list a number of acceptable options, or to evaluate whether an option is acceptable or not. Some examples of MCA in practice are choosing the location for a thermal power plant and planning land use where many interest groups (government, investors etc.) have a say.

When deciding to do an MCA, it is important that there is a decision-maker or a decision-group to set up objectives, weights and scores (DCLG 2009).

Establish the decision context

The first step of an MCA is to establish the decision context. This includes establishing the ultimate objectives and identifying alternative options, i.e., the alternative project(s) or investment decision(s) for achieving the overarching objectives.

For sustainable city projects, the ultimate objectives are usually high-level variables related to economic, environmental and/or social performance.

Identify relevant performance criteria

Step 2 seeks to establish performance criteria against which the options are assessed.

To do this, it is useful to take the strategic objectives as a starting point, and then identify the immediate impacts of the projects, e.g., a typical contribution of waste projects to environmental objectives is preservation of natural resources.

Identified impacts are then converted into measurable performance criteria. Such criteria can include both costs and negative impacts that should be minimised and positive benefits that should be maximised.

Criteria should be measurable regarding the possibility to assess the extent to which each alternative project contributes to a given performance criteria. Criteria may be measured in various numerical units (e.g., monetary costs, number of trees planted, number of drawbacks of a project), measured as binary outcomes (e.g., does the project have a branding value?) or even qualitatively (e.g., aesthetics rated by e.g., an expert group).

DOUBLE COUNTING AND ACCOUNTING FOR THE TIMING OF IMPACTS

It is important to ensure that criteria is both comprehensive and non-redundant. While all relevant performance criteria should be included, it is also important to avoid double-counting so the same benefits or costs are not covered by different performance criteria.

Measuring performance, scoring and weighting

Step 3 involves measuring how alternative options perform on each performance criteria and establishing relevant preference scores and the weights of importance to be used for comparison. One advantage of an MCA is that it provides a transparent and consistent methodology for comparing very different units not usually considered comparable.

Measure/assess impacts

First, a performance matrix is established. It contains the list of alternative project options and an assessment of the extent to which each option satisfies the identified criteria. These assessments can be based on quantitative assessments or on more qualitative assessments if the necessary data or resources for collecting the data are not available. Figure 9.1 shows an example of an initial performance matrix for a waste management project.

FIGURE 9.3 **PERFORMANCE MATRIX**

	Economic impacts			Environmental and social impacts	
	Costs	No. of jobs	Energy security	CO_2 emissions	Aestetic benefits
Project A	5 bn €	500 jobs	High	-800 tCO_2/yr	No
Project B	4 bn €	200 jobs	Low	-800 tCO_2/yr	No
Project C	2 bn €	10 jobs	Medium	-800 tCO_2/yr	No

Source: DAMVAD 2014
Note: Numbers are kept simple for illustrative purposes

Convert measured impacts into performance scores

Measured impacts can then be converted into numerical scores. Scores are assigned to reflect the preferences of the decision-maker; higher scores indicate a more preferred outcome on the performance criteria and vice versa. Different scales can be applied to the scoring, and the scores can be assigned independently or with reference to the least and most preferred options. In practice, it is often useful to use an approach where scores represent relative preference strength, giving the least preferred outcome on a performance criteria a score of zero (e.g., 10 jobs in figure 9.1 example), and the most preferred outcome a score of 100 (project A in the example). The remaining outcomes should be scored so that differences in scores reflect differences in preferences (Demetrieo et al. 2012).

Assigning weights to criteria

Each criteria is then assigned a weight reflecting the relative importance of the criteria. This can be done by ranking or rating. Often, two aspects are taken into account when assigning weights:

- The importance of the criteria: the higher the importance, the higher the weight.
- The range of difference in outcomes for each criteria. The more similar the actual outcomes, the lower the relative weights.

Evaluating options

Project options are evaluated by combining the performance scores and weights for each criterion. The higher the obtained overall value, the more attractive the option is. A common way to do this is by calculating a simple weighted average, i.e., by summing the products of scores and weights on each criterion.

Sensitivity analysis

It is important to analyse how changes in key assumptions affect the outcomes of the analysis, and in an MCA changes in the weights and scores have an important impact on the results of the analysis.

MUTUALLY INDEPENDENT PREFERENCES AND NON-TRADABLE OBJECTIVES

If preferences are not independent, the score of one objective is dependent on the score of another objective. If this is the case, the evaluation of the options cannot be done by the weighted sum and alternative scoring methods should be used. Similarly, if objectives cannot be traded against each other, it is not appropriate to use weighted averages. For alternative applications, please consult the listed literature

Keep in mind that the team in charge of making the decision chooses the objectives, sub-objectives, criteria and weights as well as assesses achievement of objectives. While this allows flexibility in the MCA, it may also be a source of concern.

Key literature

- DCLG, Department for Communities and Local Government, London (2009): Multi-criteria analysis: a manual
- Demetriou, D et.al (2012): A Spatial Multi-Criteria Model for the Evaluation of Land Redistribution Plans

9.4 Life-Cycle Cost Analysis

The LCCA estimates the overall costs of project options and makes it possible to choose the design that ensures the lowest total cost consistent with quality and function. An LCCA does not take the benefits from users (of the project) or externalities arising from the project into account.

A Life Cycle Cost Analysis includes the following steps:

- Establishment of the decision context and alternatives
- Deciding the time period for the analysis
- Estimating all costs, e.g., purchase, acquisition, construction
- Calculation of the Net Present Value by attaching discount rates
- Computing life-cycle costs
- Conduct a sensitivity analysis

Establish decision context

First, it is necessary to establish the decision context. The objective of the LCC analysis should be defined and alternative projects and their economic effects determined, or LCCAs should be conducted for alternatives as well. The economic effect include identification of maintenance and rehabilitation activities and associated costs, as an LCCA should take into account all user costs alongside initial investment costs.

Time period

Step 2 is to establish the time period in which the project is evaluated. It could be the entire life span of the asset or a limited time period. It is important for this type of analysis that the period chosen covers large rehabilitation activities, if any.
In this step, plans for operation and maintenance for the alternatives throughout the chosen time period are also developed. These

should naturally be as accurate as possible, as this can be a substantial part of a project's total LCC. In figure 9.4, such a plan corresponds to the years when an action has to be taken, though yearly costs for utilities should also be included.

List of cost

In Step 3, all costs from purchase and construction to maintenance and operation should be included in the analysis. If there are costs that are identical among alternatives, these costs can be omitted, which can simplify the analysis to some extent.

Costs that should be part of an LCCA include purchase, acquisition and construction costs and the operation and maintenance costs identified and listed in Step 2. Other relevant cost could be, e.g., fuel cost, water and energy in a building project, vehicle operating and travel time costs in a transport project, repair, replacement and possible non-monetary benefit and costs.

Discount rate

In Step 4, present value costs are calculated. As there are many costs throughout the time span of a project, it is important that a reasonable discount rate is attached. Theoretically, the discount rate should reflect the opportunity cost of alternative uses of the invested money. In practice, a good guideline is to employ the discount rate employed by the national government for large transport and infrastructure projects.

Compute life-cycle cost

Step 5 compares the total overall cost of acquiring and using the investment of the alternative options. Thus, the solution with the lowest total cost in present value of the defined timeframe should be chosen.

Life Cycle Cost Analysis is useful for decisions where high initial investment is traded for future reduced costs. It is particular useful for evaluating buildings or making decisions such as choosing lighting systems or road surface – pavement design.

Environment and energy considerations are included in this type of evaluation, as e.g. energy costs and water costs are also part of the operational cost

Sensitivity analysis

It is always advisable to conduct a sensitivity analysis. The sensitivity analysis should focus on the most uncertain input values which will have the greatest impact on a specific measure. There is a great deal of uncertainty about costs and potential savings in lifetime assessments when estimating the total cost of ownership, which is especially important to include in the sensitivity analysis.

Key literature

- US EPA (2013): Sustainability Analytics: Assessment Tools & Approaches
- D. Langdon Management Consulting for the European Commission (2007): Life Cycle Costing (LCC) as a contribution to sustainable construction: a common methodology
- State of California, Dept. of Transportation (2013): Life Cycle Cost Analysis procedures manual

FIGURE 9.4 **EXAMPLE OF CALCULATION OF LIFE CYCLE COST**

		ALTERNATIVE A		ALTERNATIVE B	
Year	**Discount factor**	**Cost related to construction (discounted)**	**Cost related to use (discounted)**	**Cost related to construction (discounted)**	**Cost related to use (discounted)**
0	1	26,000,000	11,000,000	20,000,000	8,000,000
12	0,62			3,747,582	6,245,970
20	0,46	6,845,804	13,691,608	2,738,322	7,302,191
28	0,33			2,00,865	9,337,369
35	0,25	-950,308	-1,900,616	-190,062	-886,954
Total cost (PV)		**54,686,488**		**58,268,283**	

Source: Example from US Department of Transportation (2002), Life Cycle Cost Analysis Primer
Note: Illustration onlyNote: Numbers are kept simple for illustrative purposes

9.5 Cost Effectiveness Analysis (CEA)

In practice, conducting a Cost Effectiveness Analysis includes the following steps:

- Establishing the decision context defining conditions for use
- Evaluating total costs of the project.
- Quantifying benefits
- Computing a cost-effectiveness ratio
- Conducting a sensitivity analysis

Establish the decision context and conditions
In Step 1 of CEA, the decision context and conditions for use have to be set. To be able to use the outcome of the CEA, it is advisable to know the desired outcome, which should have easily measurable direct and indirect costs. Part of establishing the decision context is to decide which effects to include, and consider who will be affected by the project. This can also be geographic. Even if there is no plan to do a wider assessment, a broad exploration can identify possible effects on neighbors (spillover effects). All relevant effects – costs and benefits – should be identified. Be aware of effects shifting among groups.

In addition, the most relevant and important effectiveness criteria (benefit) must be identified. This criterion will measure the success of the project. The benefits must be related to the objectives of the project and measured in natural units. The key for success of a CEA is the existence of one or a few measures that can be seen as a proxy for the success of the entire project, (US EPA 2013; Cellini and Kee, 2010).

CEA is an efficient way to valuate a project (cost) when the main objective of the policy can be reduced to a single result. It is a simple and effective evaluation tool to compare the different measures of the project /program prior to project initiation.

Evaluate total cost of the project

In Step 2, data on the cost of the project is obtained. Direct costs are the costs invested in the project. These are often available in project documents, etc., and can be in the form of retrospective data, financial data, or activity data on the project, investment, personnel, facilities, material, administration etc. Indirect costs include spillover effects. If there are substantial indirect costs, the level of complexity rises, as cost calculations have to be carried out.

The cost should be converted to present value.

Quantify benefits

In Step 3, the benefits are quantified in terms of units of effectiveness. Only the most important benefit is quantified to get units of effectiveness. If more than one benefit is considered important, separate cost-effectiveness ratios for additional outcomes can be calculated. Only units of effectiveness that can be attributed to the project are included – the units that rise above the status quo level. Indirect and long-term effects that reflect the interests of all stakeholders affected should also be included.

Benefits are quantified in term of units of effectiveness. It could be in the form of life years gained, heart attacks prevented, diabetes prevented, car accidents prevented, etc.

Theoretically, the discount rate should reflect the opportunity cost of alternative uses of the money invested. In practice, a good guideline is to use the discount rate that is employed by the national government for large transport and infrastructure projects.

The WHO suggests a social discount rate of 2-3%, while testing for sensitivity to higher rates. This will often be subject to what is standard for a country or a project type

As a rule of thumb, the relevant time horizon usually corresponds to the expected lifetime of the investment in question. It is possible to compute the present value of future effects, assuming that such effects continue infinitely into the future.

Compute cost-effectiveness analysis

In Step 4, the present value of costs are then related to the project-specific measures of units of effectiveness. This is done by calculating the CE- ratio for the project and alternatives:

C-E ratio = Total Cost/Units of effectiveness

This case would give an expression like amount of money saved per [effectiveness unit]. The outcome from the CEA will thus be information on what will be received in terms of the given benefit (outcome) for the amount of money spent.

Keep in mind that a CEA does not assign any value to the project, leaving it to be a subjective judgment of the analyst or policymaker. However, if two or more projects are evaluated against the same unit of effectiveness, the project with lowest CE ratio should be implemented – assuming the projects are equal in size.

When comparing the CEA ratio of different projects, it is easiest if the projects are similar in size. CEA is also suitable for comparing projects with identical outcomes, i.e., when the chosen effectiveness parameter is the cost comparison criteria.

Sensitivity analysis

Step 5 is to conduct a sensitivity analysis. As is the case in other types of analyses, it is advisable to conduct a sensitivity analysis to evaluate how sensitive the conclusion is to changes in key assumptions and in the discount rate.

Useful literature:

- WHO (2003): WHO guide to Cost-Effectiveness Analysis
- WHO (2011): Methodological approaches for cost-effectiveness and cost-utility analysis og injury prevention measures
- Cellini, S.R and J.E. Kee (2010): Cost Effectiveness and Cost-benefit Analysis. In Handbook of practical Program Evaluation

9.6 Cost-Benefit Analysis (CBA)

Conducting a Cost-Benefit Analysis includes the following steps:

- Establish the decision context
- Map the impacts
- Measure the impacts
- Monetise impacts
- Account for the timing of impacts
- Conduct a sensitivity analysis

Establish the decision context

In Step 1, the decision context is established. The relevant policy or investment option(s) should be identified, or in case of only one project, the reference case alternative is identified: what happens if the project is not undertaken?

Map the impacts

Step 2 seeks to identify all relevant impacts on different groups in society. This can be done by asking the question: "Which significant changes will or did the particular project produce for government, businesses and households in your city (or society if the project is likely to have broader effects) – both immediately and over time?"

Such effects can be a direct result of the project or indirect effects arising from changes in the first variables, e.g., a direct effect of implementing a congestion charge is a switch in transport modes from cars to public transport or cycling, while an indirect effect is improved health from reduced air pollution and increased physical activity. Moreover, costs to one group might imply benefits to another. In the congestion charge example, the charge paid by vehicle drivers will represent a revenue to government.

USING CBA TO EVALUATE URBAN PROJECTS

In the case of unlimited resources, all projects that have a positive net present value should be implemented.

Usually, however, there are not unlimited resources. When comparing alternative projects, alternative projects are usually best be prioritised according to the ratio of benefits to costs – not the net present value. This is because the benefit-cost ratio indicates the societal gains pr. invested and accounts for the employed resources (Danish Ministry of Finance).

While it is important to include all effects likely to be significant for all people – now and in the future – it is also important to avoid double counting. When choosing which costs or benefits to measure in a CBA, it is therefore important to ensure that the categories of costs and benefits are mutually exclusive and do not over overlap. When identifying relevant impacts, all costs and benefits should be included.

Measure the impacts

In Step 3, the impacts identified as relevant to the project are measured. To do this, it is useful to distinguish impacts by the ease with which they can be:

- Quantified as a monetary value e.g. reduced vehicle operating costs
- Quantified in an alternative measure e.g. reduced emissions
- Difficult to quantify e.g. the branding value of green projects for a city

For the top 2 listed impacts, the effects should be distributed across time, and the groups that they affect should be quantified, drawing on various sources described below. For the latter, expected impacts can be described qualitatively.

Information sources

There are four main types of information sources that can be used to arrive at a measure of impacts.

- Quantitative project evaluations on similar projects: The measured outcomes from this can sometimes be used directly if the context is comparable. Alternatively, it is possible to make assumptions that 'translate' effects found in similar projects into the specific context. Qualitative evaluations can be used for inspiration as to which outcomes can be expected from implementing a given project.

- Literature search. academic studies or meta-studies supply estimated effects for various types of projects and actions. Estimates can sometimes be of higher quality than single evaluations if the specific contexts differ.

- Public databases. Provide information on e.g. urban population, number of vehicles, etc. Register-based or census-based data can also be used to estimate effects of specific projects on groups of people or companies compared to a control group.

Collected data: It is also possible for cities to collect necessary data directly, such as by conducting surveys of the target group or measuring the number of people affected, e.g., by counting passengers.

It is important to note that only incremental impacts should be measured, i.e., only recording the changed outcomes compared to not undertaking the project – the 'Business As Usual' – scenario. If, e.g., a city has decided to construct a new 1000 sq. m office building for € 10 mil. but has the option to construct a 500 sq. meter office building with a green roof for – 15 mil. The incremental cost for the green roof project is € 5 mil. – Or € 20 k per square meter (a unit cost increase from 10 k to 30 k per square meter).

Monetise impacts

Step 4 will convert measured quantities into monetary values. To do this, it is useful to distinguish between cases in which there exists a market for the goods concerned and cases in which no markets exist. When a market exists (assuming markets function reasonably well), the value is simply the market price. The value of an hour saved by a business traveller is thus his/her hourly wage.

In cases where no market value exists, alternative techniques must be employed. Table 9.5 lists the most important techniques used to estimate monetary value. When estimating this, be aware of the trade-off between ease of estimation and accuracy.

Account for the timing of impacts

If all significant costs and benefits are identified and measured, timing should be accounted for and future costs and benefits have to be translated into a net present value.

Advantages/disadvantages of CBA: CBA is a time-consuming and costly form of analysis. Therefore, it is usually not suitable for relatively small projects where the resources needed to measure and monetise all relevant effects are excessive relative to the project. In such cases, the alternative methods described below are often more apt.

Which discount rate to choose?

Theoretically, the discount rate should reflect the opportunity cost of alternative uses of the invested money. In practice, a good guideline is to employ the discount rate that is employed by the national government for large transport and infrastructure projects.

Which time horizon?

As a rule of thumb, the relevant time horizon usually corresponds to the expected lifetime for the investment in question. It is possible to compute the present value of future effects, assuming that such effects continue infinitely into the future. This could, e.g., be relevant for projects with very significant climate effects that are likely to prevail far into the future.

Conduct sensitivity analysis

Lastly, it is important to analyse how changes in key assumptions affect the outcomes of an analysis. The discount rate is likely to be one such parameter, as small changes are likely to have an important impact on the results of the analysis.

Table 9.5 Approaches to estimating monetary value of non-market goods and services

Valuation approach	Description of applied methods
Revealed preference methods	Methods that use behaviours and information observed in markets to estimate non-market values. Examples of applied methods include the travel cost method, the hedonic pricing method, the market comparable method, and the cost avoidance method.
Stated preference methods	Methods that attribute economic value by asking people about their willingness to pay for a service or willingness to accept compensation for not having a service. Methods include the contingent valuation technique.
Avoided cost analysis	Can be used to determine the value of green infrastructure by quantifying the costs that would be incurred if the services provided by the infrastructure were not available or had to be provided by building conventional infrastructure.

Source: OECD 2006. Note: Not comprehensive

Key literature

- OECD (2006): Cost-Benefit Analysis and the Environment: Recent Developments.
- EU (2008): Guide to Cost-Benefit Analysis of Investment projects
- UK Department of Transport: Transport Analysis Guidance Unit A2.1: Wider Impacts (For wider economic benefits estimation)
- CBA guidelines and manuals of national governments

10. **Glossary**

Bus Rapid Transit (BRT)

BRT is a bus-based mass transit system intended to combine the capacity, speed and comfort of light rail or metro with the flexibility, lower cost and simplicity of a bus system. A BRT is characterised by dedicated lanes typically aligned in the center of the road, station platforms level with the bus floor, off-board fare collection, and fast and frequent operations.

Carbon intensity

The amount of carbon by weight emitted per unit of energy consumed. It is often used to compare the environmental impact of different fuels or activities

Cost-Benefit Analysis (CBA)

A CBA is an impact study that seeks to quantify the costs and benefits in order to reach an overall economic assessment of the project. The advantages and disadvantages, whether economic, social or environmental are valued in monetary terms – for instance in dollars – so that these are measurable and comparable. See chapter 9.

Discount rate

Theoretical or observed rates at which people convert future costs and benefits to current values. See also chapter 9.

Greenhouse Gas (GHG)

Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include e.g. carbon dioxide, methane, nitrous oxide, ozone and chlorofluorocarbons. These added greenhouse gases cause the earth to warm.

Hedonic Pricing Method

The hedonic pricing method is used to estimate the value of projects that affect market prices. The most common example of the hedonic pricing method is in the housing market: the price of a property is determined by the characteristics of the house (size, appearance, features, condition) as well as the characteristics of the surrounding neighborhood (accessibility to parks, schools and shopping, level of water and air pollution, value of other homes, etc.) The hedonic pricing method is used to isolate the extent to which each factor affects the price.



Life Cycle Cost Assessment (LCCA)

A method to determine the cost effectiveness of implementing energy conservation measures, which can have a higher first cost than standard measures, because it accounts for ownership costs after acquirement. See chapter 9.

Light Emitting Diode (LED)

A Light Emitting Diode. A LED is an electronic device that emits light when an electrical current is passed through it. Early LEDs were often used as indicator lamps for electronic devices as they produced only red light. Recent developments in LEDs permit them to be used in environmental and task lighting.

Net benefit

Total benefits minus total costs. If the net benefit is negative it can also be referred to as a net cost.

Net Present Value (NPV)

NPV is the difference between present and future benefits and costs evaluated at present value. The present value are calculated by discounting future benefits and costs by a discount rate, such that benefits and costs today and in the near future weighs heavier than benefits and costs further ahead in time. See chapter 9.

Valuation

A method to associate a monetary value with some service provided by, or some damage done to, the natural environment. See chapter 9.

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