Towards sustainability - Modeling the Danish Commuting Tax

Master Thesis

MSc. Sustainable Cities

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June, 2016

AALBORG UNIVERSITY
COPENHAGEN

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Semester: Sustainable Cities 4th semester

Project title:

Towards Sustainability - Modelling the Danish Commuting Tax

Project period:
February 1st 2016 – June 30th 2016

Semester theme:
Master Thesis

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Number of copies: 3
Number of pages: 61

Summary: Today, due to the increasing levels of individual transport, cities suffer most from congestion, poor air quality and noise exposure, which are increasingly challenging urban and transport planning paradigms. However, there is limited evidence of urban transport systems becoming more sustainable, raising the question on how can sustainable transport transitions be initiated. At the national level, income tax is generally the key policy instrument affecting the commuter transport behavior. However, very limited attention has been paid to the socio-economic and sustainability potentials of creating these tax instruments. With an emphasis on the urban context, the main focus of this thesis is on assessing the socio-economic and sustainability potential of the Danish commuting tax, and find how can it be adapted to respond the sustainability goals the Danish Government have set out for the transport sector. To answer this a socio-economic a model was created to assess the potential impacts of adjusting the Danish commuting tax to the Governments' goals for the transport sector, through a cost-benefit analysis that simulates different tax variations in different scenarios. In absolute terms, scenario 5 is considered to be the one that better fulfills the sustainability goals from the Danish Government. Since it reduces the commuting costs for both bicycles and public transport, and increases the costs for the private modes, therefore promoting better mobility, less congestion, reduction in GHG and carbon emissions, increase the amount of passengers transferred from private cars to public transport and bicycle, and finally changes in the commuting behavior. Overall, the model makes evident the socio-economic advantages, for the user, in shifting from the car to the bicycle or public transport in his daily commute, providing the economic justification for the adjustment of the current Danish commuting tax system.

Abstract

Transport and mobility are fundamental to the economy and societies, for the markets, and generally for the quality of life of the citizens. Today, due to the increasing levels of individual transport, cities suffer most from congestion, poor air quality and noise exposure, which are increasingly challenging urban and transport planning paradigms. However, there is limited evidence of urban transport systems becoming more sustainable, raising the question on how can sustainable transport transitions be initiated. Recent research indicates that urban transport transitions ultimately require new urban transport cultures, favoring other identities to individual transport. Policy instruments could and should carry its responsibility in promoting a wide variety of travel modes, and favoring those that have the least harmful impacts on the environment, and that possibly have positive effects on public health. At the national level, income tax is generally the key policy instrument affecting the commuter transport behavior. However, very limited attention has been paid to the socio-economic and sustainability potentials of creating these tax instruments. In Denmark, close to a third of all car trips are 5 km or less, while more than half are less than 10 kilometers, which shows the potential to move commuters from car to bicycle and public transport. With the right tax incentive structures this could potentially be achieved. In light of the above mentioned, and with an emphasis on the urban context, the main focus of this thesis is on assessing the socio-economic and sustainability potential of the Danish commuting tax, and find how can it be adapted to respond the sustainability goals the Danish Government have set out for the transport sector. To answer this a socio-economic model was created to assess the potential impacts of adjusting the Danish commuting tax to the Governments' goals for the transport sector, through a cost-benefit analysis that simulates different tax variations in different scenarios. After calculating the generalized travel cost from each transport mode, the model compares the different travel costs against each other's, before and after the application of different tax deduction rates. In absolute terms, scenario 5 is considered to be the one that better fulfills the sustainability goals from the Danish Government. Since it reduces the commuting costs for both bicycles and public transport, and increases the costs for the private modes - where the user has to pay for the full amount of the commute - therefore promoting better mobility, less congestion, reduction in GHG and carbon emissions, increase the amount of passengers transferred from private cars to public transport and bicycle, and finally changes in the commuting behavior. However, there are some limitations to the presented outcomes, due to the model characteristics. Overall, the model makes evident the socio-economic advantages, for the user, in shifting from the car to the bicycle or public transport in his daily commute, providing therefore, the economic justification for the adjustment of the current commuting tax system. Furthermore, this model constitutes a great baseline for the exploration and research of the social, economic and environmental impacts that tax incentives can promote towards a more sustainable commuting behavior, transport sector, and future.

Key words: commuting, tax income, tax deduction, Denmark, sustainability, modeling, CBA, external costs

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1. Introduction

Transport and mobility are fundamental to the economy and societies, for the markets, and generally for the quality of life of the citizens. Today, due to the increasing levels of individual transport, cities suffer most from congestion, poor air quality and noise exposure (European Commission, 2011b; Gössling, 2013), which is increasingly challenging urban and transport planning paradigms. Furthermore, the challenges connected to traffic congestion, and consequent air and noise pollution, are persistently drawing attention towards public transportation (Djurhuus, Sten Hansen, Aadahl, & Glümer, 2016) and other sustainable forms of transport, seen as more sustainable solutions to individual fuelled transport. Consequently, numerous cities in the world seek to change their transport systems in favor of public transport, cycling, and walking (Gössling & Choi, 2015). In cities, switching to cleaner transport modes can be facilitated by the lower requirements for vehicle route range and higher population density. Also, in cities, public transport choices are more widely available, as well as the options of walking and cycling (European Commission, 2011b). However, there is limited evidence of urban transport systems becoming more sustainable, raising the question on how can sustainable transport transitions be initiated on a larger scale (Gössling, 2013).

Recent research indicates that urban transport transitions ultimately require new urban transport cultures (Gössling & Choi, 2015), favoring other identities to individual transport. However, to reduce individual transport dependency, different and optional ways of travelling are needed. Therefore, policy instruments could and should carry its responsibility in promoting a wide variety of travel modes, and favoring those that have the least harmful impacts on the environment, and that possibly have positive effects on public health (Atterbrand et al., 2005). At the national level, income tax is generally the key policy instrument affecting the commuter transport behavior (Atterbrand et al., 2005; Gössling, 2013). Price signals can play a crucial role in decisions that can have long-lasting effects on the transport system and commuters behavior. Thus, transport charges and taxes should support the transport role in promoting sustainability objectives, and be restructured in the direction of wider application of the 'polluter-pays' and 'user-pays' principles (European Commission, 2011b).

Choosing different modes of transportation can have significant socio-economic impacts. Today's commuters can increasingly make a choice between different modes of transportation in order to arrive at their destination in the most efficient way – especially in urban areas. Therefore, there is a need for more advanced socio-economic tools to calculate the costs and the benefits of such alternatives and choices (State of Green, 2016). As a result, promoting tax incentives to alternative mobility patterns can cause significant benefits such as less congestion, less pollution and generally better urban environments and quality of life. However, limited attention has been paid to the economic and sustainability potentials of creating commuting taxes.

1.1. Research question

In light of the above mentioned, and with an emphasis on the urban context, the main focus of this thesis is on assessing the economic and sustainability potential of the Danish commuting tax, and how can it be adapted to respond the sustainability goals the Danish Government have set out for the transport sector. This study, aims therefore, at answering the following research question:

How can the commuting tax[1] *be adjusted to fit the Danish sustainability goals?*

To answer the research question, several objectives have been set out, and the creation of a socio-economic model was the final intention of this thesis. The model was created to assess the potential impacts of adjusting the Danish commuting tax to the Governments' goals for the transport sector, through a cost-benefit analysis that simulates different tax variations in different scenarios. Since the emphasis is placed on the urban context, the study focused on the Greater Copenhagen area.

Follows a brief description of the thesis structure and organization.

First a literature review, presented on Chapter 2, was undertaken in order to assess the main policies and targets, at the European Commission and Denmark levels, regarding the transport sector, with an emphasis on the challenges present at the urban level. This chapter also explores and presents the existing mechanisms to achieve changes in transport behavior, with a focus on commuting tax systems and transport pricing incentives to commuter's behavior. The following chapters, Chapters 3 and 4, present the framework for this study. Chapter 3 introduces the cost-benefit analysis and the concept of external costs and how are these used as tools to assess the economic and social impacts of transport related policies, projects and investments. Chapter 4 presents the model that was constructed and the methodology used to do so, with a detailed description on how the cost-benefit framework was applied, and the straights and limitations of this research. Chapter 5 analyses the outcomes of the model, presenting the inputs and outputs of each of the simulated scenarios, which are then followed by a detailed discussion of the results found, in Chapter 6.

The purpose of this research is thus, both the presentation of a model that can be used to assess the socio-economic and sustainability potential of changing the current commuting tax to respond the sustainability goals from the Danish Government, and also, to assess the weight that different transport modes carry in terms of their social, environmental, and economic impacts, through a comparative assessment of different scenarios.

[1]C*ommuting tax* translated from the Danish - Kørselsfradrag (befordringsfradrag)

2. Literature Review

Reduce the greenhouse gas emissions by at least 20% compared to 1990 levels or by 30%, if the conditions are right; increase the share of renewable energy sources in the final energy consumption to 20%; and a 20% increase in energy efficiency are the targets set out by the European Commission 2020 Strategy (European Commission, 2010) for the sustainable growth under the climate and energy agendas.

The European Union (EU) policies and measures to achieve the Energy 2020 goals are ambitious and will continue to impact beyond 2020, helping to reduce emissions in 40% by 2050. They will however, still be insufficient to achieve the EU's 2050 decarbonisation objective – Energy Roadmap 2050 – as only less than half of the decarbonisation goal will be achieved by 2050 (European Commission, 2011a). Among the targets of the Energy Roadmap 2050 are: a reduction in emissions by 80%, according to 1990 levels (see Figure 1) – with 40% of the emissions cuts by 2030 and 60% by 2040; and a feasible and affordable transition to a low-carbon economy, to which all the sectors need to contribute in order to meet the goals (European Commission, 2016a). However, projections for emissions towards 2020 and 2035, show an increase in the relative share of total emissions for the transport sector (see Figure 1), due to the growth in transport activity, but also due to mitigation policies and measures adopted in other sectors (Danish Government, 2013).

Both strategies, Energy 2020 and EU's 2050 decarbonisation, impose complex and demanding measures to achieve the proposed targets. This gives an indication of the level of effort and change, both structural and social, which will be required, to make the necessary emissions reduction, while keeping a competitive and secure energy sector (European Commission, 2011a).

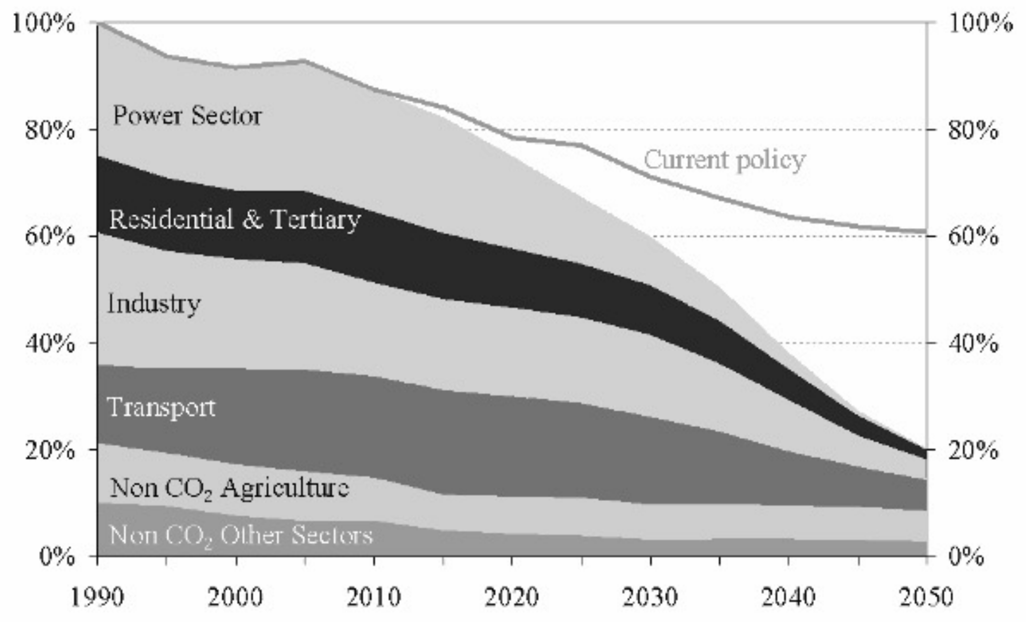

Figure 1 - Possible 80% cut in greenhouse gas emissions in the EU (100% =1990) (European Commission, 2016a).

"Resource efficient Europe" is one of the seven flagship initiatives, the Energy 2020 strategy presents to help *"decouple economic growth from the use of resources, support the shift towards a low carbon economy, increase the use of renewable energy sources, modernise our transport sector and promote energy efficiency"* (European Commission, 2010: 4). According to the 2020 Strategy this can be achieved through a mix of measures, e.g. infrastructure measures; intelligent traffic management; better logistics; reduction of CO_2 emissions (road vehicles, aviation and maritime sectors); promote new technologies and research; setting common standards; and developing the necessary infrastructure support (European Commission, 2010).

Transport and mobility are fundamental to our economy and society, for the markets and for the quality of life of the citizens. In order to enable economic growth, job creation, and sustain the challenges that are faced today, transportation needs to be sustainable and requires effective action to follow the imposed targets (European Commission, 2011b). Figure 2 shows that, the transport sector is today the second largest GHG producer, in the EU28, with 24,3% of the total share of emissions, and that, from this 24,3%, nearly 72% originates from road transport. Overall, the EU needs to reduce its emissions in 80%, below 1990 levels, by 2050 in order to fulfill the goals. While deeper cuts can be achieved in other sectors of the economy, for the transport sector, the targets impose a reduction of at least 60% of GHGs by 2050. By 2030, the goal for transport will be to reduce GHG emissions to around 20% below their 2008 level. However, given the substantial increase in transport emissions over the past two decades, this would still be 8% above the 1990 levels (European Commission, 2011b). The European Commission (EC) states, on the 2011 White Paper on transport (European Commission, 2011b), that the transport system is not sustainable, and that scenarios looking 40 years ahead show that transport cannot develop along the same path it has. By sticking to the a 'business as usual' approach, the EC predicts that in 2050 the CO_2 emissions from transport will remain one third higher than their 1990 level, congestion costs will increase by close to 50%, the accessibility gap between central and peripheral areas will widen, and the social costs of accidents and noise will continue to increase (ibid.). Meaning a general goal of reducing GHG emissions in 60% by 2050. *"Growing Transport and supporting mobility while reaching the 60% emission reduction target"* (European Commission, 2011b: 5)

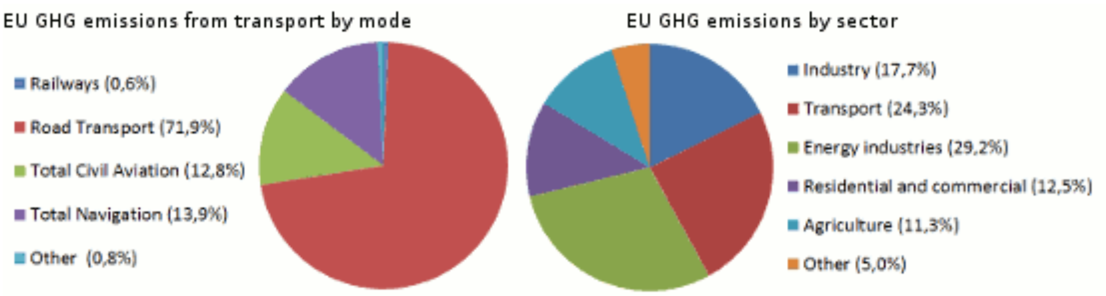

Figure 2 - EU28 greenhouse gas emissions by sector and mode of transport, 2012 (European Commission, 2016b).

One of EU main challenges is to *"break the transport system's dependence on oil without sacrificing its efficiency and compromising mobility"* (European Commission, 2011b: 5). In line with the flagship initiative "Resource efficient Europe" in the Europe 2020 Strategy (European Commission, 2010), the major goal for the European transport policy is to help establish a system that reinforces the European economic progress, improves competitiveness and compromises quality mobility services, while at the same time, uses resources in a more efficient way (European Commission, 2010, 2011b). In practice, this means that the transport system has to use less and cleaner energy, explore and bet on modern infrastructure, and reduce its negative impact on the environment and is natural systems.

Therefore, it is important to focus on the urban dimension of transport, because it is at the urban level where much of the congestion and GHG emissions are generated (European Commission, 2010), but also where they can be greatly reduced. Figure 3 shows the reduction potential of GHG emissions in urban areas, through urban planning, new technologies, and modal shift, being the latter, the one with the highest reduction potential. Thus, focusing on the urban dimension of transport, means focusing on the emergence of new transport patterns. According to these new patterns, larger volumes of goods and people are carried jointly to their destination by the most efficient modes (or combination of modes). Individual transport should preferably be used for the final kilometers of the journey and with 'clean vehicles'. Information technology can, for example, provide for simpler and more reliable information on transfers (European Commission, 2011b), which can facilitate commuting patterns. At the same time transport users can *"[…] pay for the full costs of transport in exchange for less congestion, more information, better service and more safety"* (European Commission, 2011b: 5).

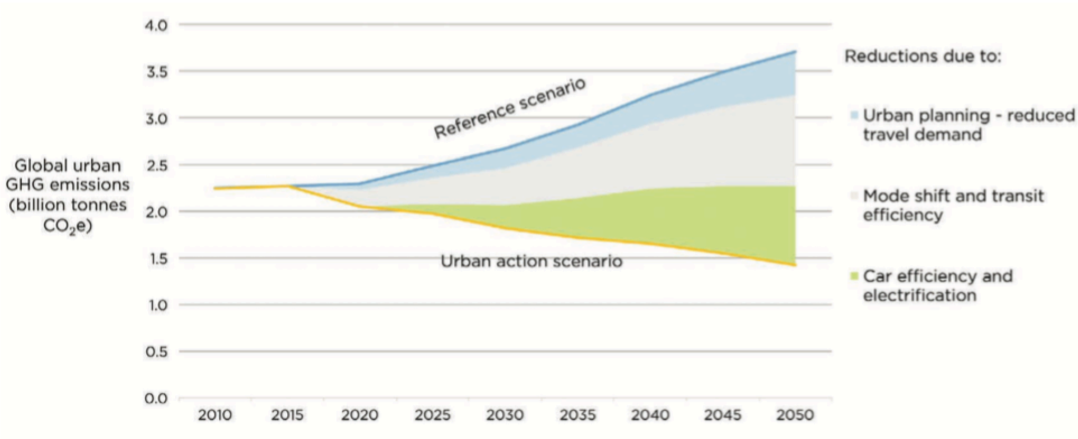

Figure 3 – Potential of GHG emissions reduction in urban areas (Bloomberg, 2014).

The targets adopted by the EU impose challenges for its Member States who need to address these issues and apply policies, measures, and reorganize its economies in order to fulfill the above-mentioned targets.

The Danish Government's strategy to put Denmark on track for the 2050 target includes a provisional goal of 40% reduction by 2020 in all Danish GHG emissions, compared to 1990 levels (Danish Government, 2013). In order to do this a transition is necessary in all relevant sectors. The energy sector is crucial to achieve the climate targets, and the Danish energy policy is a good foundation for the climate policy and for the reduction of GHG in 40% by 2020. The Danish Government goal is having electricity and heating supply completely based on renewable energy by 2035, and by 2050 energy consumption entirely based on renewables. Having all of Denmark's energy supply from renewables by 2050 will result in fossil fuels being phased out, which also implicates that the energy consumption for the entire transport sector will have to come from renewable sources. However, to achieve this, there is a need for an active climate policy in all relevant areas, which are, in addition to the energy sector, transport, agriculture, waste and environment sectors (*ibid.*). For the transport sector this means that it will have to undergo a transition in future decades, that should be reconciled with transport policy goals towards sustainability, such as ensuring mobility and reducing congestion (Danish Government, 2013).

In Denmark, road transport is responsible for the largest component of transport energy consumption and $CO_{2eq.}$ emissions. Passengers' cars today account for about 57% of $CO_{2eq.}$ emissions from road transport, followed by vans and lorries with 37%, and buses and motorcycles the remain 6%. By 2020, transport sector emissions are expected to be around 13M tones $CO_{2eq.}$, corresponding to an increase of 20% compared with the 1990. A projection of emissions towards 2020 and 2035 shows an increase in the sector's relative share of total emissions, due to the growth in transport activity, but also due to mitigation policies and measures adopted in other sectors (Danish Government, 2013).

In Denmark, the transport sector is generally characterised by significant energy taxes on fuels, as well as NO_X and CO_2, and car taxes, which have helped stem the increase in emissions from the transport sector. Opportunities to reduce emissions from transport can roughly be divided into four categories (Danish Government, 2013):

- Reduce carbon emissions through alternative propulsion systems (e.g. electric, biogas or biofuel);
- Decouple the growth in demand for transport from the economic growth, through taxes on buying, owning and using cars, as well as through spatial planning;
- More efficiency through the increase of what is transported per km (e.g. transferring passenger transport from private cars to public transport or increasing the amount of goods on an individual vehicle);
- Reduce energy consumption per km covered (e.g. technology improvements or changes in behavior).

Cities suffer most from congestion, poor air quality and noise exposure due to the increasing levels of individual motorised transport (see Figure 4) (European Commission, 2011b; Gössling, 2013). The gradual phasing out of 'conventionally-fuelled' vehicles from the urban environment is a major contribution to significant reduction of oil dependence, GHG and local air and noise pollution. In cities, switching to cleaner transport is facilitated by the lower requirements for vehicle route range and higher population density. Public transport choices are also more widely available, as well as the options of walking and cycling (European Commission, 2011b). To restructure the transport systems is thus high on the agenda of policy makers. However, there is currently limited evidence of urban transport systems becoming more sustainable in significant ways raising the question as to how transport transitions on a larger scale can be initiated (Gössling, 2013).

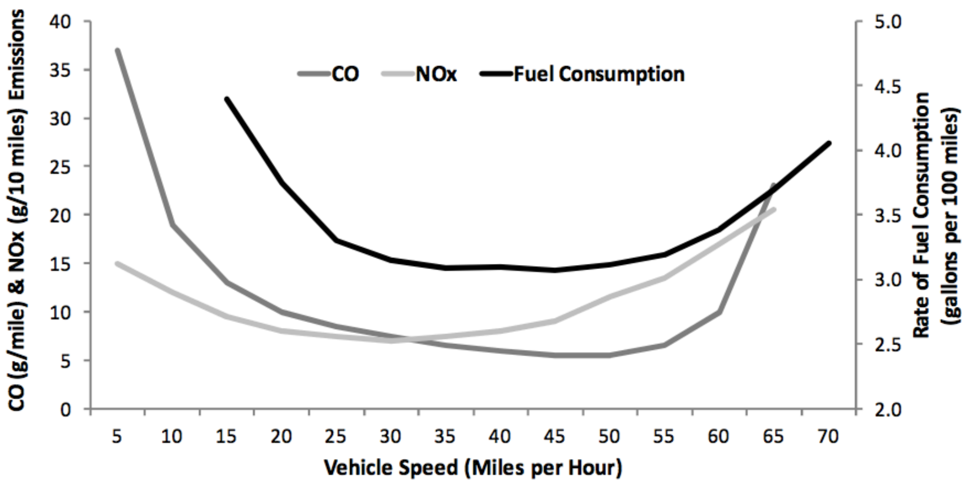

Figure 4 - Relationship between vehicle speed, tailpipe emissions (CO, NO_X) and fuel consumption (Van Benthem, 2015).

Note: At low speeds emissions are higher, reaching a minimum at moderate speeds (30 – 50 mph), as well as fuel consumption. At higher speeds, CO and NO_X emissions increase rapidly and disproportionately to fuel consumption (Van Benthem, 2015). This is challenging, especially for cities, where increased traffic congestion and motorized vehicles, promote low speed velocities.

The challenges of traffic congestion and consequent air and noise pollution are persistently drawing attention towards public transportation (Djurhuus et al., 2016) and other sustainable forms of transport, seen as a more sustainable solution when compared with private transport and car-based commuting. Consequently, numerous cities in the world seek to change their transport systems in favor of buses, trams, trains, cycling, and walking, as a result of increasing levels of local air and noise pollution, GHG emissions, accidents, and congestion (Gössling & Choi, 2015). In addition, from a public health perspective, commuting by public transportation, bicycle or walking, provides more health benefits than car-based commuting, as a consequence of more regular physical activity when walking to stops, transfers, and end locations (*ibid*).

In pair with public transport policies, policy makers seem particularly keen to increase the share of cyclists, as this transport mode incurs a wide range of benefits compared to vehicles with internal combustion engines - minimum area requirements, both with regard to tracks and parking, as well as no pollution, fewer accidents, and considerable health benefits. Bicycling has become a major component of visions of sustainable urban transport systems in Europe, supported by market-based instruments, command-and-control approaches, as well as soft policy measures (Gössling & Choi, 2015).

Recent research indicates that urban transport transformations, i.e., profound changes in transport mode choices, ultimately require new urban transport cultures favoring other identities (Gössling & Choi, 2015) then the car. When striving to reduce private car dependence many different and optional ways of travelling are needed. Therefore, policy instruments could and should carry its responsibility for promoting a wide variety of travel modes, and favoring those that have the least harmful impacts on the environment, and that possibly have positive effects on public health (Atterbrand et al., 2005).

Theories of travel behavior and related travel-mode choice studies have been of interest to transport and urban planners for a long time. Besides looking at the individual and neighborhood factors, studies have focused on how transport networks (road network or public transportation) support people in reaching their destinations such as jobs (Djurhuus et al., 2016) – commuting networks.

According to Gössling (2013), three general mechanisms to achieve changes in transport behavior can be identified: (1) market-based instruments; (2) command-and-control approaches; and (3) soft policy measures. (1) Market-based instruments include taxes, subsidies or duties, which affect behavior because of rising or declining costs for travel. (2) Control-and-command instruments, also referred to as hard policy, set standards for products and services as well as behavior, affecting transport choices through urban design and land use planning, or investments in specific transport infrastructure. (3) Soft policy measures have the objective to support decisions that are more socially desirable, generally relying on the distribution of information on more sustainable transport choices. What all the three measures have in common is their success in changing urban transport behavior, however limited, in the sense of the overall reduction in internal combustion engine transports (Gössling, 2013).

Therefore, many national and local regulations and guidelines affect the commuter behavior, especially regarding the choice of transport mode. At the national level, income tax, which is a market-based instrument, is generally the key policy instrument affecting the commuter transport. Examples of taxation policies/measures relating with income tax are (Atterbrand et al., 2005):

- Long distance commuter trips;
- Mileage allowances for car use during business trips;
- Company public transport fares;
- Car parking at employer's place of business;
- Company cars, company bikes.

At the local level, command-and-control instruments and soft policy measures, are generally the key instruments, mainly related to physical preconditions, parking supply being accentuated, amongst others (Atterbrand et al., 2005; Gössling, 2013). Thus, price signals can play a crucial role in many decisions that have long-lasting effects on the transport system. Consequently, transport charges and taxes should be restructured in the direction of wider application of the 'polluter-pays' and 'user-pays' principles (European Commission, 2011b). They should support the transport role in promoting competitiveness and sustainability objectives, while the overall burden for the sector should reflect the total costs of transport, including infrastructure and external costs (ibid.).

However, very limited attention has been paid to the socio-economic and sustainability potentials of creating these taxation policies/measures. In Denmark, close to a third of all car trips are 5 km or less, while more than half are less than 10 kilometers, which shows the potential to move commuters from car to bicycle and public transport (Cyklistforbundet, 2015). With the right tax incentive structures this could potentially be achieved.

In sum, choosing alternative modes of transportation can have significant socio-economic impacts, and today, especially in urban areas, commuters can increasingly choose between different modes of transport. However, there is a need for socio-economic tools to calculate the costs and the benefits of such choices. The potential benefits of changing commuting patterns and behavior, through the promotion of tax incentives, can lead to significant benefits such as less congestion, less pollution and generally better urban environments.

2.1. Commuting and Tax Deduction

The personal income tax rules that apply to employees with respect to transport are fiscally and environmentally important (Harding, 2014). One aspect of particular relevance is the treatment of the benefits associated with commuting expenses. The examination of the tax treatment in this area reveals important non-neutralities in the treatment of different kinds of employment benefits and expenses that have a significant fiscal cost. At the same time, tax settings in this area, create implicit incentives that favor certain modes of transport over others and influence how much employees travel. Commuting distance and mode of transport are key aspects of travel by individuals. The tax treatment of commuting expenses therefore has important impacts on the environment and can also contribute to traffic congestion, accidents, noise and other social costs (ibid.).

According to Harding (2014), the tax treatment of commuting expenses is generally determined by two factors: who has borne the expense (the employee or employer) and whether commuting expenses are considered to be private expenses or work-related expenses. In the case where the commuting expenses are considered private, the costs of getting to work are considered as a function of personal decisions (where to live and how to get to work). Under this view commuting expenses should be treated consistently with other personal expenses, and similarly to other personal expenses, these costs are non-deductible. The case where commuting expenses are considered as work-related expenses, raises from the premise that commuting expenses incurred for the purpose of earning income, and that *"people cannot be expected to live in the same place that they work"* (Harding, 2014: 39). Therefore, the cost of getting to work can be recognized as a legitimate employment expense and be tax deductible.

Commuting expenses reduce the income tax liability in many European countries, e.g. in Belgium, Denmark, Finland, France, Germany, Norway and Switzerland (Gössling, 2013; Harding, 2014). These countries calculate the amount of the deduction by applying a set rate to the distance travelled between home and workplace (Harding, 2014). The Danish system allows a deduction per kilometer at a rate that varies based on how far the employee lives from the workplace. The further the employee lives from the workplace, the lower the rate of deduction per kilometer travelled, and the deduction is set regardless the way of commuting (Harding, 2014; SKAT, 2016a, 2016b).

2.1.1. The Danish model

In Denmark the system is based on distance travelled per day (km/day). One can be entitled to a deduction for commuting if the distance between the home address and work address is more than 12 km – one way, Figure 5. The actual transport expenses and the transport mode chosen are irrelevant (SKAT, 2016a).

Transport Rate. day	Deductions per. km per. day for 2015
0-24 km	0 kr. (No deduction)
25-120 km	2,05 kr.
Over 120 km	1,03 kr. (2.05 kr. In the peripheral municipalities)

Figure 5 – Deduction rates for 2015. (SKAT, 2016b)

SKAT calculates the deduction based on a predefined number of working days. SKAT sets this number of working days/transport days at 216. The 216 working days correspond to a full working year with 6 weeks' holiday, plus 6-8 working days without transport. The extra days may be, for example, sick days, days off or days working from home (SKAT, 2016a). This can be changed manually by the individual through SKATs website. Furthermore, SKAT can yearly change the rate if the costs of fuel and the costs of maintaining a private vehicle change (SKAT, 2015b).

In order for someone to be eligible to get this tax deduction, the following rules applies:

- Only *paid work* and an *official address* (registered in the Danish national register (Folkeregistret)) recognized as place of residence, are considered in order to get this deduction. Meaning that, since the State education grants are not considered a salary, deduction for transport between home and education institution is not possible, nor for unpaid work (e.g. voluntary work). Also, if for some reason, for a period of time, for example one travel from a holiday home to work, or from a hotel to work, it is also not possible to get a deduction for that period (SKAT, 2016a). In the case of multiple jobs, if there is more than one workplace during the year, the number of days one worked at each workplace must be discriminated in the system. If there is more than one workplace during the day, the deduction is possible if the commute is of at least 24 kilometres a day. This also applies to travels to and from the same workplace several times during the day (*ibid*).
- The *actual travel distance* also applies. This means that it does not have to be the shortest route. The route to workplace may in some cases be longer than the route calculated by SKAT's system, and in those cases one should change it manually. However, if opting for public transport (train or bus), the normal distance by car is the one applicable (SKAT, 2016a). In the case of carpooling, it makes no difference how the driving expenses are distributed amongst the carpoolers, meaning that a deduction is possible, even if anything towards the transport is being paid. The only exception is for the commuters across the Øresund Bridge or the Great Belt Bridge, where only one person in the car is entitled to an additional 'bridge crossing deduction' (*ibid*).
- *Ferry and flight tickets*[2]. It is possible to get a deduction for expenses for ferry and flight tickets if these are part of the normal commute home-to-work. It is also possible to get a deduction for ferry expenses when taking the car, motorcycle or bike in the ferry, if these are used for the further

[2] SKAT's deduction calculator, calculates the deduction for most ferry connections. However, the calculator is not able to calculate deductions for flight connections.

transport. In addition, one can deduct the expenses related to the number of kilometers driven to the ferry/airport and from the ferry/airport. As the normal deduction for transport home-to-work there is a lower limit. For transport on the ground before or after the ferry or flight trip, the lower limit (i.e. the first 24 km) is calculated on the transport on ground and then on ferry and flight expenses, if any (SKAT, 2016a);

- *Peripheral municipalities* and *long commuting distances*. If the distance between home and workplace is more than 60 km and if one lives in a peripheral municipality (udkantskommune), a deduction higher than normal is possible – this higher deduction is possible until the end of 2018. SKAT's deduction calculator automatically calculates the additional deduction if one lives in peripheral municipality (SKAT, 2016a).

Examples on how to calculate the commuting tax deduction

Example 1: From island to mainland (SKAT, 2016b)

Number of transports taken: ferry

From the island to the mainland one commutes daily home-to-work by ferry and no other transport mode. The daily cost of the tickets for the ferry is 60 kr.

The daily mileage allowance is:

60 kr. – 49,20 kr. = 10,80kr.

Example 2: From the island to the mainland with a further drive (1) (SKAT, 2016b)

Number of transports: ferry and car

From the island to the mainland one commutes daily home-to-work by ferry and and another transport mode. In this example the commuting is the ferry + 8 Km from the port to work.

This means a daily commute of 16 km + the ferry. The daily cost of the tickets for the ferry with the car is 120 kr.

The 16 km drive does not entitle to a deduction because the lower limit is 24 km, therefore, the daily expenses for the ferry must be reduced by:

16 km - 24 km = - 8 x 2,05 kr. = -16,40 kr.

The daily mileage allowance is:

120 kr. – 16,40 kr. = 103,60 kr.

Example 3: From the island to the mainland with a further drive (2) (SKAT, 2016b)

Number of transports: ferry + car

From the island to the mainland one commutes daily home-to-work by ferry and and another transport mode. In this example the commuter trip is the ferry + 17 Km from the port to work.

This means a daily commute of 34 km + the ferry trip. The daily cost of the tickets for the ferry with the car is 120 kr.

The 34 km drive entitles to a deduction because the lower limit is 24 km, therefore, the daily expenses for the ferry must:

34 km - 24 km = 10 x 2,05 kr. = 20,50 kr.

The daily mileage allowance is:

120 kr. + 20,50 kr. = 140,50 kr.

Example 4: Mainland only (SKAT, 2016b)(SKAT, 2016b)(SKAT, 2016b)

Number of transports: car (the same for any other transport – bicycle or public transport)

Within the mainland one commutes daily home-to-work by car (or any other mode). In this example the commuter trip is 20 km to work.

This means a daily commute of 40 km.

The 40 km drive entitles to a deduction because the lower limit is 24 km, therefore, the daily allowance for the commute is:

40 km - 24 km = 16 x 2,05 kr. = 32,80 kr.

Given the potential benefits of changing commuting patterns, e.g. less congestion, less air and noise pollution, through the promotion of tax incentives, and based on the fact that such tax incentive already exists in Denmark, the potential to adapt the current way it is assessed and calculated, in order for it to be more sensitive to the sustainability goals described is this chapter, is clear. As previously mentioned, there is however, the need to calculate and account for the potential impacts that such change in the current system can have. The following chapter introduces the cost-benefit analysis and the concept of external costs and how can these be used as tools to assess those impacts.

3. Theory

3.1. Cost-Benefit Analysis

The notion that policies could be evaluated in terms of their economic account, i.e., costs and benefits, originated from Jules Dupuit in the 19th century (Hanley & Spash, 1993; Pearce, Atkinson, & Mourato, 2006; Watkins, n.d.). In his article, Dupuit defined these costs and benefits in terms of *"human preferences and willingness to pay"* (Pearce et al., 2006: 32). Later, Alfred Marshall, a British economist, formulated some of the formal concepts that integrates the foundation on the Cost-Benefit Analysis (Watkins, n.d.). However, there is evidence from the accounting and comparison of cost and benefits in water-related projects in the United States, as early as 1808 (Hanley & Spash, 1993).

Fundamental to CBA is the idea of externality – a negative or positive effect with no monetary value, i.e. no price (Pearce et al., 2006). Externalities are social costs or benefits that can be manifested within a project and that will influence the well being of third parties. Due to the fact that these externalities do not have any associated monetary value, they are not captured by the market mechanisms and therefore not accounted for. However, since such effects influence the welfare of the society, they must be quantified and attributed a price, in order to be accounted in the market mechanisms (European Commission, 2013). Marshall had already outlined the concept of externality, but it was Pigou, in 1920, who developed the value of the externality. This value is based on the variance between private and social cost, meaning that the value of an externality should reflect the human willingness to pay. In short, CBA is a reflection on the fact that the individuals' preferences count, and that these preferences are accounted for in the market place (Pearce et al., 2006) through their willingness to pay. These theoretical works based on the welfare economics literature from the 1930s and 1940s, *"established that gains and losses reflected preferences or "utility", and that cost had always to be interpreted as opportunity cost, the value of the project or policy that is foregone by choosing a specific action"* (Pearce et al., 2006, p. 34). The basic principles of CBA had already been set out in the beginning of the 1960s (*ibid*).

Today, CBA is a method to evaluate and judge the net economic impact, i.e. the advantages or disadvantages of a certain investment decision, through the assessment of its costs and benefits. CBA can be applicable to a variety of interventions (European Commission, 2013, 2014; Gössling & Choi, 2015; Hanley & Spash, 1993), and it is normally used as a tool that accompanies feasibility studies, as the final synthesis of a certain project, either it is a technical or legislative one (amongst others). The main advantage, compared to other evaluation techniques, is that externalities and price distortions (e.g. taxes and sticky prices[3]) are considered (European Commission, 2013; Johansson & Kriström, 2015; Pearce et al., 2006).

However, there are some difficulties associated with assigning a monetary value (a price) to the externalities of a certain project, since sometimes no market values may exist or be considered incommensurable (Gössling & Choi, 2015; Hanley & Spash, 1993). Thus, one of the most controversial problems and critiques related to this technique is on how to assign a monetary value to these externalities (Gössling & Choi, 2015) regarding their social welfare function, and that reflect the principles of fairness and value incommensurability (Gössling & Choi, 2015; Pearce et al., 2006). However, *"social decision-making is about weighing up gains and losses*

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[3] *"Price stickiness - the tendency of prices to remain constant despite changes in supply and demand."* (Goldberg & Hellerstein, 2007, p. 1)

and deciding on the relative importance of different individuals' gains and losses" (Pearce et al., 2006, p. 47).

As a result, CBA can rarely be the only way to assess the future impact of a project. However, it can significantly support the evaluation process, by accounting the advantages and disadvantages, within a complex framework. When combining the CBA approach with policy goals (e.g., how benefits are distributed across society, or the valuation of the environment), and complementary analysis tools (e.g. multicriteria analysis (MCA), Environmental Impact Assessment (EIA) or Life Cycle Analysis (LCA)), CBA becomes an instrumental tool for project evaluation (Gössling & Choi, 2015; Pearce et al., 2006; PSRC, 2010). Currently, it is the dominant evaluation method for the economic assessment of projects, and the reason is that CBA "is an extension of the principle that the purpose of any system to select among project and program alternatives is to improve the well-being of the community net of any burden on society's scarce economic resources" (PSRC, 2010, p. iii).

In short, the purpose of CBA is to compare the benefits, which are associated with a certain project, policy or investment, with the costs of implementing that certain project, policy or investment. When the sum of the benefits exceeds the costs, there is a general economic argument supporting the project, policy or investment (PSRC, 2010). CBA, can be therefore, understood as a framework for social accounting, where each benefit or cost (that can be measured and monetized) is weighed against all the other costs and benefits (*ibid*).

Research plays an important role in the projects' decision-making processes, specially when involves large-scale investments of public resources, since the findings of such research can help to assess and evaluate the impacts the project and therefore help decision-makers (Annema, Koopmans, & Van Wee, 2007; PSRC, 2010). During the past decades, *"the trend in research supporting the decision-making process has been towards an impact evaluation based on a broad definition of welfare. Not only are economic impacts […] but also increasingly more these prove to be ecological and, sometimes, even social"* (Annema et al., 2007, p. 125). Throughout the last decades, techniques for transport-related projects appraisal, based on principles of economic analysis, have been established and sophisticated (PSRC, 2010). One of them, that is particularly suited to handle the temporal and network complexities, inherent to transport project assessment is CBA, making it one of the more commonly used tools for evaluating the projects' impacts (Annema et al., 2007; Gössling & Choi, 2015; Grant-Muller & Mackie, 2001; PSRC, 2010)

In recent years, comprehensive and extended *"CBA processes have gained importance in Europe as a result of various efforts to implement more sustainable transport systems and growing concerns about the significance of externalities to society"* (Gössling & Choi, 2015, p. 107). Despite the limitations and difficulties in assessing these externalities, several studies (Essen et al., 2011; Korzhenevych et al., 2014; Santos, Behrendt, Maconi, Shirvani, & Teytelboym, 2010) recognize that externalities (e.g. air and noise pollution, accidents, and climate change) are significant, and should be better addressed and integrated in "*transport infrastructure planning, taxation and decision making frameworks"* (Gössling & Choi, 2015, p. 107). And, while it seems to be common the use CBA in transport assessments, there is a lack of research, and absence of discussion, on the implications of the costs or benefits of commuting choices and its integration with the commuting tax systems.

3.2. Internalisation of External Costs

As previously described in the Introduction Chapter, the Europe 2020 Strategy, the Energy Roadmap 2050 and the 2011 White Paper on Transport, all underline and make clear the enormous challenges faced by the transport sector, particularly when it comes to the target of reducing by 60% the GHG emissions in 2050 (compared to 1990 levels), which encompasses a great need for further policy development, and the ambitious objectives for co-modality, modal shift and the reduction of road congestion (Essen et al., 2012; European Commission, 2010, 2011a, 2011b). For the EU transport policy, internsalisation of transportation external costs, is one of the primary principles in order to solve these challenges (Essen et al., 2012) and it is one of the main focus of the 2011 White Paper on Transport (European Commission, 2011b).

According to Essen et al. (2012, p. 5) external costs (in the transport sector) are *"costs to society that, without policy intervention, are not taken into account by the transport users"*.

Inherent external costs to transport activities are, environmental impacts, congestion, accidents, and infrastructure deterioration, which, in contrast with its benefits, are not fully assumed by the transport users. Therefore, without policy intervention, transport users do not take these external costs into account when making travel decisions. Thus faced with incorrect incentives that lead to welfare losses. Internalising (the external costs) means making the costs part of the decision making process of the users (Essen et al., 2011, 2012; Korzhenevych et al., 2014). Internalisation can also be referred to as the 'user pays'/'polluter pays' principle (Essen et al., 2012) and it can be done directly through regulation – command-and-control measures; indirectly through the provision of incentives to the users – market-based instruments; or through a combination of both (e.g. EURO classes) (Korzhenevych et al., 2014). The internalization of external costs, through market-based instruments, according to the welfare theory approach, can lead to the reduction of the negative impacts of transport activity and improve the benefits for transport users. It is also generally regarded as an efficient way to do it (Korzhenevych et al., 2014). According to Essen et al. (2011, p. 15) *"when the taxes and charges are equal to the costs they impose to society, transport users will take all these costs into account in their decision making […] change their behaviour, resulting in changing vehicle type, vehicle utilisation, transport mode or even their overall transport volume"*.

3.2.1. The concept of external costs in the transport sector

As described in the Introduction Chapter, transport and mobility are fundamental to our economy and society, for the markets and for the quality of life of the citizens. The transport sector contributes significantly to the economic growth of societies and enables the global market (European Commission, 2011b; Korzhenevych et al., 2014; Maibach et al., 2008). However, most forms of transport, besides their positive impacts in our society and economy, also produce negative and harmful impacts – e.g. road vehicles contribute to congestion, noise and air pollution, trains and airplanes to noise pollution, etc. (Korzhenevych et al., 2014; Maibach et al., 2008), and in contrast to the benefits, these are generally not assumed by the users and consequently not taken into account in the user decision-making process. Thus the label of 'external' effects (Maibach et al., 2008). In economical terms, when the effects of a certain activity impose a cost for society (e.g. time costs of delays or health costs caused by air pollution), such cost is considered to be an external cost (Korzhenevych et al., 2014).

When defining external costs, it is important to distinguish between (Korzhenevych et al., 2014; Maibach et al., 2008):

- *Social costs* — the costs that occurred due to the provision and use of transport infrastructure, e.g. environmental costs, congestion costs, accident costs, capital costs and wear and tear costs of infrastructure;
- *Private or Internal costs* — the costs that are directly assumed by the user, e.g. transport tickets, taxes and charges, wear and tear of vehicle use, energy costs of vehicle use and time costs.

The external costs are the difference between both the *social* and the *private costs (ibid.)*.

Economic assessments, in the transport sector, are the foundation for critically evaluating policy-actions and instruments. Hence, the need for representative estimates of the full (or true) costs of road transport - including the external costs (Thune-Larsen, Veisten, Rødseth, & Klæboe, 2016). However, the processes of quantify the external costs are difficult, since they are dependent of the costs variation: a) among different vehicles; b) when and where the transport happens and; iii) contextual factors (e.g. climatic conditions) (Thune-Larsen et al., 2016). These variations in costs can be defined as *marginal costs*.

"Marginal costs are those variable costs that reflect the cost of an additional vehicle or transport unit using the infrastructure. Strictly speaking, they can vary every minute, with different transport users, at different times, in different conditions and in different places. Moreover for the last extra carriage on the train, car on the road, or ship at sea, marginal costs can often be close to zero. Clearly such a strict definition is of no practical use, and like all other charging arrangements in the commercial world, a degree of approximation and averaging is necessary to develop understandable, practical charging structures. Marginal costs may at times merely reflect an average of variable costs. More usefully, they should reflect infrastructure damage, congestion and pollution costs, and so would vary according to factors like unit weight or number of axles, peak times, urban travel, and engine emissions." (European Commission, 1998, p. 8)

Regarding the *private* marginal costs, infrastructure charges should reflect the marginal external costs of infrastructure use. Regarding the *social* costs and according to the economic welfare theory, transport users should pay all marginal *social* costs derived from a transport activity. However only some parts of these costs are monetary relevant, other parts, such as time losses or health damages are considered social welfare losses. From an economic perspective, a certain project is viable, if the additional social benefits exceed the additional social costs. Therefore, fixed infrastructure costs are not appropriate for efficient pricing. The reason is that, although in the short run the marginal costs are relevant for efficient pricing, these costs are connected to a constant infrastructure capacity. Meaning that, in the long run, due to changes in the infrastructure capacity, marginal costs also need to consider the financing of infrastructure expansions (Korzhenevych et al., 2014; Maibach et al., 2008). In this sense, for a future efficient mobility model, there is the need to take into account the true costs of transport. There is also the need to create incentives, within the transport regulatory/policy framework, to encourage and promote more sustainable transport choices and behaviour (Santos et al., 2010).

A detailed analysis on how all these factors affect the magnitude of the external costs is beyond the scope of this project. The values (costs) used are indicative of average considerations and cover essential variations, as a result of, e.g.

geography, time of day and the vehicle's environmental standard. The data used is provided by the Transportøkonomiske Enhedspriser (TE) (in English - *Transport Economic Unit Prices)* (DTU & COWI, 2016), which is a catalogue of common assumptions and unit prices to be used in economic analyses of transport, prepared by DTU and COWI for the Danish Ministry of Transport. The common assumptions include forecasts for economic development (GDP per. capita and inflation), population growth and fuel prices. Unit prices include time values, driving costs and the value of environmental and climate effects.

An important element in projects, programmes and/or policies evaluation is the identification of two alternate states of the world: with and without the implementation of these. The objective is to isolate the consequences of both states of the world. In all other respects, these states resemble each other. In this respect, there is a natural affinity between CBA and models of systems change (PSRC, 2010).

The intention of this project is to understand how can the current commuting tax deduction system be adapted to fulfill the sustainability goals from the Danish Government and the European Commission. This can be achieved through a socio-economic analysis where the external costs and the marginal social costs of each transport choice (in commuting home-to-work) are taken into account. With this, it will be possible to apply the full[4] costs of transport to the Danish commuting tax and in this sense inform on the users decision-making process, as well as the Danish Government.

[4] By full costs it is understood the private and social costs associated with each transport mode (Korzhenevych et al., 2014; Maibach et al., 2008).

- *Social costs* — the costs that occurred due to the provision and use of transport infrastructure, e.g. environmental costs, congestion costs, accident costs, capital costs and wear and tear costs of infrastructure;
- *Private or Internal costs* — the costs that are directly assumed by the user, e.g. transport tickets, taxes and charges, wear and tear of vehicle use, energy costs of vehicle use and time costs.

4. Methodology

In order to answer this study research question: *"How can the commuting tax[5] be adjusted to fit the Danish sustainability goals?"* different parameters had to be studied and understood. On the theoretical side: "How the commuting tax works?" and "What are the sustainability goals?"; and on the practical side: "Which data is available?" and "How to model the current commuting tax?".

From this background raises this study methodology, which seeks to find how to adapt the existing commuting tax system, to comply with the existing sustainability targets, as well as to promote a more sustainable commuting behavior. Figure 6 bellow shows the methodology followed in this study.

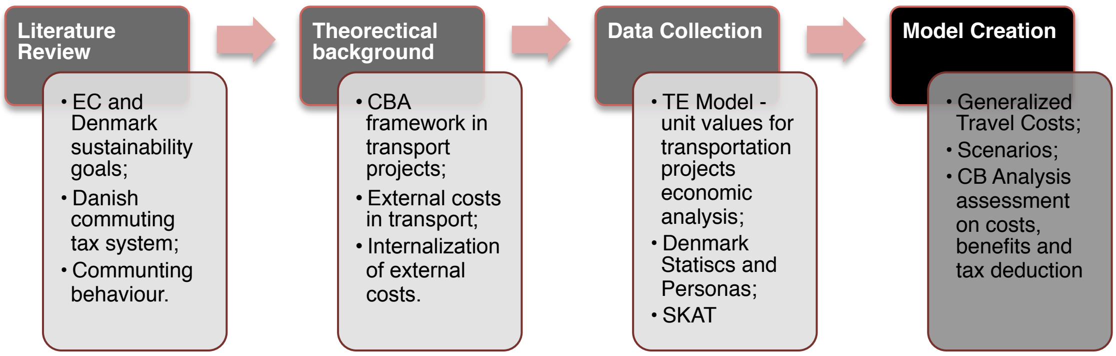

Figure 6 – Schematics of the used methodology.

This study and methodology are considered to be a first step on the research gap that exists within this area. Through the presentation of detailed calculations and evidence, it becomes clear the need to explore and adapt the existing tax incentives to a more sustained transportation sector, and a possible way to do it. Follows a detailed description of the used methodology.

4.1. Literature review

To answer the theoretical questions a literature review was essential. The literature review was undertaken in order to determine the research status quo within the research area, namely what was the available information on commuting tax systems and transport pricing incentives to commuters' behavior. From here it was comprehended that, at the national level, income tax is generally the key policy instrument affecting the commuter transport (Atterbrand et al., 2005; Gössling, 2013), and that in Denmark the system is based on distance travelled per day (km/day). However, the real travel expenses and the transport mode are irrelevant (SKAT, 2016a), for the way that the final tax deduction is calculated. Today, in Denmark, about a third of all car trips are 5 km or less, while more than half of all car trips are less than 10 kilometers, so there is undoubtedly potential to move

[5]C*ommuting tax* translated from the Danish - Kørselsfradrag (befordringsfradrag)

commuters from car to bicycle and public transport (Cyklistforbundet, 2015), specially on the shorter distances. It is believed that with the right tax incentive structures this has potential to be achieved, and what is explored in this study.

4.2. Data collection

From the literature review was possible to identify the main challenges, practices and available tools to materialize this model. In the design of this model it was essential to identify the needed inputs. For that, the Transport Economic Unit Prices (TE) model[6], the Danish SKAT agency, Denmark Statistics and real commuting cases (Personas), were essential to gather the needed information.

4.2.1. Transport Economic Unit Prices (TE) Model

In Denmark, the TE Model, has been developed and constantly updated to reflect the latest developments in economic assessments, (DTU & COWI, 2016; Gössling & Choi, 2015; Transportministeriet, 2015). This model presents the unit prices and conditions for the use of socio-economic analysis in transport projects, and used as the baseline data for this study.

The TE Model, from the Danish Transport Ministry, is a catalog of common assumptions and unit prices designed to be used in the economic appraisal of transport projects in Denmark. This catalogue is annually updated and available online at the Data and Model Center at DTU Transport website[7]. The common assumptions include forecasts of economic development (GDP per capita and inflation), population growth and fuel prices. Unit prices include time values, driving costs and the value of environmental and climate effects. The individual conditions and unit prices are calculated at constant prices. The purpose of this catalog is to ensure that the same assumptions and unit prices are used in the transport projects (Transportministeriet, 2015).

4.2.2. Denmark Statistics and Personas

To answer the research question different commuting profiles needed to be tested. For that, there was the need to limit an area of study, which was narrowed to Greater Copenhagen (the city of Copenhagen and surrounding areas). From here, Statistics Denmark, which is the central authority on Danish statistics (Statistics Denmark, 2016), provided the data to assess the commuting profiles, for the study area. Table 1 bellow shows the commuting distances for the area contemplated. For the calculations preformed, the average commuting distances were used – 2,5 km; 7,5 km; 15 km; 25 km; 30 km; 35 km; 45 km and 50 km.

[6] From the Danish Transportøkonomiske Enhedspriser (TE) Model.

[7] http://www.modelcenter.transport.dtu.dk/Noegletal/Transportoekonomiske-Enhedspriser

Table 1 – Commuting profiles for the studied areas (Statistics Denmark, 2014).

Commuting distance (one way)	Number of persons	%
No commuting	28444	4
Up to 5 km	234990	32
5-10 km	172798	23
10-20 km	145984	20
20-30 km	55151	7
30-40 km	32444	4
40-50 km	18650	3
More than 50 km	56048	8
Total	744509	100

Furthermore, real commuting cases were assessed. The real cases, from now on referred to as personas, were used in order to compare the average distances and tax deductions with the average commuting profiles above mentioned, from which it was possible to verify the SKAT calculations and the 2015 tax income. Table 2 bellow shows the cases assessed.

Table 2 - Personas commuting profiles.

Example Number	Home address	Work address	Commuting Distance (Skat calculator)
1	Nordre Kongelundsvej 3, 2300 København	A. C. Meyers Vænge 15, København	9 km
2	Nordre Kongelundsvej 3, 2300 København	Roskilde University	68 km
3	Koldinggade 5, 2100 københavn	Tinvej 16, 3060 Espergærde, Denmark	76 km
4	Nordre Kongelundsvej 19, 2300 København	Ejbovej 11, 4632 Bjæverskov	96 km

4.2.3. SKAT

SKAT TastSelv webpage (SKAT, 2015a), which is a online tool to calculate one's commuting tax deduction, was used to calculate the commuting distances for the personas that were used, as well as, to simulate their equivalent tax deductions. Through this it was also possible to compare the obtained values with the preformed calculations. Figure 7 bellow shows the online SKAT TastSelv tool.

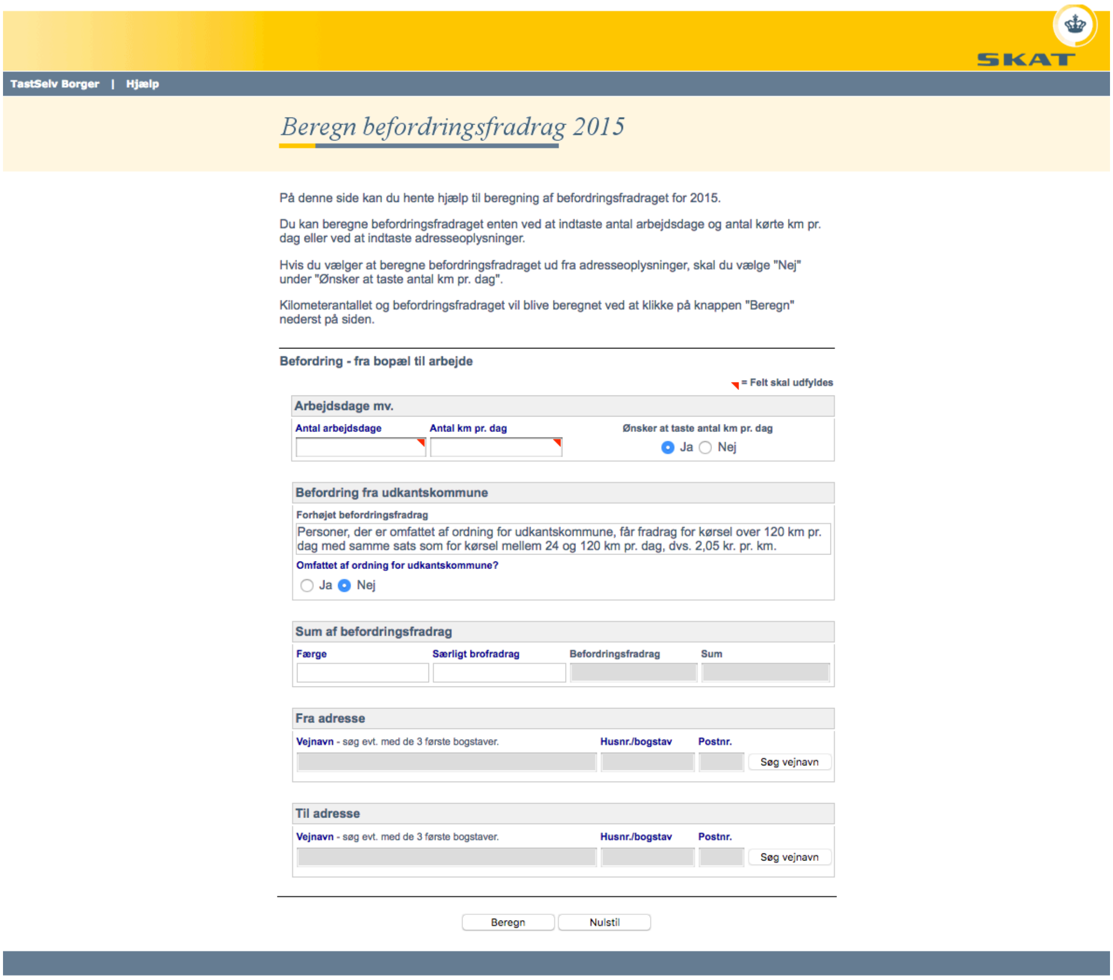

Figure 7 – Skat TastSelv Beregn befordringsfradrag 2015.

4.3. Data treatment – model creation

The model created constitutes a cost-befit analysis assessing several commuting distances on different transport modes. In this CBA model - created to assess the costs and benefits for different commuting profiles and consequent tax deduction incomes - several variables are tested and calculated to give back as output the final cost of a certain commute in different transport modes through it generalized travel cost. After calculating the generalized travel cost from each transport mode, the model compares the different travel costs against each other's, before and after the application of different tax deduction rates. The model was built in an Excel file so all calculations are centralized in a single file. Figure 8 bellow shows the model construction.

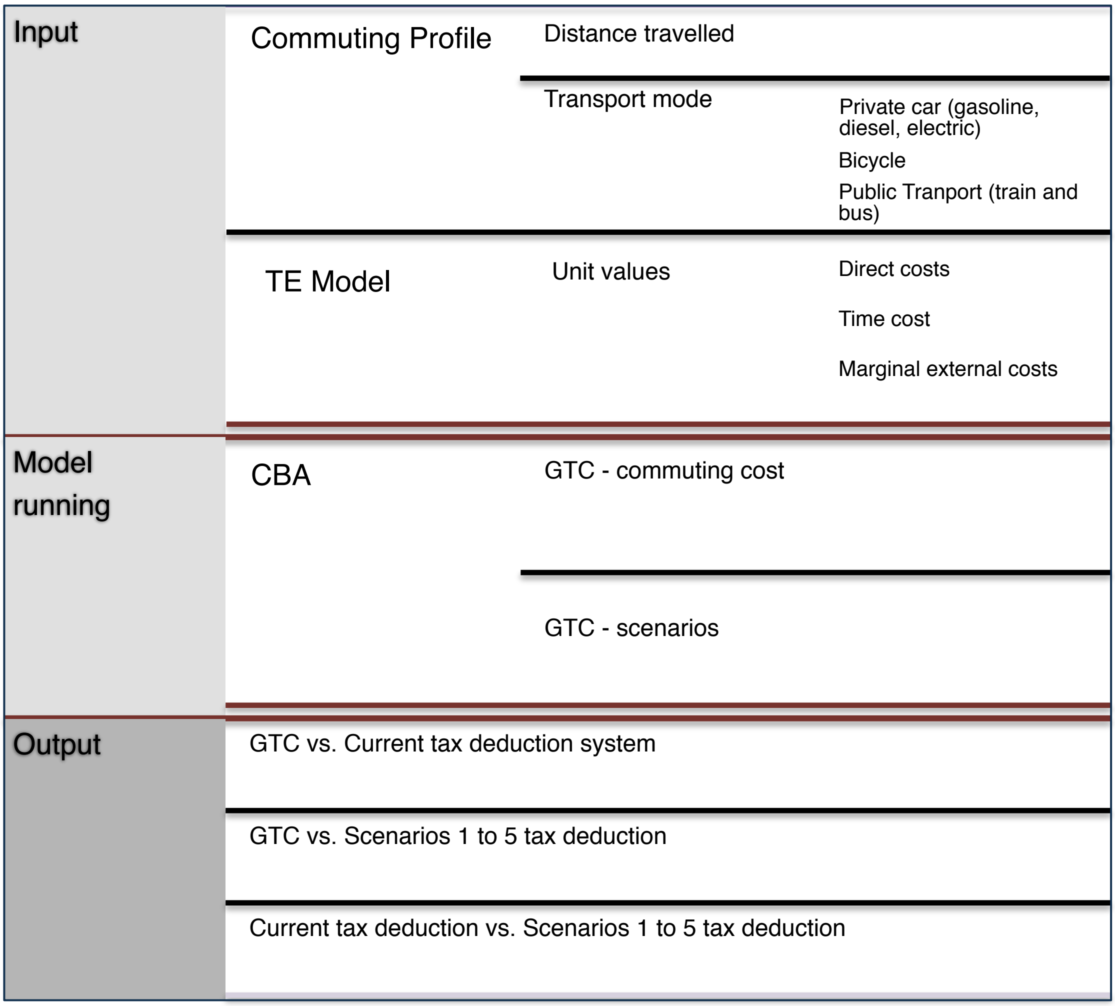

Figure 8 – Schematics on the model created.

4.3.1. Generalized Travel Cost

The commuting costs were calculated through the Generalized Travel Cost (GTC). The GTC expresses the total price of a certain trip and consists in the sum of three groups of costs – 1) direct costs; 2) time costs; and 3) other costs (Transportministeriet, 2015):

1) Direct costs (DC) can be directly expressed in monetary terms and include the costs of the journey. In the case of drivers (cars and bycicles) this cost is represented by the driving/running costs of the vehicles – fuel, tires, repair and maintenence, etc., in the case of public transport passengers it is represented by the ticket cost, which is dependent on the number of kilometers travelled;
2) Time costs (TC) cover the time spent on the travel, whether by car, public transport or cycling;
3) Other costs cover the remaining generated costs. In the case of this projects other costs are represented by the marginal external costs (MC) and benefits derived from each trip. The purpose of using the MC is to be able to quantify the costs and benefits that derived from each mode of transport, and that are not taken into account by the users. These costs are: air pollution, climate change, noise, accidents, congestion, damage to

infrastructure, and health. Quantifying environmental and social costs is necessary in order for the model to be sensitive to sustainability goals.

The decision on whether an individual makes a trip or not, depends not only on the direct costs, but also the time costs and other expenses. The sum of these three types of costs gives the actual cost of each individual trip (Transportministeriet, 2015).

Mathematically this can be expressed by the following formula:

$$GTC = \sum_{km/mode} (DC, TC, MC)$$

Follows an explanation on how each group of costs was calculated.

Direct Costs

The direct costs are part of the overall travel costs that the individual driver, cyclist or passenger experience by completing a trip. Depending on the mode of transport this will include different cost components. Thus, in the analysis a distinction is made between the different modes (car, bicycle, and public transport – train and bus). The direct costs were calculated on the basis of the unit prices for 2015 from the Danish Transport Ministry (DTU & COWI, 2016).

For cars and bycicles the DC comprehend the driving costs, for public transport (trains and busses) the ticket price.

Driving cost for cars

The cost of driving a car includes the fuel and engine oil, tires, repair and maintenance, taxes, and depreciation, Table 3. The costs were determined considering the Danish car fleet and current market prices, and were calculated in Danish kr. per km driven (Transportministeriet, 2015).

Table 3 – Driving costs for cars (kr./km), 2015. (DTU & COWI, 2016)

	Average including taxes
Fuel	0,698
Engine oil	0,032
Tires	0,047
Repair and maintenance	0,491
Owner tax	0,242
Depreciation	1,055
Total	2,564

Driving cost for bicycles

In the same way as cars, bicycles are treated in the economic analysis as an individual mode of transport. The direct costs of cycling are bicycle depreciation, tires, lights and repairs, calculated in Danish kr. per km driven, Table 4. The used unit values for the bicycle driving costs were determined based on the average direct costs of a cheap used bicycle (less oftenly used) and a new average bicycle (more commonly used) (Transportministeriet, 2015).

Table 4 - Driving costs for bicycles (kr./km), 2015. (DTU & COWI, 2016)

	Average including taxes
Driving costs	0,372787838

Driving costs for public transport

The direct costs for passengers in public transport are reflected through the change in their tickets cost. Typically there is no change in the ticket cost for the individual, unless, as a result of an action, the passenger sets his itinerary differently. For each new passengers in public transport there are costs associated with the purchase of the ticket, but the ticket cost is implicitly included in consumer surplus, therefore not shown as a direct driving cost for public tranport (Transportministeriet, 2015). For the purpose of this study, only cars and byclicles are considered as individual transport modes, since it is the driver who as to support the driving costs. Therefore, when it comes to public transport, the only direct cost the individual has is the ticket cost (which reflects the driving costs for the public transport operator (Transportministeriet, 2015)) and not the actual driving cost of the public transport.

To calculate the direct cost for public transport, i.e. the passenger ticket price, the unit prices for the average ticket prices, were used, Table 5. The average ticket prices are dependent on the length of the trip, and calculated in Danish kr. per person km. These values were determined by the Danish Ministry of Transport for both train and busses transport operators (DTU & COWI, 2016).

Table 5 - Average ticket cost (kr./person km), 2007. (DTU & COWI, 2016)

Trip length	Price
0-10 km	1,39
10-20 km	1,11
20-40 km	0,75
40-80 km	0,56
over 80 km	0,72
Average of all trips	0,75

Time Costs

Time savings, in terms of saved travel time costs, often represent a very significant part of the overall choice of transport mode (Transportministeriet, 2015), e.g. which mode will provide less travelling time and/or less delay time. For passengers, time savings fall into three categories according with the travel purposes: 1) home-to-work commuting; 2) work related; and 3) other private purposes (e.g. leisure travel) – since different purposes will emcompasse different time values. Amongst the three categories, work related is the categorie with higher time value (*ibid*).

For the objective of this project only commuting time values are considered. Time values are divided into individual and public transport. Individual transport includes car and bicycle, while public transport include passenger transport by bus and train.

For commuting travel purposes, the value of travel time derives from the population willingness to pay for time (i.e., the willingness to pay to save one hour of travel time for the individual traveler - how much does their travel time worth) (Fosgerau, Hjorth, & Lyk-Jensen, 2007; Transportministeriet, 2015). The time savings are calculated at market prices, i.e. including indirect taxes, and based on the Danish Value of Time Study (DATIV) (Fosgerau et al., 2007) that resulted from an extensive study conducted by DTU Transport (2007), Table 6.

Table 6 – Time value for passengers in commuting trips (kr./person hour) (2015). (DTU & COWI, 2016)

Drivers		Bicyclists		Collective travelers	
Driving time	85,119	Driving time	85,119	Travel time	85,119
Delay time	127,679	Delay time	127,679	Delay time	255,358
				Waiting time	170,239
				Hidden waiting time	68,096
				Transition time	127,679
				Change penalty (kr per shift)	8,512

Individual transport includes two types of fixed elements (Transportministeriet, 2015):

- Regular travel time - the expected transport time for individual road users between travel points A and B in a situation without delay, calculated per passenger hour;
- Delay - daily delay that the individual road experience every day in congestion or that may arise in case of accidents, bad weather, etc.

Public transport includes six types of fixed elements (Transportministeriet, 2015):

- Regular travel time - the time that each passenger spends in the collective transport between travel points A and B, corresponding to the vehicle scheduled travel time;
- Delay - the number of minutes that the individual is delayed compared to the expected travel time. The time value for delay in public transport is weighted by a factor of 2.0 compared to the normal travel time, and is thus higher in public transport than for passenger traffic;
- Waiting and hidden waiting (frequency) - time interval between departures;
- Transition and change penalty - the time passengers spend on switching between two modes of transport on the same trip, including waiting time between modes, and number of changes. The switching time is weighted 1.5 in relation to the general travel time, whereas a shift between modes (in the form of a switch penalty) represents the value of a 6-minute normal travel time.

Time costs can be converted into time cost per km as a function of the distance travelled per hour (Gössling & Choi, 2015). For this study the used conversion factors are based on the following average speeds: cars[8] – 50 km/h; bicycles[9] – 16 km/h; bus[10] – 50 km/h; and train[11] – 90 km/h.

To calculate the GTC only the driving/travel time was used.

[8] (Cycling Embassy of Denmark, 2012; Gössling & Choi, 2015)
[9] (Cycling Embassy of Denmark, 2012; Gössling & Choi, 2015)
[10] Maximum speed in urban roads.
[11] (banedanmark, 2016)

Marginal Costs

In addition to the direct costs and time costs this study includes the marginal external costs derived from transport, i.e. the environmental and social costs. The quantification of the MC, that derived from each mode of transport and trip length, is necessary in order for the model to be sensitive to the Danish sustainability targets (see 2). The marginal external costs reflect the costs to society that are not taken into account by the transport users.

The marginal costs were used to allow for the internalization of such costs when comparing the different commuting trips, to better inform in choosing between different alternatives for the commuting trips, as well as to inform when modeling the tax system. The internalization of the transportation external costs is one of the primary principles in order to solve the sustainability challenges the transport sector encompasses, particularly when it comes to the target of reducing by 60% the GHG emissions in 2050 (compared to 1990 levels), which encompasses a great need for further policy development, and the ambitious objectives for co-modality, modal shift and the reduction of road congestion (Essen et al., 2012; European Commission, 2010, 2011a, 2011b).

Transport has secondary effects in the form of air pollution, climate change, noise, accidents, congestion, damage to infrastructure, and health. The unit values used reflect the average values and take into account variations due to, e.g. geography, time of day, and vehicle environmental standard (DTU & COWI, 2016). The marginal external costs can be used when comparing modes of transport and/or when there is limited knowledge regarding the concrete conditions (*ibid*), as it is the case of this study.

The specified marginal external costs are based on the External Costs of Transport 1st and 2nd Reports (COWI, 2004a, 2004b), where the methods behind the determination of the values and its actual valuation is explained. The values, however, reflected some uncertainty. Therefore, the unit values, determined on a yearly basis by the Danish Ministry of Transport (DTU & COWI, 2016), are estimated set in low, medium and high scenarios. For this analysis, where the estimated costs will not have a decisive effect on the outcome, the medium scenario values were used, Table 7.

For the public transport, the marginal costs associated with each category (air pollution, climate change, noise, accidents, congestion, and infrastructure) were divided by the total capacity of each transport. This is due to the fact that, the external costs for public transport, should be borne by all users, since one do not use the bus or the train alone but in a group. Since the average scenarios are being used, the total capacity was considered to be representative of the average.

Table 7 – Average marginal costs (kr./km) (2015). (DTU & COWI, 2016)

Transport mode	Fuel	Capacity	Air Pollution	Climate Change	Noise	Accidents	Congestion	Infrastructure	Health
Bicycle		1 pers	0	0	0	0,877	0	0	-2,572
Car	Gasoline	4 pers	0,012	0,015	0,053	0,232	0,376	0,011	0
	Diesel	4 pers	0,050	0,012	0,053	0,232	0,376	0,011	0
	Electric	4 pers	0,011	0,006	0,020	0,232	0,376	0,011	0
Bus	Diesel	40 pers	0,954	0,089	0,236	0,515	0,703	0,620	0
Train	Electric	475 pers	0,827	0,497	0,349	2,560	0	0	0

Follows a brief description from each category of marginal cost.

Air pollution

Air pollution covers Nitrogen Oxides (NO_x), Hydrocarbons (HC), Sulphur Oxide (SO_2), Carbon Monoxide (CO) and Particulate Matter ($PM_{2.5}$), which are pollutants derived from transport and harmful for human health, agriculture, forestry and the built environment (COWI, 2004a; Gössling & Choi, 2015). Therefore, considered as negative external effects from transport.

The marginal air pollution costs are calculated based on the results derived from the TRIP-project (DTU & COWI, 2016), which purpose is to establish unit costs for air pollution for transport exhaust emissions in Denmark. The unit costs are assed through the application of the Impact Pathway Methodology (COWI, 2004a, 2004b), also named 'bottom-up' method (Transportministeriet, 2015) as it seeks to follow the causal links between transport and its negative impacts, and valuation of these (COWI, 2004a). The TRIP-project updates the unit costs based on the latest knowledge about 'dose-response' relationships and economic valuation (Transportministeriet, 2015).

Climate change

The costs associated with climate change are based on the prices determined by the EU's trade market value of CO_2 quotas. The marginal external climate change costs reflect the total CO_2 emission independently of the quota system (DTU & COWI, 2016). The price of a CO_2 quota reflects the willingness to pay for emissions, and thus the cost can be achieved by selling a quota. At the same time reflects also the price to be paid if one need to purchase a CO_2 quota, which enables increased emissions. Therefore, the price of a CO_2 quota can be used as an indicator of the cost associated with CO_2 emissions (Transportministeriet, 2015). However, due to the lack of knowledge, considering the impact pathway, the time lag of effects, and other reasons, the magnitude of the costs for climate change can be subject of dispute (COWI, 2004b; Gössling & Choi, 2015).

Noise

The Danish unit for measuring traffic noise is the SBT - noise annoyance index. The unit cost for noise contains two elements, annoyance and health costs. The annoyance costs reflects the perceived noise level that cause annoyance and discomfort. The health costs are related to the health impacts caused by noise exposure (COWI, 2004b). The marginal external costs of noise, are calculated by first measuring the noise emissions from traffic and then transforming them into a given noise level, expressed in dB, at the facade of properties. The total change in noise levels is calculated by marginal changes in traffic and thus converted to the change expressed in SBT. Finally, the unit price is used to calculate the cost of marginal change in traffic (DTU & COWI, 2016).

Accidents

The external effects of accidents in traffic includes both direct costs, directly associated with the accident, and welfare costs, based on the individuals willingness to pay to reduce their own risk of accident (Transportministeriet, 2015). The marginal external cost of accidents include: the direct public costs (police, rescue, and treatment); the net production loss; the loss of 'human value'; and material damage costs (DTU & COWI, 2016). Costs are calculated in comparison with the number of accidents by transport mode, and the number of km made for each transport mode (Gössling & Choi, 2015).

Congestion

"Congestion occurs when the demand for transport in a given area at a specific time exceeds the supplied transport in the form of capacity of the infrastructure" (COWI, 2004a, p. 95). According to the mode of transport, congestion can take different forms, depending e.g., if the transport is scheduled or non-scheduled. However, regardless of the transport mode, primary consequences of congestion are longer travel times and increased operation costs (COWI, 2004a).

Marginal external congestion costs cannot be transferred from one area to another, as they are specific from a given time and place, and calculated on the basis of the cost of delays per hour (COWI, 2004b; Gössling & Choi, 2015). The external cost of congestion is expressed as the marginal external costs of an additional vehicle kilometer. The marginal congestion cost should ideally reflect the costs suffered by other road users, in the form of delay, when a user is running an extra km. The external cost is determined on the basis of information from the *External Cost of Transport* (COWI, 2004a, 2004b, 2004c), supplemented with new data on the congestion cost from the Danish Transport Ministry (DTU & COWI, 2016).

Infrastructure

As opposed to the other types of external costs, infrastructure costs, can be directly expressed into monetary units, as they are typically accounted in budgets for transport projects. Therefore, the problem of estimation for these costs is not related to the valuation of the costs, but rather in defining correctly the relevant cost categories, since the definition of external costs, says these are costs that are not explicitly paid for and therefore not taken into account of the infrastructure users (COWI, 2004a). The marginal costs for infrastructure include: the damage to infrastructure (maintenance of road surfaces and tracks, repairs to bridges, noise walls and technical facilities), as well as the cost of services or other infrastructure operations (*ibid*). The specified external costs should be considered as short-term costs, as they only include the costs related to the volume of traffic and not the capital costs for infrastructure expansions (DTU & COWI, 2016).

Health

Health denotes the health gains, to the individual cyclist, in the form of improved health and extended life, based on the beneficial health effects associated with cycling. The unit price per bicycle kilometer consists on the gains and costs associated with improved health and extended life expectancy (Transportministeriet, 2015), which are calculated on the basis of avoided costs as a result of physical exercise (Gössling & Choi, 2015).

4.3.2. Scenarios

After calculating the GTC associated to the different transport modes for each commuting profile, five scenarios, composing variations to the current system, were created. The aim of this study is to adapt the current commuting tax to the Danish sustainability goals. Therefore, the scenarios were created to be aligned with those goals (see 2).

Current system

The system is based on distance travelled per day (km/day). One can be entitled to a deduction for transport for if the commuting distance is superior to 24 km/day. The actual transport expenses and the means of transport are irrelevant (SKAT, 2016a). SKAT calculates the deduction based on a predefined number of working days. SKAT sets this number of working days/transport days at 216. The 216 working days correspond to a full working year with 6 weeks' holiday plus 6-8 working days without transport. The extra days may be, for example, sick days, days off or days working from home (SKAT, 2016a). This can be changed manually by the individual through SKATs website.

Scenario 1

The first case internalizes the marginal costs, air pollution, climate change, noise, accidents, congestion, infrastructure and health, directly in the commuting tax. In order to do this, all the MC of each transport mode were added up and afterwards subtracted to the commuting tax. By doing so, the users are paying for the externalities that their choice encompasses (social costs and benefits), which in the current system are not taken into account.

This scenario was created in line with the following sustainability targets:

- Reduction in all greenhouse gas emissions;
- Ensuring mobility and reducing congestion;
- More efficiency in transferring passenger transport from private cars to public transport;
- Promoting changes in behavior.

Scenario 2

The second case penalizes the fueled private modes – private cars fueled by gasoline and diesel, i.e., that these two modes do not get any tax deduction for commuting, regardless of the distance travelled.

This scenario was created in line with the following sustainability targets:

- Reduction in all greenhouse gas emissions;
- Energy consumption entirely based on renewables by 2050, resulting in fossil fuels being phased out in the transport sector;
- Ensuring mobility and reducing congestion;
- More efficiency in transferring passenger transport from private cars to public transport;
- Promoting changes in behavior.
- Reduce carbon emissions through alternative propulsion systems (e.g. electric cars);

Scenario 3

The third case penalizes the fueled private modes – has in scenario 2; and benefits bicycles. For this mode, any commute above 4 km/day gets deduction.

This scenario was created in line with the following sustainability targets:

- Reduction in all greenhouse gas emissions;
- Energy consumption entirely based on renewables by 2050, resulting in fossil fuels being phased out in the transport sector;
- Ensuring mobility and reducing congestion;
- More efficiency in transferring passenger transport from private cars to public transport;
- Promoting changes in behavior.
- Reduce carbon emissions through alternative propulsion systems (e.g. electric cars);

Scenario 4

The fourth case penalizes the fueled private modes – has in scenario 2 and 3; and benefits bicycles. For this mode, any commute above 6 km/day gets deduction.

This scenario was created in line with the following sustainability targets:

- Reduction in all greenhouse gas emissions;
- Energy consumption entirely based on renewables by 2050, resulting in fossil fuels being phased out in the transport sector;
- Ensuring mobility and reducing congestion;
- More efficiency in transferring passenger transport from private cars to public transport;
- Promoting changes in behavior.
- Reduce carbon emissions through alternative propulsion systems (e.g. electric cars);

Scenario 5

The fifth and final scenario is the most radical one, since it is the one that encompasses most variations. This scenario was chosen in order to privilege most changes in the commuting behavior. In this scenario all private modes are penalized, i.e., no commutes by car get tax deduction, and commutes, both by public transport and bicycle, are beneficiated. Therefore, bicycles get deduction always, regardless of the distance travelled, and public transport gets deduction for commutes above 10 km/day.

This scenario was created in line with the following sustainability targets:

- Reduction in all greenhouse gas emissions;
- Energy consumption entirely based on renewables by 2050, resulting in fossil fuels being phased out in the transport sector;
- Ensuring mobility and reducing congestion;
- More efficiency in transferring passenger transport from private cars to public transport;
- Promoting changes in behavior.

4.4. Strengths and limitations

CBA is a method to evaluate and judge the net economic impact, i.e. the advantages or disadvantages of a certain investment decision, through the assessment of its costs and benefits. The main advantage of this tool is that externalities and price distortions are considered (European Commission, 2013; Johansson & Kriström, 2015; Pearce et al., 2006). Despite its limitations, when valuating externalities, Essen et al., 2011; Korzhenevych et al., 2014; Santos, Behrendt, Maconi, Shirvani, & Teytelboym, 2010, amongst others, recognize that externalities are significant, and should be integrated in transport planning, e.g. taxation frameworks (Gössling & Choi, 2015). When using the CBA framework, the high cost of driving a car in comparison to the cost of cycling or using public transport becomes more obvious as result of accounting for the cost of externalities when commuting. However, it may be argued that spillover externalities are important for the comparison between cars and the other modes. As Gössling & Choi (2015, p. 111) argue that e.g. *"bicyclists engender less risk on other street users than cars, while accident risks are in no small part related to traffic density and crowding effects mostly attributable to cars"* making the TE model, and therefore this CBA analysis, biased towards the cars, in this specific case. In summary, while the used TE model, as well as the CBA preformed in this study, tries to reflect social and environmental costs – through the account of the MC – the chosen background data may constitute an imperfect instrument to compare the different transport modes. However, since the unit values used are based on market values, and complemented with forecasts of economic development (GDP per capita and inflation), population growth and fuel prices, amongst other's, and that the these values are always updated to the most recent year, for which data is available, they are also seen as the most accurate data available to use.

Another limitation to this study is that all the GTC are preformed for commutes up to 100 km/day. This is merely a theoretical exercise, since that for bicycles very few people commute more than 20 km/day and maybe none above 40 km/day. A similar situation happens for commutes by bus, where for long commutes the number so users declines (see 5.1) in the area of study. Also, no scenarios considering the use of more than one transport mode for the same commute were tested. This can be seen as a limitation, since that maybe there is a considerate portion of commuters that combine more than one mode on their daily commutes. However, as mentioned, this is a theoretical exercise that aims at categorize the individual commuting costs of the different transport mode choices. An additional and important reflection, is that this study, is only looking at the problem from the commuter point of view, i.e., it does not, for instance, reflects on how the State income is going to be affected by the proposed changes. Supposing that these changes are enforced in the future, the State would receive less money for fuel taxes, as the consumption would go down, since in theory there would be a transfer of passenger transport from private cars to bicycles and public transport. In fact, it can be argued that the State would receive more in taxes from those that continue to use gasoline, diesel and electric cars, yet it would also have to pay back more to those commuting by bicycles and/or public transport. However, for the purpose of this study, the impact on the State overall income in transport related taxes and investments, is not being calculated.

Despite the limitations associated with the method used and the uncertainty associated with the quantification of the unit values, this analysis is considered a useful methodology to investigate the potential advantages and disadvantages of changing the current Danish commuting tax. Therefore, it is considered that this model can be an important tool to provide an economic justification for the alteration of the current commuting tax system.

5. Analysis

To answer the research question a model was created (see 4.3). As previously mentioned, this model aims at assessing the socio-economic and sustainability potential costs and benefits of adapting the Danish commuting tax to the Government's goals for the transport sector. The model runs a cost-benefit analysis that simulates different tax variations in different scenarios. The scenarios were created in line with the Governments' goals, so that the potential change of the tax could be determined. Those goals can succinctly be identified as (Danish Government, 2013):

- Reduction of greenhouse gas emissions;
- Energy consumption entirely based on renewables – which implicates that the energy consumption for transport sector will have to come from renewable sources;
- Ensure mobility and reduce congestion;
- Reduce carbon emissions through alternative propulsion systems (e.g. electric, biogas or biofuel);
- Decouple the growth in demand for transport from the economic growth, through taxes on buying, owning and using cars, as well as through spatial planning;
- More efficiency through the increase of what is transported per km (e.g. transferring passenger transport from private cars to public transport or increasing the amount of goods on an individual vehicle);
- Reduce energy consumption per km covered (e.g. technology improvements or changes in behavior).

The area of study is limited to Greater Copenhagen (the city of Copenhagen and surrounding areas) from where the average commuting profiles were identified, as well as the personas. Furthermore, it is at the urban level that most challenges from transport derive, as congestion, poor air quality and noise exposure (European Commission, 2011b; Gössling, 2013), but it is also at the urban level that the promotion of more sustainable commuting behavior is facilitated, hence Greater Copenhagen.

This chapter presents the outcomes from the model created. As explain in Chapter 4 – Methodology, the model runs a cost-benefit analysis on different commuting distances and transport modes, while simulating different tax variations in those commuting profiles – the scenarios, allowing for a comparative assessment between them. It is through these outcomes that the social and economic impacts to the alteration of the existing commuting tax are measured and assessed. These outcomes are assessed from the commuter perspective.

In the following sections, 5.1 and 5.2, the results of this research are presented. First an overview of the commuting costs for each of the transport modes - car (gasoline, diesel and electric), bicycle, train, and bus - and the commuting profiles used, are introduced. Secondly, the results for the scenarios are exposed and analyzed.

5.1. Commuting costs

"How can the commuting tax be adjusted to fit the Danish sustainability goals?" is the research question this work tries to find and answer.

As explained in the 2.1.1 section, in Denmark the system is based on distance travelled per day (km/day). One can be entitled to a deduction for transport if the distance between the home address and work address is more than 12 km in one direction. SKAT calculates the deduction based on a predefined number of working days - 216 working days, that corresponds to a full working year, with 6 weeks holiday, plus 6-8 working days without transport (e.g. sick days, days off or working from home) (SKAT, 2016a). The actual transport costs (private and social) and the mode of transport chosen are irrelevant, thus, the potential to adjust the system to be sensitive to changes in transport mode. In order to have a sensitive system, it is important than it can differentiate the costs - private and social - of each transport mode, and that is able to calculate the cost of a certain journey based on those costs.

Table 8 and Figure 9 provide the overall average costs per transport mode (DKK/km).

Table 8 - Average cost in DKK/km for each group of costs and per type of transport[12].

	car (gasoline)	car (diesel)	car (electric)	bicycle	train	bus
Direct costs	2,56	2,56	2,56	0,37	0,75	0,75
Time costs	1,70	1,70	1,70	5,32	0,95	1,70
Marginal costs	0,70	0,73	0,66	-1,69	0,01	0,08
Total costs (DKK/km)	4,97	5,00	4,92	4,00	1,70	2,53

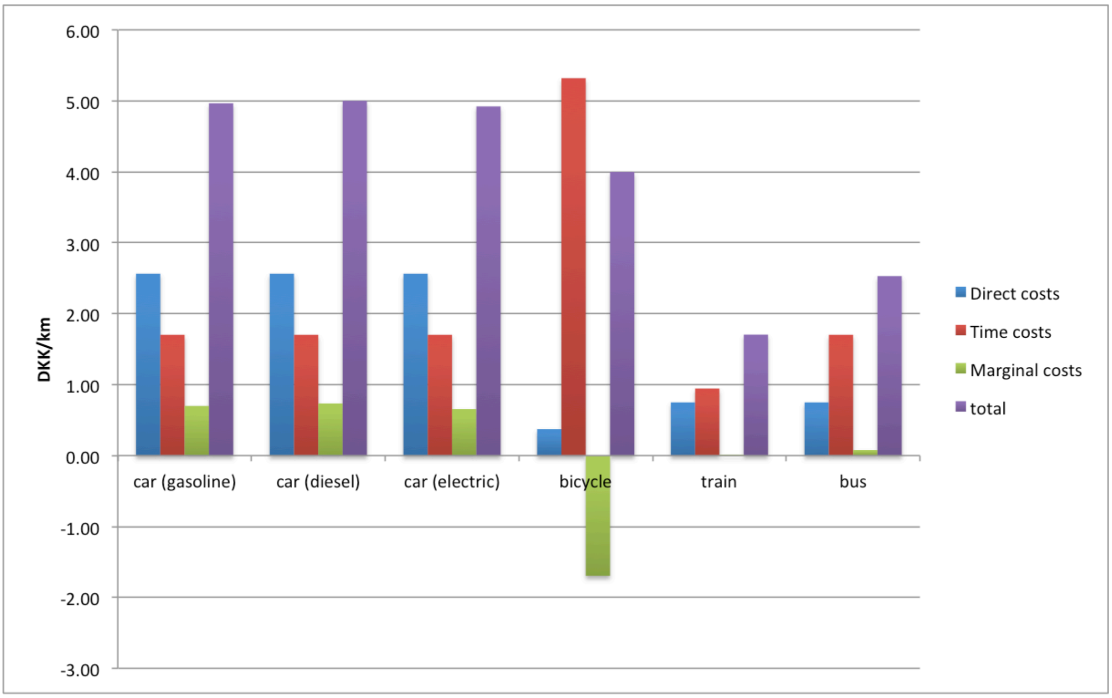

Figure 9 - Average cost in DKK/km for each group of costs and per type of transport.

For the data presented it is possible to conclude that the motorized private modes (car – diesel, gasoline and electric) are the ones with the highest overall costs,

[12] In the case of public transport the direct costs are given by the average cost of the ticket per km, Table 5.

followed by bicycle, train and bus. This is due to the fact that the principal cost for private vehicles are the direct costs, which represent 51,6%, 51,3% and 52,1% of the overall costs, for gasoline, diesel and electric, respectively. The driving costs include the fuel, engine oil, tires, repair and maintenance, owner tax and depreciation. The highest associated costs for both bicycles and public transport are time costs, which represent 133,1%, 55,5% and 67,3% of the overall costs, for bicycles, trains and buses, respectively. In terms of the overall marginal external costs, only for bicycles it encompasses a benefit instead of a cost, and this is due to the fact that there are health gains generated from cycling and not from driving or using other types of transport.

The total overall cost for each mode of transport shows that public transport is the less expensive to drive per km, especially the train. This is due to the fact that the marginal costs for the PT were calculated only for one passenger. The total marginal costs for trains and buses were divide by the total capacity[13] of these transport modes, since when using PT the unit values for the marginal costs produced are shared by all the passengers, which doesn't happen in the case of cars and bicycles (see 4.3.1 section).

To answer the research question *"How can the commuting tax be adjusted to fit the Danish sustainability goals?"*, different commuting distances were tested, for different transport modes. Since, the focus is on the urban context, the area of study was Greater Copenhagen (the city of Copenhagen and surrounding areas) and its commuting profiles, Table 9.

Table 9 – Commuting profiles for the studied areas (Statistics Denmark, 2014).

Commuting distance (one way)	Number of persons	%
No commuting	28444	4
Up to 5 km	234990	32
5-10 km	172798	23
10-20 km	145984	20
20-30 km	55151	7
30-40 km	32444	4
40-50 km	18650	3
More than 50 km	56048	8
Total	744509	100

Furthermore, real commuting cases were assed, Table 10. The personas were used in order to compare the average distances and tax deductions, from the average commuting profiles above.

[13] For the bus the capacity used is 40 persons and 475 for the train. Both values resulted from the average scenarios calculated for the unit prices for 2015 from the Danish Transport Ministry (DTU & COWI, 2016).

Table 10 - Personas commuting profiles.

Example Number	Home address	Work address	Commuting Distance (Skat calculator)
1	Nordre Kongelundsvej 3, 2300 København	A. C. Meyers Vænge 15, København	9 km
2	Nordre Kongelundsvej 3, 2300 København	Roskilde University	68 km
3	Koldinggade 5, 2100 københavn	Tinvej 16, 3060 Espergærde, Denmark	76 km
4	Nordre Kongelundsvej 19, 2300 København	Ejbovej 11, 4632 Bjæverskov	96 km

In Table 9 and 10, it is possible to see the commuting profiles for Greater Copenhagen and the personas used. It shows that 32% of all commuting trips (one way) are under 5 km, 23% under 10 km, and 20% under 20 km. This means that 75% of all commuting trips in Greater Copenhagen are less than 20 km, one way, or 40 km both ways. By looking into the commuting profile and to the share of journeys by transport mode (Figure 10) it is possible to verify that for trips shorter than 10 km, the bicycle is the preferred mode, being the car the dominant mode for distances bigger that 10 km. it is also possible to see that for trips between 2 and 5 km there is a shift of modal share, from the bicycle to the other modes, which leads to the realization of the great potential to increase the shift from private cars to more sustainable modes, as bicycles and public transport.

	0 - 2 km	2 - 4.9 km	5 - 9.9 km	10 - 14.9 km	> 15 km	ALL
WALK	30,000	6,000	0	0	0	36,000
BICYCLE	35,000	67,000	43,000	9,000	1,000	155,000
CAR	3,000	18,000	27,000	23,000	67,000	138,000
BUS	1,000	9,000	14,000	3,000	1,000	29,000
TRAIN	1,000	4,000	13,000	13,000	43,000	74,000
OTHER	0	0	1,000	1,000	4,000	6,000
ALL	70,000	105,000	98,000	49,000	116,000	438,000

Figure 10 - People who work or study in Copenhagen, divided by mode and distance to work/educational institutions (The City of Copenhagen, 2011).

5.2. The Scenarios

As previously described, the daily commuting costs were assessed through the GTC formula, in which, the sum of the unit costs for direct, time, and marginal costs was calculated.

In order to understand the costs associated with commuting, several commuting profiles were assessed. The commuting profiles were chosen based on the average commuting profiles for the studied area, Table 9, and based on real cases provide by 4 different personas, Table 10.

Table 11 - Commuting costs calculated through the GTC formula.

	Total commuting cost (DKK)					
Distance (km)	Car (gasoline)	Car (diesel)	Car (electric)	Bicycle	Train	Bus
5	24,64	24,80	24,54	10,07	11,72	15,85
9	44,35	44,64	44,17	18,13	21,10	28,53
15	73,91	74,40	73,62	30,22	35,17	47,55
30	147,82	148,79	147,23	60,44	61,94	86,71
44	216,80	218,23	215,94	88,64	75,01	111,33
50	246,36	247,99	245,39	100,73	85,23	126,52
68	335,05	337,26	333,73	137,00	115,92	172,06
70	344,91	347,18	343,55	141,02	119,33	177,12
76	374,47	376,94	372,99	153,11	129,56	192,30
90	443,45	446,38	441,70	181,32	136,32	210,63
96	473,02	476,14	471,15	193,41	145,41	224,67
100	492,72	495,98	490,78	201,46	151,47	234,03

In line with the results from the GTC preformed for the overall unit costs (see Table 8) and through the presented results (Table 11) it is possible to conclude that the motorized private modes (car – gasoline, diesel and electric) are the ones with the highest commuting costs, showing that the alternatives to car-based commuting are actually cheaper. In connection with the research question, these results show that, promoting the alternative modes to the car, besides creating benefits such as less congestion, less pollution and generally better urban environments, to mention some of the sustainability targets the Government as set, are actually, from a socio-economic point of view cheaper.

It is relevant for this to note that for commuting trips up to 30 km the bicycle is the cheapest mode, which goes against with the expected from the results presented in Table 8, that shows that the PT (train and bus) are the cheapest options. This is due to the fact that the direct costs for PT – which reflects the tickets cost, are higher for shorter commutes (see Table 5). According to these results it is possible to conclude that for commutes up to 30 km/day, the cheapest transport mode is the bicycle. However, above 30 km/day the train becomes the cheapest option.

When applying the current tax deduction (see Table 12) to the tested commuting profiles (2,05 DKK/km above 24 km), the motorized private modes remain, as expected, the ones with highest associated costs. However, there is a marked decrease in the total cost of the trip, Table 12, Figure 11, and Figure 12.

Table 12 - Commuting costs calculated after the tax deduction (2,05 DKK/km above 24 km/day).

	Total commuting cost (DKK) after tax deduction					
Distance (km)	Car (gasoline)	Car (diesel)	Car (electric)	Bicycle	Train	Bus
5	24,64	24,80	24,54	10,07	11,72	15,85
9	44,35	44,64	44,17	18,13	21,10	28,53
15	73,91	74,40	73,62	30,22	35,17	47,55
30	135,52	136,49	134,93	48,14	49,64	74,41
44	175,80	177,23	174,94	47,64	34,01	70,33
50	193,06	194,69	192,09	47,43	31,93	73,22
68	244,85	247,06	243,53	46,80	25,72	81,86
70	250,61	252,88	249,25	46,72	25,03	82,82
76	267,87	270,34	266,39	46,51	22,96	85,70
90	308,15	311,08	306,40	46,02	1,02	75,33
96	325,42	328,54	323,55	45,81	-2,19	77,07
100	336,92	340,18	334,98	45,66	-4,33	78,23

What is interesting to note is that, both for bicycles and for the bus, above 30 km/day (equivalent to the application of the tax), the cost remains almost inalterable, stabilizing around 50 DKK/day, for commutes by bicycle, and around 80 DKK/day for the bus, meaning that, above 30 km/day the cost of the commute is almost independent from the commuting distance. Also relevant to note that, commutes by train, when applying the tax deduction, become really cheap when comparing to the remaining modes. Even more, above 90 km/day the tax deduction becomes higher than the actual cost of the commute, which means that, above 90 km/day one can actually get money back in taxes, if the preferred mode is the train. These results (Table 12, Figure 11, and Figure 12), show again the potential existing in promoting cycling and public transport, since besides contributing to the achievement of the Government sustainability goals, they are in fact cheaper for their users.

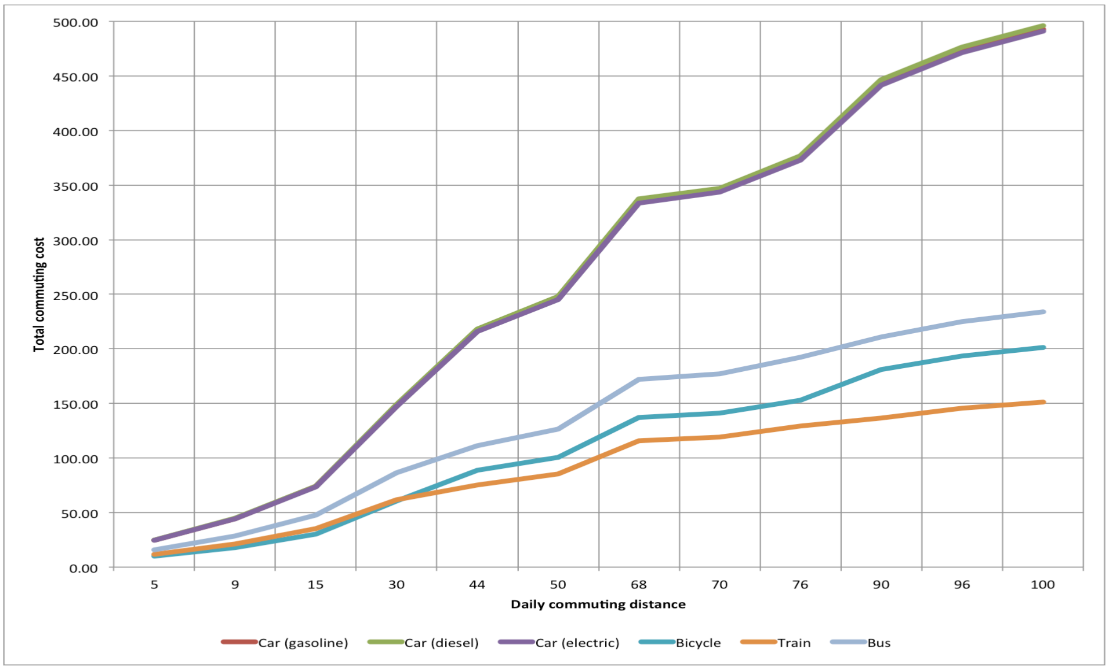

Figure 11 - GTC applied to the commuting profiles, without tax deduction.

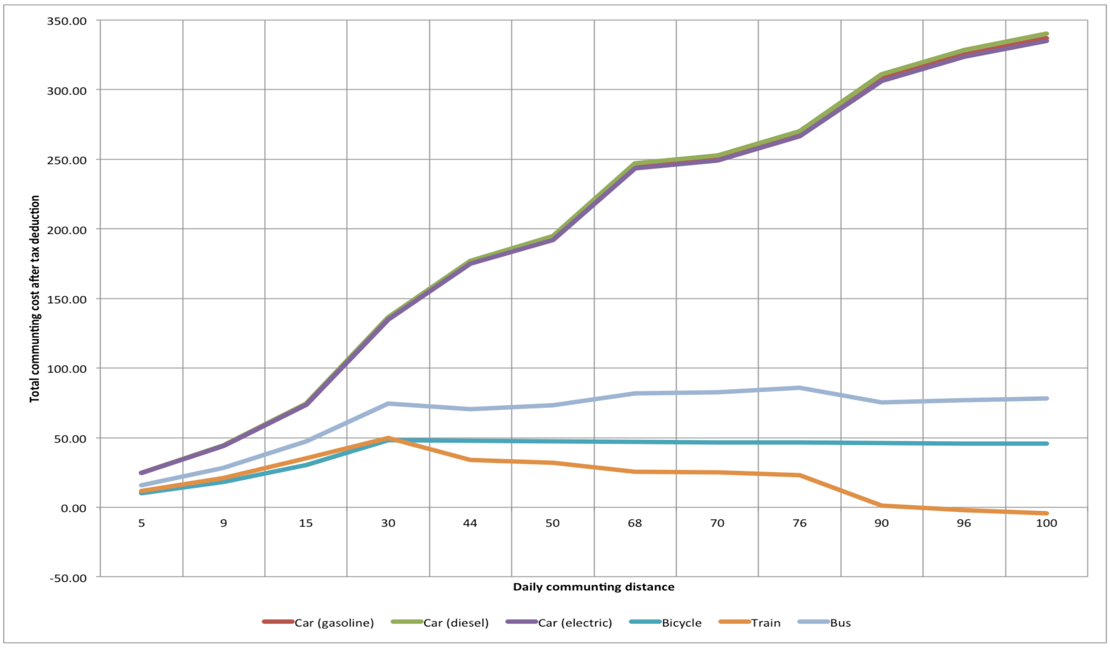

Figure 12 - GTC applied to the commuting profiles, with tax deduction.

After calculating the GTC associated to the different transport modes for each commuting profile, five scenarios, composing variations to the current system, were created. These scenarios were created in line with the goals of: reduction of greenhouse gas emissions; a transport sector dependent only on renewable sources; increase mobility and reduce congestion; reduce carbon emissions by promoting alternative propulsion systems (e.g. electric); transfer passenger transport from private cars to public transport; and finally promote sustainable changes in commuting behavior (see 4.3.2). Succinctly the five scenarios simulated are:

1. Scenario 1: Internalizing the marginal costs – this was achieved by subtracting the MC to the tax rate;
2. Scenario 2: No deduction for fueled private cars and normal deduction for the remaining modes (including electric cars);
3. Scenario 3: No deduction for fueled private cars, normal deduction for electric cars and public transport, and a deduction for bicycles commuting above 4 km/day. This was chosen due to the fact that above 5 km (one direction) there is an accentuated reduction in the modal share from bicycles to other modes (see Figure 10);
4. Scenario 4: No deduction for fueled private cars, normal deduction for electric cars and public transport, and a deduction for bicycles commuting above 6 km/day. This was chosen due to the fact that above 10 and 15 km there is 79% reduction in the modal share from bicycles to other modes (see Figure 10and because 55% of all commutes are under 10 km (see Figure 10);
5. Scenario 5: The final scenario is the most radical one. In this case private cars do not get any deduction, bicycles get deduction always and public transport gets deduction for commutes above 10 km/day. This scenario aims at increase the maximum modal share for bicycles and public transport.

For each case the rate applied to each tax deduction was as follows:

Table 13 - Commuting tax rates (DKK/km) applied to each case.

Rate/km	Private cars			Bicycle	Public transport	
	Gasoline	Diesel	Electric		Train	Bus
Todays rate	2,05	2,05	2,05	2,05	2,05	2,05
Case 1	1,35	1,32	1,39	3,74	2,04	1,97
Case 2	0	0	2,05	2,05	2,05	2,05
Case 3	0	0	2,05	2,05	2,05	2,05
Case 4	0	0	2,05	2,05	2,05	2,05
Case 5	0	0	0	2,05	2,05	2,05

The rates that were applied to each case, Table 13, show that only for the first case, the actual value of the rate was changed, due to the fact that in this case the value of the rate internalizes the marginal costs associated to each transport mode. For all the other cases, the same rate that is applicable (in 2015) was maintained and the changes were only applied to the mode of transport and to the commuting distance travelled, to respond to the Danish sustainability targets for the transport sector. The choice of maintaining the same value for the tax rate was chosen to facilitate the general SKAT calculations, since this rate can be changed according to the costs of fuel and the costs of maintaining a private vehicle (see 2.1.1).

The obtained results are as follows:

5.2.1. Scenario 1

The first Scenario internalizes the marginal costs, air pollution, climate change, noise, accidents, congestion, infrastructure and health, directly in the commuting tax. In order to do this, all the MC of each transport mode were added up and afterwards subtracted to the commuting tax, (see Table 13). By doing so, the users are paying for the externalities that their choice encompasses (environmental and social costs and benefits), which in the current model are not taken into account. Furthermore, this scenario is specially aligned with the following sustainability targets:

- Reduction in all greenhouse gas emissions;
- Ensuring mobility and reducing congestion;
- More efficiency in transferring passenger transport from private cars to public transport;
- Promoting changes in behavior.

From Table 13 it is possible to see that the rate changes for each transport mode, being the most affected the individual motorized modes, since they are the ones with greater marginal costs, namely in terms of air pollution and congestion.

As previously described, the daily commuting costs were assessed through the GTC formula, which gives the real costs of each commute. In this exercise, the new tax deduction rates were applied above 24 km.

Table 14 - Commuting costs calculated after the tax deduction – Scenario 1.

km/day	Scenario 1					
	Car (gasoline)	Car (diesel)	Car (electric)	Bicycle	Train	Bus
5	24,64	24,80	24,54	10,07	11,72	15,85
9	44,35	44,64	44,17	18,13	21,10	28,53
15	73,91	74,40	73,62	30,22	35,17	47,55
30	139,72	140,90	138,87	37,97	49,69	74,88
44	189,79	191,92	188,06	13,75	34,18	71,89
50	211,26	213,79	209,14	3,37	32,17	75,24
68	275,64	279,39	272,39	-27,77	26,11	85,29
70	282,80	286,68	279,41	-31,23	25,44	86,41
76	304,26	308,55	300,49	-41,61	23,42	89,76
90	354,34	359,57	349,69	-65,82	1,61	80,47
96	375,80	381,44	370,77	-76,20	-1,55	82,68
100	392,76	390,02	384,82	-83,12	-3,65	78,91

When applying the new tax deduction (see Table 13) to the tested commuting profiles (above 24 km/day), the motorized private modes remain the ones with highest associated costs, as expected. Besides being these modes the ones with higher associated GTC, they are also the ones with higher marginal costs, and therefore also the ones that get a lower deduction rate. Compared to the current system, the total cost of commuting after tax deduction is around 50 DKK more expensive for these modes.

The main difference, in this case, is reflected on the bicycle, continuing more or less equal for the remaining modes. In this case the bicycles becomes the cheapest mode for every commuting distance. In fact, for commutes above 50 km/day the tax deduction becomes higher than the actual cost of the commute, which means that, it is possible to get money back in taxes, if the preferred mode is the bicycle. The results can be seen in Table 14 and Figure 15.

5.2.1. Scenario 2

The second Scenario penalizes the fueled private modes – private cars fueled by gasoline and diesel, i.e., that these two modes do not get any tax deduction for commuting, regardless of the distance travelled. In Table 13 it is possible to see that the tax rate stays the same as the one currently in use for the remaining transport mode. This scenario is aligned with the following sustainability targets:

- Reduction in all greenhouse gas emissions;
- Energy consumption entirely based on renewables by 2050, resulting in fossil fuels being phased out in the transport sector;
- Ensuring mobility and reducing congestion;
- More efficiency in transferring passenger transport from private cars to public transport;
- Promoting changes in behavior.
- Reduce carbon emissions through alternative propulsion systems (e.g. electric cars);

As previously described, the daily commuting costs were assessed through the GTC formula, which gives the real costs of each commute. In this exercise, fueled private modes do not get tax deduction; the remaining modes get deduction above 24 km (as in the current system).

Table 15 - Commuting costs calculated after the tax deduction – Scenario 2.

km/day	Scenario 2					
	Car (gasoline)	Car (diesel)	Car (electric)	Bicycle	Train	Bus
5	24,64	24,80	24,54	10,07	11,72	15,85
9	44,35	44,64	44,17	18,13	21,10	28,53
15	73,91	74,40	73,62	30,22	35,17	47,55
30	147,82	148,79	134,93	48,14	49,64	74,41
44	216,80	218,23	174,94	47,64	34,01	70,33
50	246,36	247,99	192,09	47,43	31,93	73,22
68	335,05	337,26	243,53	46,80	25,72	81,86
70	344,91	347,18	249,25	46,72	25,03	82,82
76	374,47	376,94	266,39	46,51	22,96	85,70
90	443,45	446,38	306,40	46,02	1,02	75,33
96	473,02	476,14	323,55	45,81	-2,19	77,07
100	492,72	495,98	334,98	45,66	-4,33	78,23

When applying this scenario to the tested commuting profiles (see Table 15) the fueled private modes are the ones with highest associated costs, and also the ones where the user has to pay the real cost of commuting, based on the GTC formula, i.e. the user pays the direct costs, time costs and marginal costs. Comparing to the current system, in this scenario, and above 30 km/day, the fueled private modes carry the extra cost that was previously covered by the tax deduction, Table 16.

Table 16 – Difference in the total cost (DKK) for fueled private modes between the current tax deduction and Scenario 2, where these modes do not get deduction.

Distance (km)	Car (gasoline)	Car (diesel)
5	0,00	0,00
9	0,00	0,00
15	0,00	0,00
30	-12,30	-12,30
44	-41,00	-41,00
50	-53,30	-53,30
68	-90,20	-90,20
70	-94,30	-94,30
76	-106,60	-106,60
90	-135,30	-135,30
96	-147,60	-147,60
100	-155,80	-155,80

For the remaining modes there is no difference between the current system and Scenario 2. The results can be seen in Table 15, and Figure 15.

5.2.2. Scenario 3

The third Scenario penalizes the fueled private modes – has in Scenario 2; and benefits bicycles. For this mode, any commute above 4 km gets deduction. The reason for this choice is that above 5 km (one direction) there is an accentuated reduction in the modal share from bicycles to other modes (see Figure 10). In Table 13 it is possible to see that the tax rate stays the same as the one currently in use for the remaining transport modes. This scenario is aligned with the following sustainability targets:

- Reduction in all greenhouse gas emissions;
- Energy consumption entirely based on renewables by 2050, resulting in fossil fuels being phased out in the transport sector;
- Ensuring mobility and reducing congestion;
- More efficiency in transferring passenger transport from private cars to public transport;
- Promoting changes in behavior.
- Reduce carbon emissions through alternative propulsion systems (e.g. electric cars);

Table 17 - Commuting costs calculated after the tax deduction – Scenario 3.

km/day	Scenario3					
	Car (gasoline)	Car (diesel)	Car (electric)	Bicycle	Train	Bus
5	24,64	24,80	24,54	8,02	11,72	15,85
9	44,35	44,64	44,17	7,88	21,10	28,53
15	73,91	74,40	73,62	7,67	35,17	47,55
30	147,82	148,79	134,93	7,14	49,64	74,41
44	216,80	218,23	174,94	6,64	34,01	70,33
50	246,36	247,99	192,09	6,43	31,93	73,22
68	335,05	337,26	243,53	5,80	25,72	81,86
70	344,91	347,18	249,25	5,72	25,03	82,82
76	374,47	376,94	266,39	5,51	22,96	85,70
90	443,45	446,38	306,40	5,02	1,02	75,33
96	473,02	476,14	323,55	4,81	-2,19	77,07
100	492,72	495,98	334,98	4,66	-4,33	78,23

As expected, for the fueled private modes are the same as in Scenario 2 and for public transport the same as in the current system. The main difference in this case is for commutes by bicycle. In this exercise all commutes above 4 km get tax deduction, and therefore the bicycle is the privileged mode in this case, Table 17. It is possible to verify that commuting by bicycle becomes really cheap when compared with the other modes, except for commutes above 80 km/day, where the train remains the cheapest mode of all, Figure 16. When compared to the Scenario 1, where there is an internalization of the MC directly in the tax rate, and in which above 50 km/day one can get money back in taxes by using the bicycle to commute, this scenario is not as favorable to bicycles.

5.2.3. Scenario 4

The fourth Scenario represents a slight variation of Scenario 3, i.e., that this is the same as Scenario 3, however, instead of applying a deduction above 4 km/day for bicycles, it applies the deduction above 6 km/day. This was chosen due to the fact that above 10 and 15 km there is a 79% reduction in the modal share from bicycles to other modes (see Figure 10), and because 55% of all commutes are under 10 km (see Table 9). In Table 13 it is possible to see that the tax rate stays the same as the one currently in use for the remaining transport modes. This scenario is aligned with the same sustainability targets as Scenario 3.

Table 18 - Commuting costs calculated after the tax deduction – Scenario 4.

km/day	Scenario 4					
	Car (gasoline)	Car (diesel)	Car (electric)	Bicycle	Train	Bus
5	24,64	24,80	24,54	10,07	11,72	15,85
9	44,35	44,64	44,17	11,98	21,10	28,53
15	73,91	74,40	73,62	11,77	35,17	47,55
30	147,82	148,79	134,93	11,24	49,64	74,41
44	216,80	218,23	174,94	10,74	34,01	70,33
50	246,36	247,99	192,09	10,53	31,93	73,22
68	335,05	337,26	243,53	9,90	25,72	81,86
70	344,91	347,18	249,25	9,82	25,03	82,82
76	374,47	376,94	266,39	9,61	22,96	85,70
90	443,45	446,38	306,40	9,12	1,02	75,33
96	473,02	476,14	323,55	8,91	-2,19	77,07
100	492,72	495,98	334,98	8,76	-4,33	78,23

As expected, the results remain are very similar to the ones encountered in Scenario 3, whit a slightly difference in the final costs of commuting by bicycle, Table 18 and Figure 17.

5.2.4. Scenario 5

The fifth and final Scenario is considered to be the most radical one, since it is the one that encompasses most variations. This scenario was chosen in order to privilege most changes in the commuting behavior. In this scenario all private modes are penalized, i.e., no commutes by car get tax deduction, and commutes, both by public transport and bicycle, are beneficiated. Therefore, bicycles get deduction always, regardless of the distance travelled, and public transport gets deduction for commutes above 10 km/day. This scenario aims at increase the maximum modal share for bicycles and public transport, Table 19.

In Table 13 it is possible to see that the tax rate stays the same as the one currently in use. This scenario is aligned with the following sustainability targets:

- Reduction in all greenhouse gas emissions;
- Energy consumption entirely based on renewables by 2050, resulting in fossil fuels being phased out in the transport sector;
- Ensuring mobility and reducing congestion;
- More efficiency in transferring passenger transport from private cars to public transport;
- Promoting changes in behavior.

Table 19 - Commuting costs calculated after the tax deduction – Scenario 5.

km/day	Scenario 5					
	Car (gasoline)	Car (diesel)	Car (electric)	Bicycle	Train	Bus
5	24,64	24,80	24,54	-0,18	11,72	15,85
9	44,35	44,64	44,17	-0,32	21,10	28,53
15	73,91	74,40	73,62	-0,53	24,92	37,30
30	147,82	148,79	147,23	-1,06	20,94	45,71
44	216,80	218,23	215,94	-1,56	5,31	41,63
50	246,36	247,99	245,39	-1,77	3,23	44,52
68	335,05	337,26	333,73	-2,40	-2,98	53,16
70	344,91	347,18	343,55	-2,48	-3,67	54,12
76	374,47	376,94	372,99	-2,69	-5,74	57,00
90	443,45	446,38	441,70	-3,18	-27,68	46,63
96	473,02	476,14	471,15	-3,39	-30,89	48,37
100	492,72	495,98	490,78	-3,54	-33,03	49,53

When comparing with the remaining scenarios it is possible to realize that in this exercise, both bicycles and public transport were intentionally benefitted comparing to the private modes. In this case, and because the bicycle gets a tax deduction regardless the distance travelled, when commuting by bicycle one can always get money back in taxes. However, when compared to Scenario1 the deduction is not as higher, which makes this scenario more favorable than the first for the first 50 km, since after that, one can get a much higher deduction. For public transport this is the most favorable scenario. In the case of commuting by train, one can get money back in taxes if the distance travelled everyday is higher than 50 km, instead of 90 km, as in cases above, Table 19 and Figure 18.

Follows a graphical presentation of all the scenarios described above, in which a comparison between the different scenarios is shown.

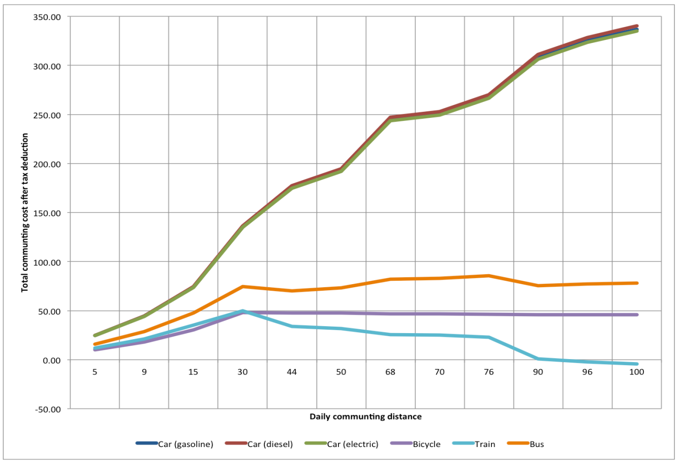

Figure 13 - Total commuting costs after tax deduction. Today's case – Reference scenario.

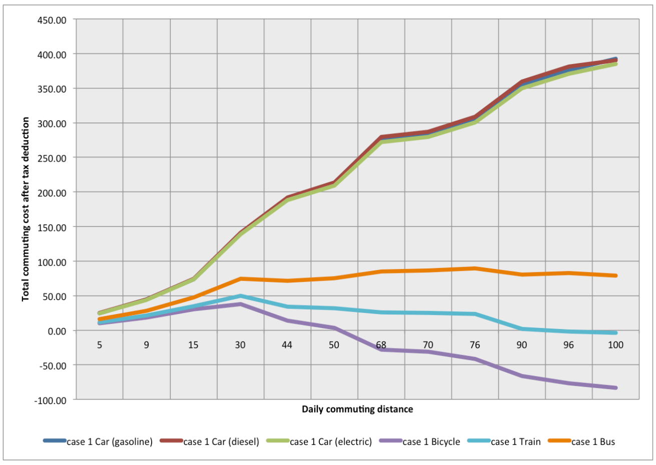

Figure 15 - Total commuting costs after tax deduction. Scenario 1.

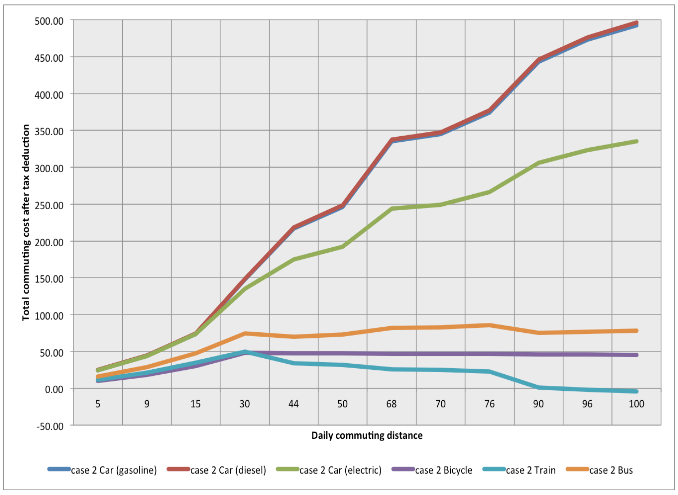

Figure 14 - Total commuting costs after tax deduction. Scenario 2.

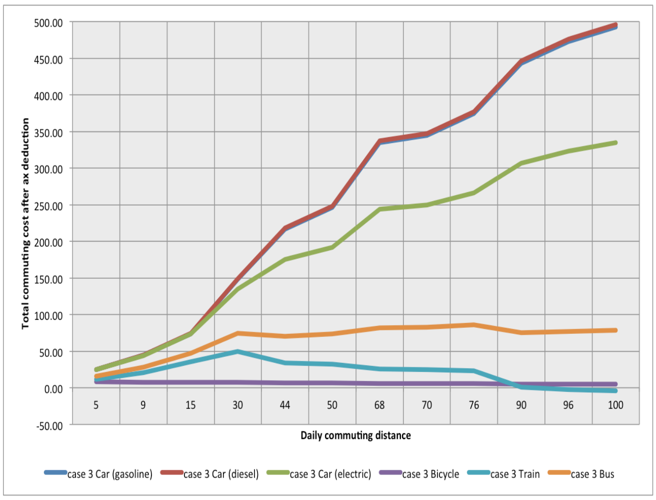

Figure 16 - Total commuting costs after tax deduction. Scenario 3.

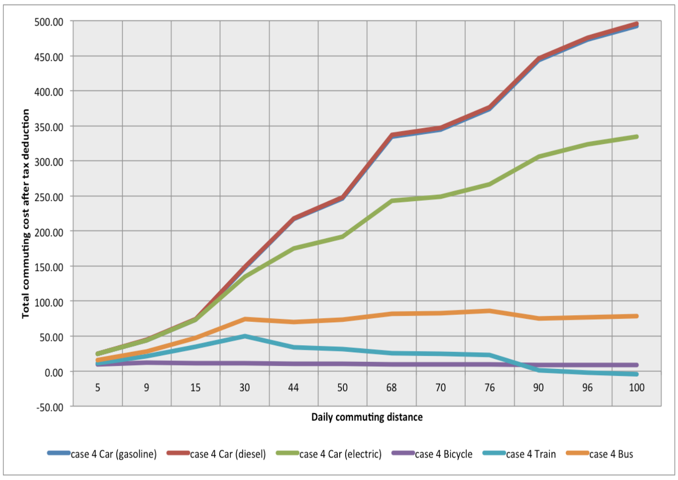

Figure 17 - Total commuting costs after tax deduction. Scenario 4.

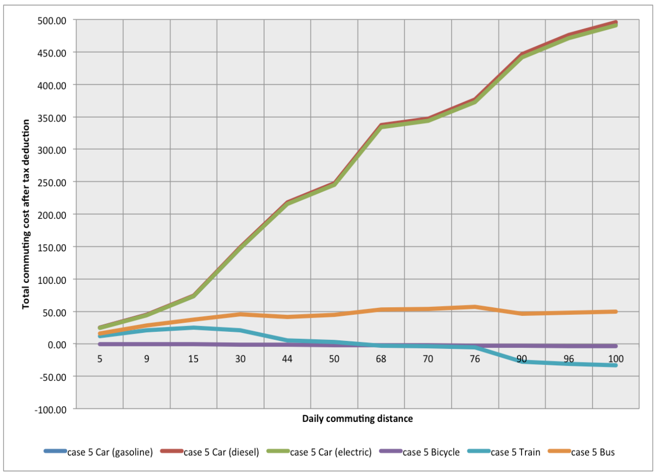

Figure 18- Total commuting costs after tax deduction. Scenario 5

6. Discussion

Today, in Denmark, about a third of all car trips are 5 km or less, while more than half of all car trips are less than 10 kilometers, so there is undoubtedly potential to move commuters from car to bicycle and public transport (Cyklistforbundet, 2015). Which, with the right tax incentive structures has potential to be achieved, and is explored in this study.

CBA is frequently used as a tool to assess transport projects, as it can be applicable to a variety of interventions (European Commission, 2013, 2014; Gössling & Choi, 2015; Hanley & Spash, 1993), and it main advantage is that externalities and price distortions are considered (European Commission, 2013; Johansson & Kriström, 2015; Pearce et al., 2006). Despite its limitations, in consider and account for externalities, several authors (Essen et al., 2011; Korzhenevych et al., 2014; Santos, Behrendt, Maconi, Shirvani, & Teytelboym, 2010) recognize that externalities are significant, and should be integrated in transport planning, e.g. taxation frameworks (Gössling & Choi, 2015). And, while it seems to be common the use CBA in transport assessments, there is a lack of research, and absence of discussion, on the implications of the costs or benefits of commuting choices and its integration with the commuting tax systems. Against this background, this study investigates how this integration can be addressed.

When using a CBA framework, the high cost of driving car in comparison to the cost of cycling or using public transport becomes more obvious, as result of accounting for costs such as externalities for commuting purposes. However, it may be argued that spillover externalities are important for the comparison between cars and the other modes, as Gössling & Choi (2015, p. 111) argue that e.g. *"bicyclists engender less risk on other street users than cars, while accident risks are in no small part related to traffic density and crowding effects mostly attributable to cars"* making the TE model, and therefore the CBA analysis, biased towards the cars, in this specific case. Or regarding other costs that could be considered in the used TE model. In summary, while the used TE model, as well as the CBA preformed in this study, tries to reflect social and environmental costs – through the account of the MC, and also time and direct costs, the chosen framework may constitute an imperfect instrument to compare the different transport modes. Therefore, and for the purpose of this study, one should have into account that these results are the work of an exercise, which seeks to identify what is/are the be st way(s) to adjust the current tax commuting system to the Danish sustainability targets.

These sustainability targets can generally be identified as (Danish Government, 2013):

- 40% reduction of GHG emissions;
- Fossil fuel free transport sector;
- Increase mobility and reduce congestion;
- Reduce carbon emissions through alternative propulsion systems;
- Decouple the growth in demand for transport from the economic growth, through taxes on buying, owning and using cars, as well as through spatial planning;
- Transferring passenger transport from private cars to public transport;
- Technology improvements or changes in behavior).

The above-mentioned targets were taken into account in the creation of this model that assesses the Danish tax commuting system. Follows a general overview from the different scenarios analyzed for each transport mode.

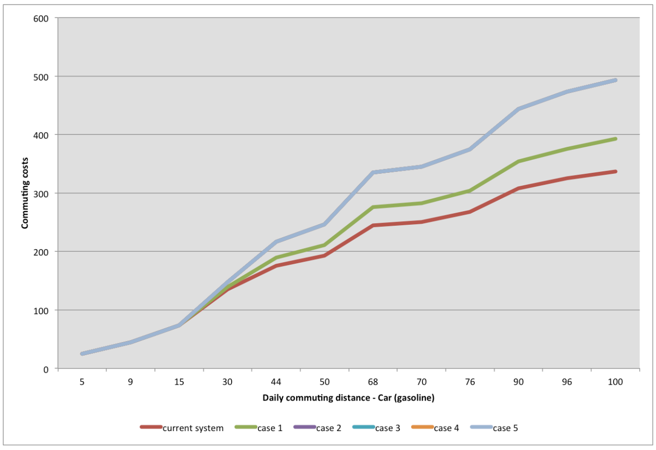

Figure 19 – Comparison between the different Cases – Car (gasoline).

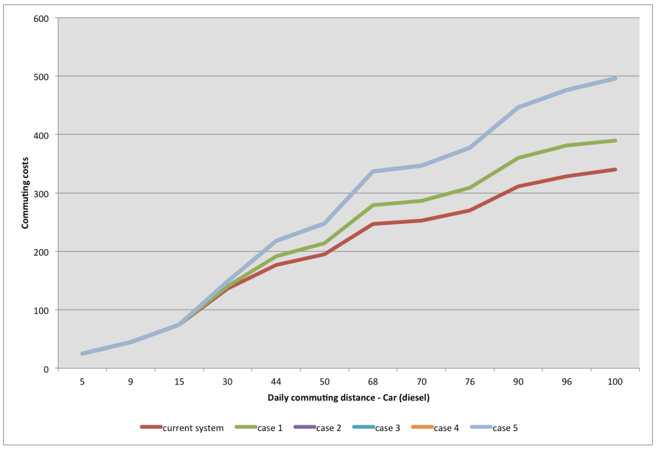

Figure 22 - Comparison between the different Cases – Car (diesel).

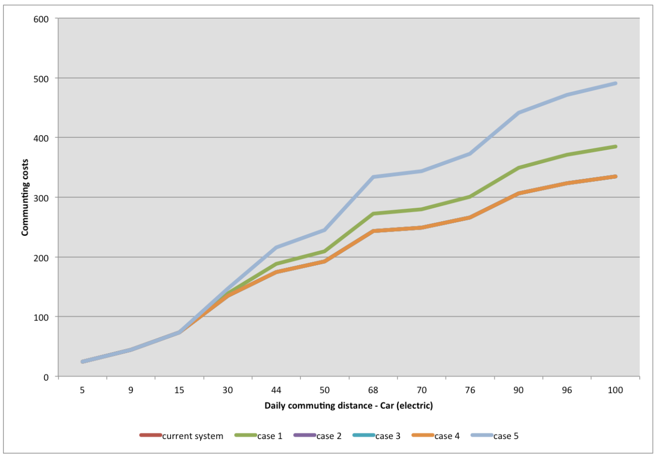

Figure 20 - Comparison between the different Cases – Car (electric).

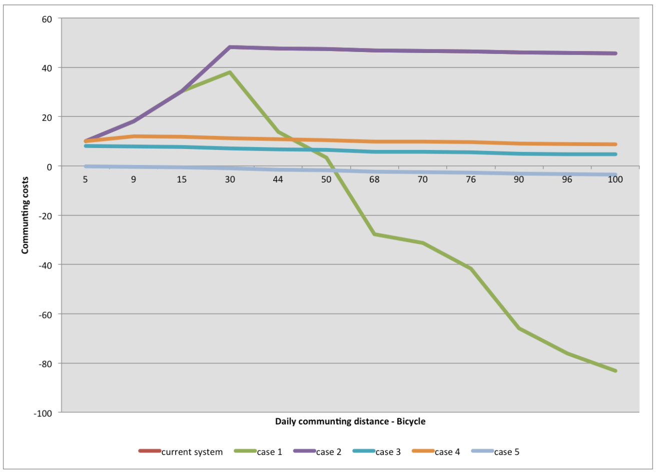

Figure 23 - Comparison between the different Cases – bicycle.

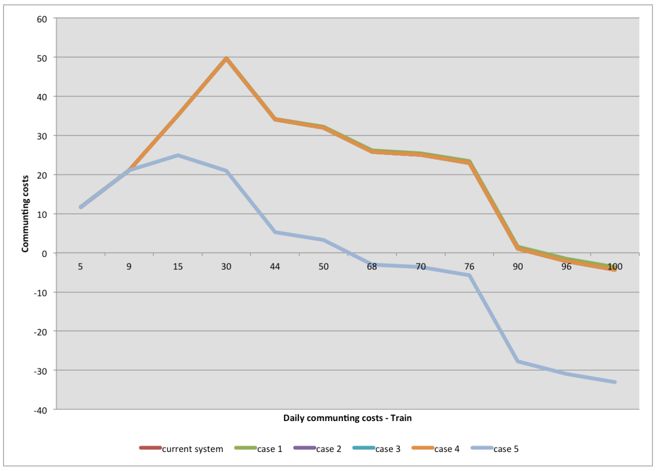

Figure 21 - Comparison between the different Cases – Train.

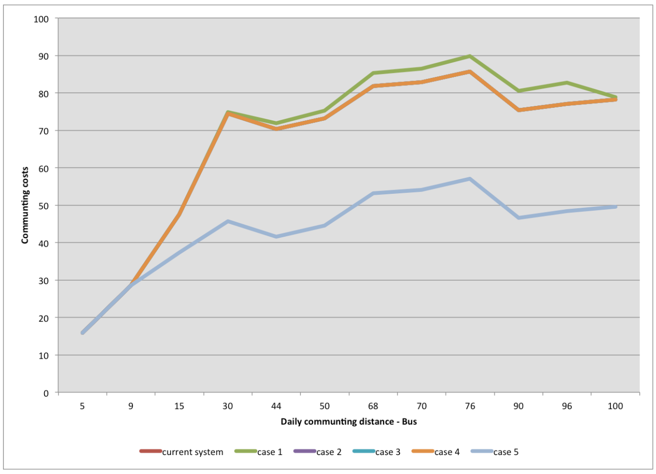

Figure 24 - Comparison between the different Cases – Bus.

The above figures show the different scenarios for each transport mode.

For both private fuelled modes (car – gasoline and diesel), the results are very similar. From Figure 19 and Figure 22 it is possible to see that the current system is the one that is cheaper, in the user perspective, followed by scenario 1, where the marginal costs of each mode, are internalized in the tax rate itself. For all the other scenarios (2, 3, 4, and 5) the user has to pay for the full amount of the commute. Although, in the user perspective, the current system, is the one that encompasses lower costs, one can argue this is not aligned with the sustainability goals from the Danish Government, since car users are beneficiated when choosing the car for their daily commute. In order to promote: reduction in GHG and carbon emissions; a fossil fuel free transport sector; ensure mobility and reduce congestion; transfer passengers from private cars to public transport; and promote changes in behavior, the preferred scenarios are the ones where the user as to pay for the full amount of is travel, i.e., scenarios 2, 3, 4 and 5.

In the case of electric cars, only scenario 1 and 5 present variations from the current system, as shown in Figure 20. However, in both cases, the final costs of commuting are higher than the ones from the current system - presenting scenario 1 lower costs than scenario 5. As previously described, for scenario 1 the marginal external costs were internalized in the tax itself. Even though cheaper than gasoline and diesel cars – since these have overall higher MC – electric cars still encompass high marginal costs for accidents, congestion and infrastructure; and therefore higher final commuting costs. In scenarios 2, 3 and 4, the same rates as for the current system are applied and thus not showing differences, however these scenarios are aligned with the sustainability goals, namely the reduction of carbon emissions through alternative propulsion systems (e.g. electric). In the final scenario, scenario 5, in the same way as for the other private modes (car – gasoline and diesel) and in order to promote better mobility and less congestion no tax deduction was applied to the electric cars, since they still represent a private mode, and that there is a need to promote changes in behavior and transfer passengers from the private modes to the other modes – bicycle and public transport.

The bicycle is the only transport mode, in this study, where there are variations in most of the scenarios (only scenario 2 is the same as the current system). This is due to the fact that this transport mode besides being the most sustainable one, since it does not carry marginal costs such as air pollution, climate change, noise, and congestion (DTU & COWI, 2016), - which are the main problems caused by transportation in urban areas (European Commission, 2011b; Gössling, 2013), - is the only transport mode, studied here, that brings health benefits for its users. Between scenario 1, where the MC are internalized, and the remaining scenarios the difference is striking, and the reason is that the overall sum of the marginal costs is a negative value, i.e. it is a benefit instead of a cost (see 3.1 and 3.2.1.). Scenario 3, 4, and 5, are very similar, however, in scenario 5 where, regardless of the distance travelled the users always get tax deduction, the final commuting cost is always lower than the tax rate, i.e. that it is always possible to get money back in taxes for bicycle commutes, Figure 23. Comparing scenario 1 and 5, one can argue that the latter is more favorable, since there is a high decline in bicycle share for commutes above 10 km in one direction, see Figure 10. Also for scenario 2 and 3 the same argument can be discussed, since for both cases the final commuting cost is lower for the first 45 km, however after that scenario 1 becomes the cheapest.

Considering PT (train and bus), only scenarios 1 and 5 show variations from the current system, Figure 21 and Figure 24. However, there is not a substantial difference in the final commuting cost between the current system and scenario 1, due to the fact that the overall marginal costs for PT are not very significant. The marginal costs associated of each category (air pollution, climate change, noise, accidents, congestion, and infrastructure) were divided by the capacity of each transport, see 4.3.1. In scenario 5, there is a notorious decline on the total commuting costs, which was expected since PT users get tax deduction for commutes above 10 km. This scenario was created to be aligned with the sustainability goals for the transport sector, namely in order to ensure mobility and reduce congestion, transfer passenger transport from private cars to public transport, and to promote changes in behavior. Also, the share of passengers in the train for distances above 10 km increases substantially, however for the bus the opposite happens (see Figure 10), therefore this scenario aims at benefit the users that choose PT, either because it is the only available alternative or because for these distances the private modes vs. the available public transport options are preferred.

The following, Table 20, shows a brief comparison between all the studied alternatives versus the current system, which is used as a reference scenario. The table shows the final cost of commuting (after the applied tax deductions) is higher (+), lower (-), or identical (•), in comparison with today's cost.

Table 20 - Comparison between studied scenarios for the adjustment of the current commuting tax to the Danish sustainability goals.

Transport mode	Today commuting costs after tax deduction	Case 1	Case 2	Case 3	Case 4	Case 5
Car (gasoline)	Ref.	+	+	++	++	++
Car (diesel)	Ref.	+	+	++	++	++
Car (electric)	Ref.	+	•	•	•	++
Bicycle	Ref.	--	-	-	-	--
Train	Ref.	•	•	•	•	--
Bus	Ref.	•	•	•	•	-

In absolute terms, scenario 5 is considered to be the one that better fulfills the sustainability goals from the Danish Government. Since it reduces the commuting costs for both bicycles and public transport, and increases the costs for the private modes - where the user has to pay for the full amount of the commute - therefore promoting better mobility, less congestion, reduction in GHG and carbon emissions, increase the amount of passengers transferred from private cars to public transport and bicycle, and finally changes in the commuting behavior.

However, there are some limitations to the presented outcomes. Even though a final case/scenario is considered as the best, or in broader terms, the most sustainable, this result should only be considered as an exercise and possible attempt to the adaptation of the current tax system to fit the sustainability targets. For example, no alternatives considering the use of more than one transport mode for the same commute were tested, which could be discussed as possibly more sustainable or even more practical, from the user perspective. It can also be argued that the probability of a bicycle user do a commute longer than a certain number of kilometers is virtually inexistent, the same way as a short commute, for example by train. However it is considered that the model that is here presented, and the scenarios tested, compose a first step towards the exploration of a more sustainable commuting tax system for Denmark.

Examples from Belgium, the Netherlands, and France, where financial incentives for bicycle commuters have been introduced, showed positive results in the change from car to bicycle. Today, in the Netherlands cyclists can get an annual deduction for the use of their own bicycle for commuting to work, allowing for employer to be tax-free up to 0,15€ per km. In Belgium private companies and public authorities also pay their employees to commute to work on bicycles, also at a rate of

0,15€/km, for a maximum 15 km per year. The subsidy is tax-free for cyclists, and the companies have a deduction for the expenses. In France, a pilot test that ran in 2014, where bike commuters got a payment of €0.25/km showed that the bike share increased by 50% for the companies that participated in the trial (Cyklistforbundet, 2015).

Commuting tax incentives, can therefore, encourage the use of bycicles and public transport, if the right incentives are found. Meaning that the conditions in which one decide to commute instead of car, by bicycle or public transport need to be found and understood, in the sence of creating the right alternatives for the users. How much would it cost to change the commuting behaviour through the right tax incentives and how can that be weighted in a walfare state are questions that need to be addressed and better explored.

Nontheless this study shows that socio-economic and environmental considerations, when taken into account, can encourage the use of alternatives transport modes to the car, by comparing hard-evidence, in the form of the socio-economic and environmental costs that are connected to each transport mode.

7. Conclusion

Choosing different modes of transportation can have significant socio-economic impacts. Today's commuters can increasingly make a choice between different modes of transportation in order to arrive at their destination in the most efficient way – especially in urban areas. Therefore, there is a need for more advanced socio-economic tools to calculate the costs and the benefits of such alternatives and choices. The potential benefits are perhaps most significant when changing mobility patterns to commuting by bike and/or public transport instead of by car, and the socio-economic impacts of such potential can lead directly to an improved quality of life, and productivity, if less time and expenses are spent on the daily commute (State of Green, 2016). As a result, promoting tax incentives to alternative mobility patterns can cause significant benefits such as less congestion, less pollution and generally better urban environments. Today in Denmark, more than half of all car trips are less than 10 kilometers, which shows the great potential, especially on the shorter distances, to move commuters from the private car to the bicycle and public transport (Cyklistforbundet, 2015). However, very limited attention has been paid to the economic and sustainability potentials of creating commuting taxes. This study has created, through a cost-benefit analysis, a model in which such potentials are explored, through the use of the already existing Danish commuting tax, and transportation unit values from the Danish Transport Ministry (TE model) (DTU & COWI, 2016; Fosgerau et al., 2007).

The CBA is a method to evaluate and judge the net economic impact of certain investment decisions, through the assessment of its costs and benefits. The main advantage of this tool is that externalities and price distortions are considered (European Commission, 2013; Johansson & Kriström, 2015; Pearce et al., 2006). Despite its limitations, when valuating externalities, several studies recognize that externalities are significant, and should be integrated in transport planning, e.g. taxation frameworks (Essen et al., 2011; Korzhenevych et al., 2014; Santos, Behrendt, Maconi, Shirvani, & Teytelboym, 2010; Gössling & Choi, 2015). When using the CBA framework, the high cost of driving a car in comparison to the cost of cycling or using public transport becomes more obvious, as result of accounting for the cost of externalities when commuting. However, it may be debated that spillover externalities are important and should be integrated in the comparison between cars and other modes (Gössling & Choi, 2015) and that this the TE model used as background data, and therefore this CBA analysis, can be biased towards the cars, when it comes for example to the risk of accidents. Therefore, the chosen background data may constitute an imperfect instrument to compare the different transport modes. However, since the unit values used are based on market values, and complemented with forecasts of economic development, population growth and fuel prices, amongst others, they are also seen as the most accurate data available to use.

Limitations to this study are that all the GTC are preformed for commutes up to 100 km/day and that no scenarios considering the use of more than one transport mode, for the same commute, were tested. However, this is a theoretical exercise that aims at categorize the individual commuting costs of the different transport modes. Therefore, even though a final scenario is considered as the best, or in broader terms, the most sustainable, this result should be pondered as restricted to the limitations of the created model.

Despite the limitations associated with the CBA and the uncertainty associated with the quantification of the unit values, this model is considered to be a useful tool to investigate the potential of changing and adaptation of the current Danish commuting tax to fit the Government sustainability goals.

For future studies, scenarios including the use of more than one mode of transport for the same commute, as well as the use of more detailed commuting profiles, based on inquiries to the commuters, should be included. This would improve the model accuracy. It would also be interesting to complement the present study with an estimate on the impact in the State overall income in transport related taxes and investments, if such changes to the current commuting tax system were enforced.

Overall, the model makes evident the socio-economic advantages, for the user, in shifting from the car to the bicycle or public transport in his daily commute, providing therefore, the economic justification for the adjustment of the current commuting tax system. Furthermore, this model constitutes a great baseline for the exploration and research of the social, economic and environmental impacts that tax incentives can promote towards a more sustainable commuting behavior, transport sector, and future.

References

Annema, J. A., Koopmans, C., & Van Wee, B. (2007). Evaluating Transport Infrastructure Investments: The Dutch Experience with a Standardized Approach. *Transport Reviews*, *27*(2), 125–150. doi:10.1080/01441640600843237

Atterbrand, A.-S., Jorde, B., Kasin, O., Krag, T., Silfverberg, B., Skur, J., & Stenvall, M. (2005). *Mobility Management in the Nordic Countries*. *Norden* (Nordic Cou., Vol. 1). Copenhagen. doi:10.1017/CBO9781107415324.004

banedanmark. (2016). Højere hastighed på nogle strækninger. Retrieved June 15, 2016, from http://www.bane.dk/visFoelgMed.asp?artikelID=7461

Bloomberg, M. R. (2014). Advancing Climate Ambition: cities as partners in global climate action.

COWI. (2004a). *External Costs of Transport. 1st Report - Review of European Studies*.

COWI. (2004b). *External Costs of Transport. 2nd Report - Marginal external cost matrices for Denmark*.

COWI. (2004c). *External Costs of Transport. 3rd Report - Total external costs of road and rail transport in Denmark*. Retrieved from http://ecocalc-test.ecotransit.org/CE_Delft_4215_External_Costs_of_Transport_in_Europe_def.pdf

Cycling Embassy of Denmark. (2012). *Collection of cycle concepts*.

Cyklistforbundet. (2015). Skat. Retrieved June 24, 2016, from http://www.cyklistforbundet.dk/Om-os/Vi-mener/Cyklistforbundet-mener/Skat

Danish Government. (2013). *The Danish Climate Policy Plan. Towards a low carbon society.* Denmark. Retrieved from www.kebmin.dk

Djurhuus, S., Sten Hansen, H., Aadahl, M., & Glümer, C. (2016). Building a multimodal network and determining individual accessibility by public transportation. *Environment and Planning B: Planning and Design*, *43*(1), 210–227. doi:10.1177/0265813515602594

DTU, & COWI. (2016). Transportøkonomiske Enhedspriser til brug for samfundsøkonomiske analyser. København: Transportministeriet. Retrieved from http://www.modelcenter.transport.dtu.dk/Noegletal/Transportoekonomiske-Enhedspriser

Essen, H. van, Nelissen, D., Smit, M., van Grinsven, A., Aarnink, S., Breemersch, T., … Harmsen, J. (2012). An inventory of measures for internalising external costs in transport, 1–42, 115–126.

Essen, H. van, Schroten, A., Otten, M., Sutter, D., Schreyer, C., Zandonella, R., … Doll, C. (2011). External Costs of Transport in Europe Update Study for 2008. *CE Delft, INFRAS, Fraunhofer ISI*, (September), 161. Retrieved from http://ecocalc-test.ecotransit.org/CE_Delft_4215_External_Costs_of_Transport_in_Europe_def.pdf

European Commission. White Paper. Fair Payment for Infrastructure Use : A phased approach to a common transport infrastructure charging framework in the EU. (1998). European Comimission. Retrieved from http://aei.pitt.edu/1136/1/transport_infra_wp_COM_98_466.pdf

European Commission. Europe 2020. A European strategy for smart, sustainable and inclusive growth (2010).

European Commission. Energy Roadmap 2050 (2011). doi:10.1017/CBO9781107415324.004

European Commission. White Paper. Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, Pub. L. No. COM(2011) 144 final (2011).

European Commission. (2013). *Evalsed Sourcebook: Method and Techniques* (Vol. 1). doi:10.1017/CBO9781107415324.004

European Commission. (2014). *Guide to Cost-benefit Analysis of Investment Projects Economic appraisal tool for Cohesion Policy 2014-2020*. doi:10.2776/97516

European Commission. (2016a). 2050 low-carbon economy. Retrieved March 11, 2016, from http://ec.europa.eu/clima/policies/strategies/2050/index_en.htm

European Commission. (2016b). Reducing emissions from transport - European Commission. Retrieved March 11, 2016, from http://ec.europa.eu/clima/policies/transport/index_en.htm

Fosgerau, M., Hjorth, K., & Lyk-Jensen, S. V. (2007). *The Danish Value of Time Study*. Copenhagen: Danish Transport Research Institute.

Goldberg, P., & Hellerstein, R. (2007). Sticky prices: why firms hesitate to adjust the price of their goods. *Current Issues in Economics and Finance*, *13*(Nov). Retrieved from http://ideas.repec.org/a/fip/fednci/y2007inovnv.13no.10.html

Gössling, S. (2013). Urban transport transitions: Copenhagen, city of cyclists. *Journal of Transport Geography*, *33*, 196–206. doi:10.1016/j.jtrangeo.2013.10.013

Gössling, S., & Choi, A. S. (2015). Transport transitions in Copenhagen: Comparing the cost of cars and bicycles. *Ecological Economics*, *113*, 106–113. doi:10.1016/j.ecolecon.2015.03.006

Grant-Muller, S., & Mackie, P. (2001). Economic appraisal of European transport projects: the state-of-the-art revisited. *Transport Reviews*, *21*(2), 237–261. doi:10.1080/01441640151098097

Hanley, N., & Spash, C. L. (1993). *Cost-Benefit Analysis and the Environment*. Edward Elgar Publishing Limited.

Harding, M. (2014). Personal Tax Treatment of Company Cars and Commuting Expenses, (20), 1–71. doi:10.1787/5jz14cg1s7vl-en

Johansson, P., & Kriström, B. (2015). *Cost-Benefit Analysis for Project Appraisal*. Cambridge University Press. doi:http://dx.doi.org/10.1017/CBO9781316392751

Korzhenevych, A., Dehnen, N., Bröcker, J., Holtkamp, M., Meier, H., Gibson, G., …

Cox, V. (2014). Update of the Handbook on External Costs of Transport. *Final Report*, (1), 139. doi:Ref: ED 57769 - Issue Number 1

Maibach, M. (Infras), Schreyer, C. (Infras), Sutter, D. (Infras), van Essen, H. P. (Ce D., Boon, B. H. (Ce D., Smokers, R. (Ce D., … Bak, M. (University of G. (2008). *Handbook on estimation of external costs in the transport sector. CE Delft*. doi:07.4288.52

Pearce, D., Atkinson, G., & Mourato, S. (2006). *Cost-Benefit Analysis and the Environment. Recent Developments. OECD* (Vol. 6). Paris: OECD Publishing.

PSRC. (2010). *Benefit-Cost Analysis: General Methods and Approach*.

Santos, G., Behrendt, H., Maconi, L., Shirvani, T., & Teytelboym, A. (2010). Part I: Externalities and economic policies in road transport. *Research in Transportation Economics*, *28*(1), 2–45. doi:10.1016/j.retrec.2009.11.002

SKAT. (2015a). Beregn befordringsfradrag 2015. Retrieved April 16, 2016, from https://www.tastselv.skat.dk/borger/befor/BeregnOpgoer.do

SKAT. (2015b). Fradraget og godtgørelsen for befordring falder i 2016. Retrieved June 15, 2016, from http://skat.dk/skat.aspx?oId=2184901&vId=0

SKAT. (2016a). SKAT: Deduction for transport between home and work. Retrieved February 16, 2016, from http://www.skat.dk/skat.aspx?oId=2084150&vId=0

SKAT. (2016b, January 6). SKAT: Kørselsfradrag (befordringsfradrag). Retrieved February 19, 2016, from https://www.skat.dk/SKAT.aspx?oId=1988906

State of Green. (2016). *Sustainable Urban Transportation*.

Statistics Denmark. (2014). AFSTB3: Employed persons (end November) by region, socioeconomic status, sex and commuting. Retrieved April 26, 2016, from http://www.statbank.dk/statbank5a/selectvarval/saveselections.asp

Statistics Denmark. (2016). About us. Retrieved April 27, 2016, from http://www.dst.dk/en/OmDS

The City of Copenhagen. (2011). *Good , Better , Best. The City of Copenhagen Bycicle Strategy 2011-2015*. Copenhagen.

Thune-Larsen, H., Veisten, K., Rødseth, K. L., & Klæboe, R. (2016). *Marginal external costs of road transport*. Oslo.

Transportministeriet. (2015). *Manual for samfundsøkonomisk analyse på transportområdet*. (Transportministeriet, Ed.) (Marts 2015.). København.

Van Benthem, A. (2015). What is the optimal speed limit on freeways? *Journal of Public Economics*, *124*, 44–62. doi:10.1016/j.jpubeco.2015.02.001

Watkins, T. (n.d.). An Introduction to Cost Benefit Analysis. Retrieved April 6, 2016, from http://www.sjsu.edu/faculty/watkins/cba.htm