Charging the Use of Studded Tires in Stockholm-

A Cost Benefit Assessment

Swedish Project on

Health and Environmental Economics

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Abbreviations and Meaning

YOLL: Years of Life Live

CAFE: Clean Air for Europe

VSL; Value of statistical Life

QALY; Quality Adjusted life years

PM; Particle Matter

CBA; Cost Benefit Analysis

CEA; Cost Effective Analysis

RAD; Restricted Activity Days

SWoPec; Scandinavian Working Papers in Economics

ANL&ENL: Exposed Noise Level (ENL) and the Acceptable Noise level (ANL)

Abstract

The Stockholm County proposed legislation for the imposition of charges on the use of studded tires in the city. The aim of the policy was to reduce the use of studded tires by 50%. The research question investigates the authenticity of this policy whereby it was hypothesized that the NSB for the imposition of this charge was less than or equal to zero. Empirical Literatures were chosen systematically based on keywords and with the help of theories on welfare economics, a CBA was employed quantifying costs and benefit estimates of all outcomes. The findings show a NSB less than zero which agrees with the null hypothesis. Conclusions were drawn from these findings that it would be a wise decision to reject the proposal of imposing charges. It can therefore be recommended that other ways of environmental regulations such as legal procedures of police checks, heavy fines on vehicle owners using studded tires after the winter season is over, or a complete band of studded tires in the city could be best options. Performing sensitivity and uncertainty analysis shows that the results may be inconsistent with other research findings especially when the winter turns to be mild without snow. Also uncertainty here is how to correctly value morbidity in Sweden where confusion is on whether to use the level of PM10 emissions or YOLL as outcome measures. Areas of further research could be on the health impacts of different PM in general, and more research on how to correctly value morbidity particularly in Sweden. Also investigations could be made on how improvements on road maintenance can impact the cost of the increased accident risk from imposing the charge on studded tires.

Keywords: Cost Benefit Analysis, Particle Matters, studded tires charges, Noise emission, health impacts, value of statistical life, Willingness to pay, Congestions charges, Morbidity and Mortality Net Social Benefits etc.

1. INTRODUCTION

The Effects of high levels of urban air pollution became a critical issue in the mid-20th century when cities in Europe began to experience high levels of air pollution episodes such as the infamous 1952 London Fog (WHO, 2002). During this period, nations began to re-industrialize to counteract the aftermaths of the Second World War resulting to the contamination of the environment as well as the release of Sulfur dioxide (SO_2) and Carbon dioxide (CO_2) in the atmosphere which hampers human health. Clean air is a basic requirement for human health despite threats from pollution caused by human actions. Thus, the desire for clean air is a global phenomenon and for this reason, World Health Organization (WHO) has put together a report with air quality guidelines for Europe. These guidelines are designed to provide guidance in reducing the health impacts of air pollution, most recently updated in 2005 (WHO, 2005). According to Nerhagen and Li, (2010), the major contributor to urban air pollution is emissions from traffic and the emerging consensus is that the main influence is due to particle matter (PM) in the atmosphere that results from the use of studded tires as well as emission of carbon dioxide from car exhausts. In the year 2003, Stockholm's emission from traffic alone made up 70% of total emissions while 25% comes from power plants and residential heating (Nerhagen and Li, 2010). Inhalable concentration of particles (PM10) in the atmosphere results to mortality and different kind of health related problems. This concentration of particles is caused by wear particles from road pavements and tires. This mostly occurs during winter and spring when about 70% of light duty vehicles use studded tires in Sweden.

Gustafson et al. (2008, p.1) citing Jacobson and Hornvall (1999) stipulated that "despite the improvement of pavements since the 1980's, the use of lightweight alloys in the production of studs instead of steel has caused about 100 000 tons of pavement worn each winter season in Sweden, leading to the production of more particles matters which contaminates the air". Particle Matter (PM) is usually measured as $PM_{2.5}$ and PM_{10} where the subscript figures depict the size of the particles. For example $PM_{2.5}$ includes particles less than 2.5 micrometer and PM_{10} includes particles up to 10 micrometer in diameter. The PM that originates from the combustion processes of fuel in the course of driving is $PM_{2.5}$ while PM generated by road wear is in the coarser range of $PM_{2.5\text{-}10}$. Adding to this is winter sanding in urban areas and as vehicles grind the sand with their studs' inhalable particles are being suspended in the atmosphere. Similar studies conducted in Finland as seen in the case of Gustafson et al.,(2008), shows that "the use of studded tires produce more PM_{10} than non-studded tires as this is fueled or worsen by both pavement and traction sand thrown on the road to increase friction. It is important to understand that the kind of diseases contracted varies with the particle matter. According to American Health Association (AHA, 2010), smaller particles causes cardiovascular effects while larger particles are more likely to cause respiratory diseases. This is so because larger particles are filtered out in the upper airways while small particles are not. From an economic perspective, if those external health costs caused by traffic emissions are not taken into account in the decisions making regarding transport, the result will be non-optimal allocation of resources and a welfare loss (Nerhagen and Li, 2008). The emission of coarse particles during spring in Sweden is 30 times the direct combustion emissions from the exhaust pipe and the major source of these coarse particles is wear of vehicle components, for example breaks and studded tires and re-suspension of road dust by traffic (Nerhagen and Mellin, 2010). The WHO has a standard of 20 µg/m3 but Stockholm's air measured an annual average of 28 µg/m3 (micrograms per cubic meter) of air PM10 particles (a collective name for particles smaller than 10 micrometers in size). So the city needs to lose another 8 units to comply (Linde: the local, 2011).

It was noted that the cause of this air pollution was a result of the use of studded tires in the City Centre. A policy of a charge on studded tires was therefore imposed in 2010 with the aim of reducing the use of studded tires by 50%. Reducing the use of studded tires by imposing fines in cities has been a successful way to reduce coarse particles in countries such as Norway, but in the case of Sweden not much has been noted regarding the authenticity of this policy. It is for this reason why this research has been conducted to find out whether the decision taken by the board was justified. Mindful of the problem above, the goal of this work is to carry out a cost benefit analysis for the charge of studded tires in Stockholm. The question to be answered is:

-What is the net social benefit associated with the imposition of a charge for the use of studded tires in Stockholm?

-And secondly, was the policy a sensible one?

The paper will therefore focus on a Cost Benefit Analysis on road wear emissions caused by studded tires and its impact on air quality in Stockholm, Sweden. The cost-benefit analysis of a project or program uses the *net social benefits* (NSB) criterion for evaluation purposes, where NSB equals social benefits (B) less social costs (C). Here I hypothesized that; *the net social benefit for the use of studded tires in Stockholm is less than or equal to zero.* To be able to perform a CBA, a meta-analysis is employed, using estimates of costs and benefits calculated in previous studies. The remaining part of the paper is structured as follows. Section 2 provides a theoretical overview of the health impacts caused by road wear emissions; Section 3 presents the literature review and section 4 presents the methods and section 5 is results related to the findings of this paper. Section 6 is the analysis and conclusion.

2. THEORIES

2.1 Present Value Annuity

In other to investigate the authenticity of the studded tires charging policy, it will be wise to examine the present value of the cost and Benefits. It is important to note that all the cost and Benefit Values are assessed at annual rates, but there are some fixed payment such as the cost of information campaign and the cost of initial investment. This requires me to compute the PV (a) assuming a period of 20years and a Swedish discount rate of 4%. It sensible to assume 20years as the life span of the project because I considered that before this period expires, a different form of technology could emerge which will require the manual or automatic systems controls to be substituted. The concept of Present Value Annuity relies on the time value of money with the notion that 1SEK spent today is worth more than the same SEK at a future date. The Present Value Annuity could be given as;

$$p\left[\frac{1-(1+r)^{-n}}{r}\right] \tag{1}$$

Where P= periodic payment, r= rate per period and n= number of periods.

The formula above is an Ordinary annuity and assumes that the periodic payment does not change, the rate does not change and the first payment is one period way. Should the payment or rate changes, then there required to be an adjustment. For example consider that the payments increases at a particular rate, the present value of a growing annuity formula would be used. On the other hand if the first payment is not one period away, the present value of annuity due or present value of deferred annuity may be used. An annuity due is an annuity that's initial payment is at the beginning of the annuity as opposed to one period away. A deferred annuity pays the initial payment at a later time (Finance Formulas, retrieved 2015). The subsequent theories constitute the CBA.

2.2 Cost Benefit Analysis Theory

In other to review the effects for the imposition of charges on the use of studded tires using Cost Benefit Analyses, it is imperative to understand the theoretical settings that surround this study. CBA compares the discounted future streams of incremental program benefits with incremental program costs with the difference between these two streams being the Net Social Benefit of the program. It examines whether a program’s benefit exceeds its cost, a positive net social benefit will therefore indicates that the program is worthwhile (Drummond et al., 2005).

According to ASEK 5.1 report, in other to determine the admissibility of a project without considering any budget constraint, ASEK recommends the use of NPV (Net Present Value) but with respect to constraint budget the decision criteria should be based on The Ratio of NPV and public sector support (RNPSS). In Swedish this ratio is indicated by NNK (VTI, 2014). There are two different NNK recommended be used.

NNK-i = NPV/I (2)

This is equal to the ratio of NPV and the social cost of the investment. Where I = the social cost of investment and NNK-idu = NPV/ (I + DoU) (3)

This is equal to the ratio of NPV and the sum of the social cost of investment and the social costs of operation and maintenance during the life time of the investment. Where I = the social cost of investment cost; DoU = changes in the social costs of operation and maintenance due to the investment (VTI, 2014).

The social costs of the investment and changes in costs of operation and maintenance are including the marginal cost of public funds due to the public funding of infrastructure investments and infrastructure operation and maintenance. The social costs of investment and operation and maintenance also includes over-head costs for planning and administration. In this case, the decision criterion is: NPV ≥0 NNK-i ≥0 and NNK-idu ≥0 (4)
(VTI, 2014).

2.3 Kaldor /Hicks criterion

The first theory to examine in welfare economics is that of Kaldor /Hicks criterion seen in the light of Pareto efficiency and the Pareto improvement criterion. This theory is important in this study because it will enable us to understand whether the policy put in place was authentic speaking in the light of whether it makes the society better or worse since the social welfare function links certain allocation of resources to the social utility derived from a policy initiated by the government. As a result the government may use such policies to regulate the behavior of particular agents in the society or to choose the set of regulations which maximizes total output (Angelov, 2013). According to the Pareto efficiency criterion, “a state of affair is optimal if and only if there is no alternative state that would make some people better off without making anyone worse off. Therefore, a state of affairs *x* is said to be at the sub-optimal level if and only if there is some state of affairs *y* such that no one strictly prefers *x* to *y* and at least one person strictly prefers *y* to *x*” (Britannica Encyclopedia, 2014).

On the other hand, the Pareto improvement criterion or Khador/Hicks improvement is a means of resource allocation where at least one participant would favor the effect of change or to be more precise better off and no participant would be made worse off. Therefore a policy change will represent progress if the winners from the change could compensate losers from the change and still be better off (Wonnell, 2001). Zerbe and Bauman (2005) stated that the (KH) criterion is an acceptable standard for benefit-cost analysis, but subjected to criticisms. Just like any other theory, it was criticized for not considering equity and moral sentiments. Therefore the modern version of KH has been put in place with the assumption of equal marginal utility of income, a project is efficient if it passes the Potential compensation test (PCT), and gains are measured by WTP and loses by WTA. This therefore brings us to theory of WTP/WTA. WTP/WTA comes to play because charges are imposed on studded tires in the city and this will involve how the society is willing to move with the policy.

2.4 WTP and WTA Theory

The WTP/WTA approaches measures how life is valuable by considering the amount that the society is prepared to pay or prepared to accept for a given government program so as to reduce risks to their lives. These approaches uses the stated or revealed preference to discover the value people place on reducing risk to life and reflects the value of intangible elements such as QoL, health and leisure. Even though the theory overcomes the theoretical difficulties of the human capital approach, it involves more empirical difficulties in measurement. Willingness to Pay and Willingness to accept could be calculated based on the compensation variation (CV) and Equivalent Variation (EV). The compensation variation refers to the amount of money that has to be given to or taken from the public to place them at their original level of utility (Zerber, 2001). This implies that the CV is the amount of money that makes the equality

$V(p, y - CV, z_1) = V(p, y, z_0)$ holds (5)

Where V depicts the level of indirect utility, p is price, y is income, and z the state or level of the good, for example health or environmental quality before ($_0$) and after ($_1$) an improvement or deterioration. Therefore if the imposition of charges on studded tires leads to a change with improvement, the CV represents the maximum pay from the individual that will equally leave them as well off before the change. This is known as the WTP for the improvements. On the other hand, should the change be a deterioration the measure will therefore be the minimum pay made to the public to fully compensate for the change. This is known as the willingness to Accept for the change of that policy (Angelov, 2003).

Contrary is the Equivalent Variation $V(p, y, Z_1) = V(p, y + EV, Z_0)$ (6)

This is the money that would be given or taken away from the consumer to give them equivalent utility of the proposed action (Zerber, nd). The EV proposes that the individual has a right in a change. If the change is an improvement, then the individual has to be compensated if the condition prevails but considering she cannot stay in the initial situation, they must pay to avoid deterioration (Angelov, 2003). This can also be applied in a different way.

2.5 Application in the Swedish settings

Now consider this as an example that we want to measure the welfare impact on a household if air quality is increase as a result of reduction in the use of studded tires due to charges? If the existing quality level of air service is given by *Q0*, and the price charge on car users for this is given by *pW0*, and the price of the other "composite" good is *pZ0*, then the improvement in air quality from *Q0* to *Q1* due to the imposition of a charges, with no concomitant price changes, produces a welfare gain of: CV = E (pW0, pZ0, Q0, U0) – E (pW0, pZ0, Q1, U0) > 0 (7)

Where *CV* is the compensating variation that provides the true measure of the welfare effect of the air quality improvement that is being evaluated, *E* (.) represents the consumer's expenditure function, and U0 is the household's initial level of welfare. It is also important to see into it that E (pW0, pZ0, Q0, U0) is simply the household's initial income (Y0). Therefore CV is the amount of money that the consumer is willing to pay to see air quality improve from Q0 to Q1. Therefore, the maximum amount of utility (U0) is given by U0 = V (pW0, pZ0, Q0, Yo) with prices equals to pW0 and pZ0, quality Q0, and income y. Now the function [*f* (.)] can now be re-written as a generic function as; CV = WTP = *f* (pW0, pZ0, Q0, Q1, Y0) (8)

(Devicienti et al., 2004)

2.6 Value of statistical Life

The value of statistical life is also an important concept to be examined in this work. This is so because particle matters in the atmosphere can leads to severe health consequences that can reduce the life span of the people or make them less productive. Productivity approaches has been used also as a means to calculate the VSL based on the Net Present Value. With this approach one is able to calculate the NPV of future stream of lost earnings as a result of a reduced health (ASSC, 2008). This is given as shown below:

$$NPV = \sum_i \frac{Y_i}{(1+r)^i} \qquad (9)$$

Where Yi = income in year i, n = years of remaining life and r = discount rate. Also there was conflicting views on how the size of the Social Rate of Discount should look like and what consensus should be made of it. In estimating the size of the Social Rate of Discount, we use the Ramsey equation given as $r = z + ng$ (10)

Where r = the social rate of discount, z = the pure rate of time preferences (d) + risk of disaster (L)

n = the absolute value of the elasticity of the marginal utility of consumption, g = rate of growth of consumption per capita. The values of z, n and g, may be set based on results from empirical studies or based on ethical grounds (VTI, 2014).

3. LITERATURE REVIEW

Some major studies as well as similar studies have being conducted to examine the effect of studded tires use in Sweden. It is clearly noticed that increase use of studded tires leads to poor air quality. This poor air quality can be aggravated by congestion in the inner city cause by high volume of traffic. Consequently the government has sought for measures to reduce congestion so as to gain air quality and one of the ways apart from charging studded tires use is imposition of congestion charges. It is very important to note that charging studded tires in the inner city will reduce congestion which will in turn reduce the amount of particle matters in the atmosphere. Therefore elements of the congestion charges could be used as a proxy for determining air quality. According to the Stockholm trial report (2006), another way of preventing health effects in the Stockholm area is to avoid congestion in the inner city. It should be noted that decrease in congestion will reduce the amount of particle matters in the atmosphere produced by studs as well as car emissions. For this objectives to be achieve studies on the Stockholm congestion charging system has been conducted. On average it can be estimated that 2,155 people are injured and 23 people die in road accidents per year in Stockholm County. This trial has reduced the number of accidents by 5-10% and if this is converted to yearly values, this will give an annual reduction of between 40-70 accidents in which people were in injured (Hugosson and Eliasson, 2006)

The purpose of the study was to test whether the efficiency of the traffic system can be enhanced by congestion charges and with this efficient traffic system, traffic volume of busiest roads could be reduced by 10-15%, traffic flow on streets and roads are improved, emissions of pollutants harmful to health is reduced and finally provides more resources for public transport.

Based on the results, vehicle traffic declined more than expected as the number of vehicles passing over the charge cordon declined between 10-15%. It was also noted that for a 24hr period, which is one full day, the decline was about 22% which is equivalent to 100,000 passages over the charge cordon (Stockholm trials, 2006). The findings also show that "emitted particles and nitrogen dioxide fell by 8%-12% in Stockholm's inner city. For all road traffic in the City of Stockholm this corresponds to between 3%-5%. This means that, with a congestion tax, both the average particle levels for the population of Stockholm and the nitrogen oxide levels would be some percent lower" (Stockholm trials, 2006).

According to Hugosson and Eliasson, (2006), with congestion charges, vehicle traffic will decline which leads to improved accessibility and travel times. This makes travel time more reliable. With travel time being more reliable, commercial drivers (as in bus drivers, taxi drivers, courier and trades people) benefits from better work environment. With this also, the noise level generated by vehicles also falls and finally leads to less damage to the environment and better health. Because of these trials, there is reduction in the emissions of both carbon-dioxide (CO_2), NO_2 and particles. Without this, individuals will be exposed to particles which affect the population health thereby increasing mortality. Calculations that connect the congestion tax effects and early mortality due to exposure to air pollution shows that traffic reductions resulting from the Stockholm Trial save about 5 otherwise "lost" years" (Hugosson and Eliasson, 2006)

Angelov (2003) had worked on similar research but this time a cost-benefit assessment on studded tires within the Swedish setting. Using Swedish data on population, traffic accidents, and the level of studded tire usage, calculations have been made as well as estimates on studded tire road abrasion. Calculations on road abrasions shows that in the late 1990,s wear had diminished to around 110,000 as compared to 300,000 tons before. The SPS ratio (specific wear, grams of abraded material per vehicle with studded tires and kilometer) shows a decrease from 30 during the early 1990,s to an average of 8 at the beginning of the 20th century with the most resistance pavement having an SPS ratio of 2-4. However with increase speed, axel load pressure and tire pressure, the wear is more intense 2-7 times (Angelov, 2003).

Citing Jacobson (1999), with a total pavement wear from a studded tire use level of 60%, the following computations could be made:

$$W = SPS \times TDs \tag{11}$$

Where W denotes total wear, SPS is the average SPS rate, TDs are traveled distance by passenger cars with studded tires in million vehicle km.

The total stud travel distance was estimated to be 13 986 million vehicle km which further increased by 6% between 1998 and 2001 thus giving rise to a travel distance of 13 986 x 1.06 = 14 825.16 km in 2001. Given that the average SPS rate was eight, the pavement wear of 2001 can be estimated to 118 601.28 tons which is applicable only at a studded tire use level of 60%. This model is linear in studded tire used and the wear estimation for the year 2001with the use of different studded tires is given as W = 118 601.28 x TD.s/60, where TD.s denotes the studded tire use level. Therefore with this road abrasion there is a need for maintenance cost. If the road is not maintained, wearing will continue and particles in the atmosphere will increase deteriorating the health of the population. The imposition of charge on studded tires will lead to a reduction of maintenance cost. This serves as a benefit to the society.

Noise is also another outcome that has a serious health impact on the society. As the car moves with stud on the tar, noise is easily produced. Studies shows that during winter time, the noise level increase with 2 or 3 dBA assuming a speed of 70-90 km/hr and 15-25 percent heavy traffic. Citing Sandberg and Ejsmont (2002), the author stipulated that “the sound of studded tires can be very noticeable, emanating due to the metal pin making its impact on the stones of the pavement”. The various variations in noise levels are feasible such as high stud protrusion: The noise increases approximately 2-6 dB within 500-5000 Hz, and 5-15 dB above 5 000 Hz. Also for low stud protrusion the noise increases is approximately 3-7 dB above 5 000 Hz (Angelov, 2003). In the study of Angelov (2003), the noise effects of studded tires has not being monetized but according to Ronny et al. (2011), studies from the European road public administration in Norway uses monetary valuation with respect to the number of decibels (dB). In 2005/6, the value was NOK 238 per dB per person affected per year, or NOK 524 per household which is equivalent to EUR 65.45. PM_{10} emissions are valued at EUR 51.25 per kg, in application to Norwegian urban areas in general, but these values are possibly higher for larger cities. These values will be used for the case of Stockholm multiplied by the number of households in affected areas.

Further to this is the study by Nerhagen and Mellin (2010) provides an overview of health impacts and external costs of emissions from traffic. PM emissions in general have been proven to cause mortality and morbidity, both acute (short-term) and chronic (long-term). However, wear PM in particular is only associated with acute and chronic morbidity as well as acute mortality. Recent studies suggest that wear PM has considerable impact respiratory diseases, while the impact on cardiovascular risk is relatively small. Nerhagen et al. (2009) provides an overview of how to treat external costs due to emissions in the Stockholm area. The paper highlights that there is recognition among the research community that different types of PM also have different impacts on human health. Fine PM is considered to be more detrimental to health, but in a lot of the current practice PM is treated as equally harmful irrespective to origin. Since the contribution of wear PM to total concentration of PM in Sweden is large, whether or not to assume PM of different origin is equally harmful is of particular interest. The paper also states that when investigating the external costs, it is also important to consider how the exposure varies between different emission sources. Using the impact pathway approach (IPA), the paper concludes that wear PM generates a lower estimated cost per unit of emission compared to combustion PM, but also that more research is needed to assess the impact on health from wear PM. In other words, there is currently a considerable amount of uncertainty in the external health cost.

Furthermore, Nerhagen et al. (2009) describe a methodology on how to value health impacts caused by air pollution. In their paper it is explained that the health costs can be divided into two components; the cost related to illness, such as the cost of medical treatment and lost production, and the value placed on the loss of welfare of being ill. The former is mainly associated with morbidity, while the latter is associated with both morbidity and mortality. Values for the cost related to illness can be obtained from register data, while the loss of welfare of being ill is measured using so called valuation studies. These are of two kinds, either revealed preference studies that rely on observed behavior or revealed preferences studies that use responses to hypothetical questions. The theoretical basis for this type of analysis is that people are willing to trade money for reductions of risks and that this willingness to pay (WTP) is a monetary approximation of the utility lost from being in a bad state of health. For example, the value of a statistical life (VSL) can be calculated by dividing the WTP for a risk reduction by the probability of death. However, as argued by the authors, the problem with using VSL in the context of air pollution is that most calculations of VSL come from studies of working age people where many years are assumed to be lost, while air pollution mainly impact elderly. To account for the length of lifetime lost the metric needs to be changed from VSL to value of life year lost (VOLY). Since no studies in Sweden have tried to estimate VOLY, it is argued that the estimate suggested by Bickel and Friedrich (2005) should be used. The median estimate of VOLY in this study is 55 800 euro, adjusted down to 50 000 euro. The median estimate is preferred to the mean estimate, because it is unaffected by distributional assumptions. The values are similar to the ones used in the CBA in the Clean Air for Europe (CAFE) program.

According to Svensson (2006 p.2), who investigated on “the value of a statistical life in Sweden: Estimates from two studies using the 'Certainty Approach’ calibration. His paper suggested that using full samples of two different surveys in Sweden to estimate the WTP in reducing traffic mortality risks by only including the most certain respondents estimates of VOSL are $4.2 and $7.3 million. Estimates of VOSL on the subset of the samples only including the most certain respondents are lower and consistent between the two surveys with values of $2.9 and $3.1 million”. In addition to the uncertainty of the health impact caused by wear PM, there is an uncertainty in the effectiveness and associated cost of abatement measures. This uncertainty is addressed in a paper by Nerhagen and Li (2010), where a cost-effective analysis (CEA) is used to evaluate different Stockholm policies aimed at satisfying certain targets of emission levels or expected mortality health impacts. Since the health impacts do not only depend on the level of PM emitted, but also the emitting source, those measures of outcome yield different results when applied in the CEA. Two models are applied when calculating the CEA, one deterministic model and one model including a stochastic variable to account for the uncertainty in the effectiveness of abatement measures. In the deterministic model, the policy of a charge on the use of studded tires resulted in a 929.5 tonne reduction in PM_{10} giving a reduction in years of life lost (YOLL) of 5.95. Because of the uncertainties of the health impacts caused by PM emissions, there is an argument made by the authors for targeting emission levels and concentrations instead of the health impact YOLL.

However, to be able to assess a monetary value to the benefits of decreased emissions which is needed in the CBA, YOLL will be of particular interest for this paper. The results of the deterministic CEA performed by Nerhagen and Li is that if emission level of PM_{10} is chosen as the target measure, decreasing the use of studded tires will be chosen as one of the policies for PM reduction. However, if YOLL is chosen as the target, the charge on studded tires will not be chosen. This is because the coarser wear PM generated by studded tires contributes to a large proportion of the emissions of PM_{10}, but the finer PM from the combustion process has more detrimental impacts on health. No matter what target is being used, the policies of congestion charging, increasing the use of low emissions vehicles and installing accumulator tanks for residential heating will be chosen. In the case of using YOLL as a target, a policy imposing a standard of having PM filters on heavy duty vehicles will be chosen as well.

A study by Nerhagen et al. (2010) attempts to value not only the mortality impact, but also the morbidity impact, for wear PM. The health endpoint used for morbidity is restricted activity days (RAD). To estimate the impact wear PM has on RAD, the authors use a method also used in CAFE. They use $PM_{2.5}$ measurements and later use a conversion relation to apply it to wear PM. For RAD the value to be used depends on the kind of restriction imposed on the individual and is arrived to by making assumption about how individuals react to exposure of different emissions. It is argued that even though morbidity impacts have made a small contribution to total cost in most studies, it may be of importance regarding wear PM since the estimated exposure to this pollutant is comparatively large. The study results are a high and low estimate of morbidity cost due to wear PM emissions from road traffic in Stockholm; the high estimate is EUR 11.8 million and the low estimate is zero. The high and low estimate of mortality cost is EUR 1.1 million and zero. The policy evaluated in this paper was suggested by the county board of Stockholm County (2004). The proposed policy consists of two parts. The first part is a charge on the use of studded tires in the Stockholm region and the income from the charge is suggested to be used to improve winter road maintenance. The second part is an informational campaign explaining the negative health impacts of wear PM for the charge on studded tires to gain acceptance among the public. The aim of the policy is to decrease the proportion of studded tires being used by 50%. A certain proportion of studded tires are wanted, because they help keeping the asphalt and the ice on the roads rugged, which in turn increases the road friction and thus traffic safety.

With regards to how traffic safety in Sweden is impacted by a reduced use of studded tires, a study by Möller and Öberg (2009) investigates the impacts on the amount of injuries for three different scenarios. The first scenario is a reduction of studded tires in cities by 50%, the second is a ban on studded tires in April and the third is a ban of studded tires in Southern Sweden. As the use of studded tires decrease, the use of friction winter tires will in increase. The study acknowledges that the impact on traffic safety will depend on what type of friction tire will be chosen to replace the studded tires, since Nordic friction tires are considered to have higher road friction than friction tires from the rest of Europe. The study concludes that a 50% reduction of the use of studded tires in Stockholm would result in an additional 10-18 minor and 2-4 serious personal injuries, with only a very small risk of additional deaths. A ban on studded tires in April is not expected to increase the amount of traffic related injuries, while a ban in Southern Sweden would increase the amount of minor and serious personal injuries by 88-135 and 21-33, respectively, as well as an additional increase of 2-4 deaths.

4. METHODOLOGY

4.1 Approach of study

Economic evaluation methods compare costs and effects of alternative measures to clarify which alternative will give the biggest return on the resources spent, i.e. which measure has the highest cost-effectiveness. It is also possible to evaluate separate measures in order to tell whether they are profitable on the societal level. This project examines the CBA analysis associated with the imposition of charges on the use of studded tires in Stockholm. In the year 2010, the Stockholm commune Board made a proposal for the imposition of charges for studded tires used in Stockholm city. Consequently, this is an *investigation study* using Cost Benefit analysis to find out whether the decision made by the board is sensible. A cost benefit analysis (CBA) is the most advanced economic evaluation method where both costs and benefits are evaluated in monetary terms. This means that the alternatives compared can have differing consequences but can still be useful in making comparisons since they are valued in the same unit. The aim is to value costs at their opportunity cost, i.e. the value of the best alternative use of the resources. The perspective taken is that of society as a whole, meaning that all effects are taken into account regardless of who bears or benefits from them. In between these two extremes, there is cost-effectiveness analysis (CEA) which compares the costs to achieve a given effect, meaning that monetary valuation can be avoided in cases where this is considered difficult.

4.2 Sources and Method of Data Collection

Considering the fact that this study requires a combination of findings from different studies, a meta analysis is employed. Also, since a meta analysis is used, this means that articles are retrieved and reviewed systematically. Crombie and Davies (2009) suggested that “systematic review methodology is the bedrock of meta analysis and that it provides a balanced and impartial summary of the existing research which permits decisions on effectiveness to rely on relevant studies of adequate quality”. The reason for the choice of systematic review is because such review provides a quantitative estimate of net benefit aggregated over all the included studies. Articles for this study have being retrieved based on key words. Articles were retrieved from sources such as SWoPec, Orebro University Library data base, Google and Google Scholar. Majority of articles reviewed were mostly related to studies from the Swedish National Road and Transport Agency, Samhällsekonomiska principer och kalkylvärden för transportsektorn, meaning that the review has being on similar studies.

More than 40 papers were retrieved for this study. Once all these studies were identified, only empirical studies that relates to Economic evaluation for health and environmental economics passed the inclusion criteria and were included in the work and those that reviewed on CBA but not directly related to environment and health fell under the exclusion criteria. This is so because Economic evaluation methods can be applied in different field not necessarily related to the topic. Out of these 40 papers, I deliberately selected 25 of these articles not based on whether they are related to environmental economics but based on key words such as studded tires charging in Stockholm, Noise level and studded tires, congestion charges in Stockholm, travel distance during winter in Stockholm etc. which specifically relates directly to my subject matter under investigation. This means 15 of these articles were abandoned even though they related to health and environmental economics. These remaining articles were used in the analyzes.

4.3 Method of Decision Analysis

Decision for this study will be analyzed based on values from the present value for cost and benefits. If the PV(C) is greater than the PV (B) then the project will be sensible and the government should go ahead with the charge otherwise they should quit and resort to other methods of control. For the case of onetime costs, the present value annuity has being used.

4.4 Environmental Regulation Approaches: Incentive design

Incentives are the key between economics and better environmental policy. People have less incentive to protect the environment today when the social costs fall on others. For example, a producer chasing profit may not have the incentive to clean up its emission to the desired level of the society as well as vehicle owners may understand that using studded tires during summer periods causes high particle matters in the atmosphere but may not take the incentive to change their tires after winter because of their tight schedule or may not just consider it important. Therefore people willingness to protect the environment may be limited by certain contingencies which require public regulations to ensure that their private motives align with social objectives to protect the environment.

With this in mind, there are many regulative approaches to ensure that private incentives align with environmental goals. These include legal mandates and technological restrictions (e.g. air and water filtration and technology), cooperative institutions to share information between regulators, polluters and victims (e.g. voluntary agreements, coasean bargaining), and economic incentive mechanism to increase the cost of "environmental shirking" on environmental protection such Charges, subsidies, fees, tradable permits and taxes etc. (Hanley et al., 2007). Considering that we are dealing with charges, the focus will be on economic incentives which can be grouped into 3 categories namely; Price rationing (Pigovian tax), Liability rules and quantity rationing (tradable permits).

4.4.1 Price rationing: Emission and Ambient Charge

One method of environmental regulation is through an emission charging system. Pigovian taxes or fees are levied on the discharge of pollutants into air, water, or onto the soil or on the generation of noise. These taxes reduce the quantity or improve the quality of pollution by making polluters pay at least part of the cost of the harm they do to the environment. This will be possible if the regulator can actually measure the Marginal Social Cost that fall on the entire population, through which he could set the Pigovian tax accordingly. The regulator sets the tax t, equal to the level at which the marginal benefit equal the marginal control cost i.e. $MB=MC=t$. (Hanley et al., 2007).

However, due to asymmetric information such as moral hazards and adverse selection, these taxes are said to be inefficient. Thus to reduce the moral hazards problems, regulators can design a charge system based on the overall ambient concentration of a pollutant in a region. An ambient charge scheme which combines penalties and reward for exceeding or beating a particular level of total ambient concentration consisting of two parts; a per unit charge or subsidy based on the deviation from some ambient standard or a lump sum penalty for not achieving the standard (Segerson, 1988). Adding to this, the regulator can also offer subsidies as an incentive to encourage pollution control. This can take the form of grants, loans and tax allowances.

4.4.2 *Liability Rules, bonds or deposit funds.*

With Liability rules, a producer is fined if his actions lead to a level of pollution which exceeds some set standards. “Liability rules regulate pollution in that the pollutant pays a bond up-front and is reimbursing if no environmental harm occurs or he pays a non-compliance fee after the harm has occurred. This attempts to reduce the level of shirking on environmental pollution control by raising the expected costs of misbehaviour. Liability rules are also limited by moral hazards in terms of identifying the exact culprit responsible for pollution since ambient concentrations cannot be perfectly assigned to the responsible producer. Furthermore, performance bond is another form of regulation which could be used to control pollution. With Performance bond a producer post a bond before operation begin, forfeiting the bond if his activities cause environmental harm or if he pollutes in excess of acceptable levels. The bond increases the cost of shirking thereby reducing the incentive to malfeasance” (Hanley et al., 2007 p.105-112).

4.4.3 *Quantity rationing (tradable Permits)*

Pollution control can be controlled through quantity rationing whereby tradable permits are issuing allowing the pollutant to pollute the environment only equal to the permissible total stated in the permit. As a result, it is possible for individual holders to trade this permits among plants of a single producer as well as among other producers if they kept their emission levels below the allotted permit. With tradable permits, if the regulator knows the marginal costs and Benefits of pollution control with certainty, the level of permits could be set such that they leads to socially optimal reduction of pollution where marginal benefits equal marginal costs i.e. m=MB=MC. With complete certainty, the permit market price will equal the optimal emission charge, m=t=MB=MC.

4.4.4. *Technological Control systems*

In this section, I examined two systems of control for studded tires which I classified them under the automatic versus the manual control. Based on automatic control methods, the main engine is technology and for manual control, human beings are the engine of control. Technological method(s) can be through road electronic recording system in the inner city that can pick up the metal alloy or studs from any vehicle and with an automatic plate number reading system through the help of street Laser cameras (Just like the Stockholm congestion charging system), it will be possible to identify who owns the vehicle. Therefore, in case where the commune wants to reduce the use of studded tires in the inner city, different levels of charges could be levied at specific snowing periods and bills will be directed automatically to vehicle owners with studs passing through the toll cordon. The charges imposed will be a function of the road condition such that vehicle owners would be influenced to use studded tires only when required. The Road conditions are considered to be wintry where there is snow, ice, slush or frost on any part of the road. By this I meant, there will be behavioural change where human ways of life will be shaped to achieve the goals of the policy.

4.4.5 *Legal mandates*

On the other hand, the manual checks are done under the auspices of the police. The Swedish Police determines whether the wintry conditions in the city is high or whether the conditions are high on certain roads and then stand on the guard to check whether or not vehicle passing on such roads have studs or not. Also when wintry condition is low, they ensure that vehicles passing through those areas or moving on the entire city are stud less so as to avoid particle matters in the atmosphere. It should be noted here that winter tires are produced specifically for winter driving labelled M+S (M.S, M-S, M&S or Mud and Snow) to be used between October and

April (transportstyrelsen, 2013). But most often not every vehicle owners may want to change their tires during the spring, some due to negligence. With this continuous usage, road wares and particle matters in the atmosphere will increase causing severe health consequences. Therefore with Manual check police are the custodians.

4.5 Identification of Costs and benefits

4.5.1 Costs.

Measures in the transport field may lead to a number of different economic effects from the societal perspective. Examples are changes in travel time, accident risks, emissions or environmental or cultural intrusions. In the CBA, the costs and benefits associated with the measure being studied are identified, quantified and valued in monetary terms. The costs and benefits I have identified due to the imposition of a charge on studded tires are presented in Table 4.1 and Table 4.2 below. When deciding on which costs and benefits to include in this work, I look into the results and assumptions made in previous studies.

In the study by Nerhagen and Li (2010), the costs of increased travel time and increased accidental risks are of significant magnitude, and are thus included in my study as well. The above mentioned study does not take the cost of an information campaign into consideration; however, I decide to include it in the study. Based on the amount spent on the information campaign in Trondheim municipality and the need to increase the acceptance of a charge on studded tires in Stockholm, the information campaign is considered to be of importance for implementing such a policy (County board of Stockholm County, 2004). The cost of administration of charges is not taken into account in their study partly due to the lack of data on such a cost and partly due to previous studies not considering it important (Nerhagen and Li, 2010; Asano et al., 2002). However in this study, I have used the operation cost for the Stockholm congestion charging system as a proxy for administration cost of studded tires charges. The Operation cost according to Hamilton (2010 p.7) is the amount spent on collecting the congestion tax. From above we noted that decrease in congestion will leads to better air quality considering that more cars in the inner city with studs will produce high air pollution. Thus, the congestion administration charges could be adjusted to assume studded tires charging system. Even though they may not be the same, this could be reasonable. Also based on ASEK 5.1 report, the prices of cars are given and thus it is possible to compute cost of shifting to non studded tires. Here it is assumed that since the policy aim to reduce the use of studded tires by 50% I consider that 50% of car owners in Stockholm must buy non-studded tires. Thus I consider 50% of cars in the city after the charges are made multiplied by 4 x the price per tire as seen in ASEK 5.1 Report. Furthermore, without studs maintenance cost of cars will increase due to over steering. The study of Angelov (2003) will be used in this domain and it should be noted that maintenance cost of cars is different from maintenance cost for road wear due to the use of studs.

4.5.2 Benefits.

On the other hand regarding the benefits of imposing a charge on studded tires, the focus in this as well as in previous studies is the health impacts from a decreased amount of wear PM emissions. I noticed that when this charge is imposed congestion will reduce and the value of time as well as accessibility will increase. Eliasson (2006) in his study of the CBA of Stockholm congestion charging system, explained that when charges are impose congestion Vehicle traffic will decline which leads to improved accessibility examined in the Value of travel time. This is a huge benefit for imposing charges on transport systems. This therefore implies that these concepts are different. Decrease in congestion will therefore be measured by the Value of time per vehicle as a result of the charge. Decrease in congestion will also leads to decrease in noise and pollution of the atmosphere because the particle matter in the atmosphere will reduce which will leads to reduction in Morbidity and Mortality. Also to examine the authenticity of the policy, noise and maintenance cost of road will be included for assessment since the health Impact is associated with them. The decreased level of ambient noise will also be computed as seen in the study of Andersson and Ögren (2012) charging the polluters, a price model for road and railway. The benefit of decreased fuel consumption is recognized, but assumed to be negligible, in the study by Nerhagen and Li (2008). However, in this study, it will be computed considering data from ASEK5.

Table **1.** *The costs of imposing a charge on studded tires in Stockholm.*

Increased travel time	Less use of studded tires is considered to increase the travel time to some extent.
Increased accident risk	In certain conditions, studded tires are considered safer than non-studded tires meaning that the risk for accidents will increase.
Information campaign	The introduction of a fee for using studded tyres will call for an information campaign which will have to be paid for.
Administration Cost	After the system has being setup, there is the need for maintenance of the system as well as the back office staffs that ensures that the system functions. This can be seen also as the cost of operating or running the system after it is installed.
Buying of non-studded tires	Car-owners will have to buy new tires if wanting to avoid the charge.

Maintenance cost of cars will increase	Because of over steering and engine pressure on snow, it is important to note that maintenance cost will increase.

Table **2.** *The benefits imposing a charge on studded tires in Stockholm.*

Decrease congestion	Vehicle traffic will decline which leads to improved accessibility and reliability.
Decreased amount of particles	The decrease in the amount of particles will lead to health benefits in terms of reductions in morbidity and mortality rates.
Decrease of noise	Non-studded tires lead to less ambient noise than studded tires.
Decreased fuel consumption	Non-studded tires lead to lower fuel consumption, both through a decreased road friction and a lowered travel speed.
Decreased road maintenance	If the use of studded tyres is decreased, the wear of the road surface will decrease and so the need for road maintenance

5. RESULTS: (Quantifying Costs and Benefits)

5.1 Increased travel time

The cost of increased travel time will be valued according to the estimates in the study by Nerhagen and Li (2008). The study uses an average time value per vehicle of SEK 122/hour. This value has previously been used in a Transek study (Transek, 2006) and is based on recommendations by the national Working Group for Cost Benefit Calculations in Sweden (ASEK). However, according to ASEK (2010), the value of travel time for business and non-business trip gives 108 and 291 respectively for cars. Now taking the average adjusted to 2010 prices gives 399*1/2 equal to 199.5 SEK. According to Nerhagen et al. (2005), about 6500 million vehicle km are driven in the Stockholm region each year, at the average speed of 50 KM/hour. It is assumed that the reduction in studded tires will increase travel time between 0.5% and 1%. Using these values, the annual cost of increased travel time can be calculated as

$$C_t = \frac{6\,500}{50} \cdot 0.005 \cdot 199 = \text{SEK } 129.35 \text{ million.}$$

And

$$C_t = \frac{6\,500}{50} \cdot 0.01 \cdot 199 = \text{SEK } 258.7 \text{ million.}$$

5.2 Increased accident risk

In Nerhagen and Li (2008) it is assumed that the studded tire policy would result in one death extra in traffic. However, in this paper I will use the estimates from a study by Möller and Öberg (2009). They estimated that the increased amount of accidents would result in 2-4 additional persons being heavily injured and less than 0.1 additional deaths annually. It is also estimated that the increase in minor personal injuries would be 10-18. For minor and heavy injuries the estimated costs are 0.338 and SEK 7.05 million, respectively. Minor and heavy personal injuries are defined and valued in 2006 year prices by ASEK (Vägverket, 2008). Based on this information, I create a high and low estimate for the cost of increased accidents. In the high estimate I have assumed that the annual increase in minor injuries is 18, the increase in heavy injuries is 4 and the average increase in deaths is 0.1 In the low estimate I assume that the increase in minor injuries is 10, the increase in heavy injuries is 2, and that the policy has no impact on the numbers of deaths in traffic. Now according to the Swedish transport sector (ASEK 5.0) deaths is valued at SEK 23. 739 Million For one fatality at 2010 prices. The resulting costs are

$$C_a^h = 0.1 * 23.739 + 4 * 7.05 + 18 * 0.338 = \text{SEK } 36.7\text{million}$$

And

$$C_a^l = 2 \cdot 7.05 + 10 \cdot 0.338 = \text{SEK } 17.5 \text{ million.}$$

It is worth noting that property damages are neglected. These costs were not calculated for the Stockholm region policy by Möller and Öberg (2009), but their contribution to total cost in the scenario of a ban of studded tires in Southern Sweden was small.

5.3 Cost of information campaign

The cost of the information campaign when implementing a charge on studded tires in Trondheim 1999 was NOK 2 million. The money was spent on advertisements in newspapers, TV and radio as well as a website. Since the Stockholm region is significantly bigger than the Trondheim region, the expenses are expected to be higher as well (County board of Stockholm County, 2004). To arrive at an approximate cost for the Stockholm information campaign, I assume that the cost is proportionate to the population size of the region in which the policy is implemented. The cost for the information campaign can then be calculated as;

$$C_i = 2 \cdot \left(\frac{POP_S}{POP_T}\right) = 2 \cdot \left(\frac{2\ 054\ 343}{153\ 332}\right) = \text{NOK } 13.4 \text{ million}$$

$$\text{SEK15.3 Million}$$

Where POP_S denotes the Stockholm region population in 2010 and POP_T denotes the Trondheim municipality population in 1999. Valued in 2006 year prices, the cost of the information campaign is equivalent to SEK 15.3 million (Statistics Sweden, 2011; Statistics Norway, 2011).

5.4 Buying of non-studded tires

5.4.1 *Purchase of non studded tires for all cars:*

It should be noted that charging the use of studded tires will cause car owners to avoid travel using studded tires if they want to avoid the charge. They will resort to buying new tires. The goal of the policy was to reduce studded tires use by 50%. According to Stockholm facts and figures (2013), the number of private cars in use as of 2012-12-31, was 318,131cars. If we assume only private cars are available, then multiplied by 4 wheels, this will give a total of 1,272,524 studded tires use during the winter season. Considering that the goal is to reduce the number of studded tires use by 50%, this implies that 1/2 *1,272,524 give 636,262 new non-studded tires which must be bought if these car owners want to avoid the charge. In this case, I assume that every one behaves well and that cars are checked against any malpractice during the winter season. Based on (Asek$_{2010}$ 5.0), the price of tires (Including VAT) as for SEK$_{2010}$ is 780sek per tire. Therefore one can estimate that the cost of purchasing non-studded tires as a means to avoid the charge is *496.3m* SEKS. This could be presented tabular as shown below;

Table 3: Upper bound value for studded tires purchase for all cars in Stockholm

Buying of non-studded tires	**No of Cars in Stockholm**	**No. of Studded tires required**	**50% Policy*Price per tire (780SEK)**	**Total costs of new tires Purchase**
	318,131cars	1,272,524	636,262*780sek	*496.3m* Seks.

Source: Data derived from Stockholm facts and figures (2013).

5.4.2 Resale value due to Depreciation:

From the table above, the total cost for purchase of new studded tires is 496.3MSeks. This is to assume that everyone is responsible enough to change their tires by buying new ones. But when the studded tires are changed, vehicle owners often sell the old depreciated tires. Thus the resale value must be calculated and this is value of the tires due to depreciation. It is the returns car owners gained when they sell their winter tires to buy summer tires or vice versa as a result of the policy. When the resale value is subtracted from 496.3millionSeks, will give the lower bound cost incurred on buying new tires as a result of the policy. Thus in this way, I assumed that the cost of depreciated studded tires according to blocket (2015) stands at 1600SEKS on average for four tires or the complete set. This implies one will cost 400seks.

Table 3.1: Lower bound limits due to depreciation

Resale Values	No of studded tires	Total Cost
400SEKs	636,262	254,504,800SEKS≈254.5

Therefore, the lower bound value is 254.5 and the upper bound value is 496.3 for resale and sale values respectively.

5.5 Maintenance cost of cars will increase

Placing a charge on the use of studded tires therefore implies that maintenance cost will increase because the use of non-studded tires will leads to over steering and engine pressure. According to Mattias Hjort (VTI, 2011) fatal accidents on winter roads are 64% accounted for by vehicle skidding while 82% are caused by over steering i.e., accidents where the vehicle has started to rotate because of no friction. According to studies by Nerhagen et al. (2005), it is calculated that about 6500 million vehicle km are driven in the Stockholm region each year, at the average speed of 50 km/hour. From this, one can compute the maintenance cost by considering the cost of wear and tear per km or depreciation. Since the research focus on winter seasons, I also assume this figure to be divided by ½ since studded tires are considered to be used in Sweden from 1ST October to 15th of April. This is a period of 6 months which is one-half of the year. However, the season of concentrated snow is between December and March meaning the other two months snow may be mild that is in October and November and part of April. Therefore intensive or effective snowy period leading to over steering and engine pressure is a maximum of 31/2 or (7/2) of the six months of winter while the remaining 2.1/2 or (5/2) may be associated with gentle snow but not concentrate enough to leads to over steering and engine pressure. This is so because maintenance cost is considered to result from over steering and engine pressure which are outcomes of heavy winter season. Therefore, if 6500million Km is covered in the Stockholm region for one yr according to Nerhagen et al. (2005), then one can estimate that for the winter 1/2 x 6500Mkm which gives 3250Mkm assumed to have being covered during period of Snow. Now considering ASEK$_{2010}$ 5.0

figures, Cost of wear and tear, SEK per kilometer, (including VAT) 0.16. This therefore implies the Maintenance cost of cars will give 520million SEK. However, maintenance cost does not have direct impact on health. But when Maintenance cost for car is high, disposable income will fall and standard of living is going to drop which can have severe health consequences. This could be clearly presented as shown below:

Table 4: Figures of highly concentrated snow in a six month period

Total KM distance covered in Stockholm.	Total Covered During winter season assumed.	Cost of wear and tear, SEK per kilometre, (including VAT) 0.16	Maintenance cost
6500MKMs	3250MKMs	0.16	520 MSEK

Source: Nerhagen et al. (2005); $ASEK_{2010}$ 5.0 figures

The table above assumes that snow is highly concentrated for six months. Now consider that the winter turn to be mild with 5/2 of the 6 months having just mild or windy snow that does not provokes over steering. In this regard, I assumed that 5/2 (40%) to 7/2 (60%) of 6 months to be the lower bound and upper bound values respectively. This gives values from 208MSEKS to 312MSEKS (which is the difference between the upper bound and the lower bound) for light and severe snows. Therefore the lower bound is 208MSEKS where the winter is considered to be Mild and the lower bound is 520MSEK where the winter period is assumed to be totally heavy leading to over steering.

5.6 Administration Costs.

Here, there has being no previous study that examine the administrative cost for the charge of studded tires in Stockholm. However, an understanding of the theory of benefit/cost analysis requires all costs and benefits converted into a monetary metric and then measures whether the benefits outweigh the costs. The goal here is to ask whether a single policy change would be desirable, thus it does not necessarily mean that the system must be in operation. In this way, I have used the operation cost of the Stockholm congestion reduction charge system as a proxy to stud tires administrative cost. The reason being that almost the same cost will be incurred for administration same as the congestion charging system. Eliason (nd), cited that a comparison of the Stockholm congestion charge system to that of Oslo could be made in the domain of factor supply. The Oslo system is more labour intensive with manual payment methods as compared to that of Stockholm which is technological intensive with no manual payment methods. Due to these differences the operation or administrative cost of Norway lies at 150 mSEK/year.

Based on studies of Hugosson and Eliason (2006, p18-19), the operation cost is considered as the administration cost with the congestion charge system giving an annual Cost-Benefit Operation Cost of 220 million SEK which is argued to be almost half of the annual cost-benefit surplus of about SEK 760 million (after deducting operating costs) of the congestion system (Eliason, 2009). Therefore in this study, since no research has being conducted on the Stockholm studded tires band administrative cost charges, I have used the congestion charge operation cost as a proxy to the administrative cost.

To capture uncertainty I also assumed the Norway value to be a lower bound value of 150million Sek and upper bound of 220 million Seks. Here, Operation cost includes cost of maintenance, legal and tax administration, cost to the call centre, and finally paying labour for wear and tear (maintenance) of the system.

5.7 The initial investment costs

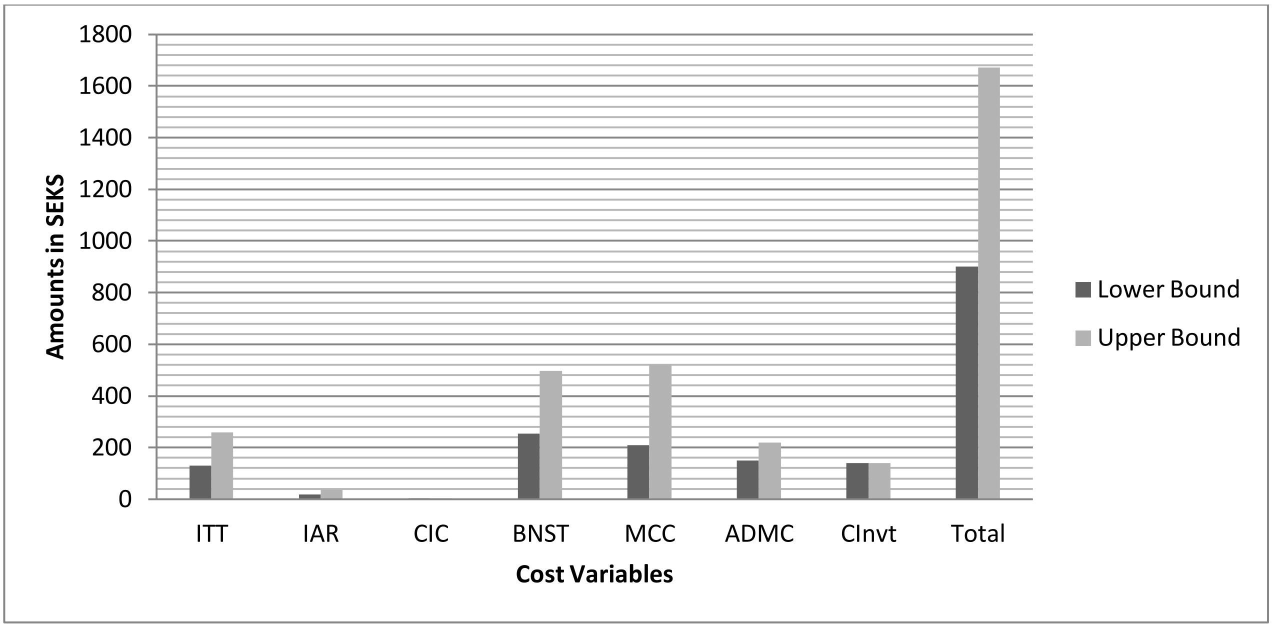
Just like the Stockholm congestion trial, I have assumed an initial investment cost of SEK1900millions. In this case I also assumed that the Swedish recommended discount rate of 4% per year (Eliason, 2006).

Table 5: Tabular Representation of Cost Data.

N	Cost Variables	Amount (MSEKs)	Present Value annuity for onetime costs (MSEKS)
1	Increase Travel Time (ITT)	129.35—258.7	*
2	Increased Accident Risk (IAR)	17.5 — 36.7	*
3	Cost of information campaign (CIC)	15.3	1,125,800.78≈ 1.126
4	Buying of non-studded tires (BNST)	254.5 — 496.3	*
5	Maintenance cost of cars(MCC)	208—520	*
6	Administration Costs (ADMC)	150 —220	*
7	Cost of Initial Investment(CInvt)	1900	139,805,325.62≈ 139.805
T	Total (Without Initial Investment Costs and PVa)	774.65—1339	-
T	Total with Initial Investment Costs		900.281—1,464.631

(*)Means the same values and (-) means not applicable.

Figure 1: Graphical presentations of cost scenario associated with studded tires used.



The graphical presentation of costs scenario shows the ticker lines illustrating the lower bound and the lighter lines illustrate the upper bounds. Cost of information campaign which is onetime costs have least values compared to maximum value has higher scores.

5. Quantifying Benefits

It should be noted that the goal examines the CBA on health impact and the research answers two questions: net social benefit associated with the imposition of a charge for the use of studded tires in Stockholm and secondly whether the policy was justified? The following benefits have being quantified.

5.8 Benefit of decreased amount of particles

The health benefits from a decreased amount of wear PM are generally analyzed by studying three different health endpoints, acute mortality, acute morbidity and chronic morbidity. Mortality is measured in Years of Life years lost (YOLL) and morbidity in RAD. However, there is no evidence for wear PM being associated with chronic mortality (Nerhagen and Mellin, 2010). When estimating the impact the decreased amount of wear PM has on the different endpoints, I applied the assumptions used in previous studies. Nerhagen et al. (2010) argues that the ambiguous results from research on the effect of wear PM on mortality makes a lower estimate zero effect reasonable for acute mortality. As a high estimate, it is assumed that wear PM has the same effect as PM_{10} in general. The results from an evaluation of a charge on studded tires by Nerhagen and Li (2010) concludes that the impact on mortality is a reduction of 5.95 YOLL. The Value of YOLL has been greatly debated. A median estimate of 50.000 euro was accepted to be used for chronic mortality because “this was the estimate unaffected by distributional assumption but however the sum of

75 000, as suggested by Bickel and Friedrich (2005) was estimated to be used for acute mortality at a discount rate of 3%" (Nerhagen et al., 2010 p.26). Using annuity calculations such as: VOLY=(VSL*(1+r)t *r) / ((1+r)t -1), Bickel and Friedrich (2005) estimated an approximate YOLL for Sweden at a discount rate of 4% they came out with a YOLL equal to 100.000euro higher than that recommended in ExternE. Thus using a Mortality reduction of 5.95 the resulting estimated high and low benefit gained by a reduction in acute mortality is

$$B^h_{mort} = 5.95 * 75\ 000 = \text{EUR } 595000$$

At 2006 prices this will give 5.551Million SEKS

And,

$$B^l_{mort} = \text{EUR } 0.$$

When valuing the acute and chronic morbidity, I also used again the results from a previous study by Nerhagen et al. (2010). As a low estimate they assume wear PM has no impact on morbidity. As a high estimate they use the impact estimate for $PM_{2.5}$, suggested by Bickel and Friedrich (2005). This impact estimate is then converted to apply for wear PM by using the same relation used in APHEIS (Air Pollution and Health: A European Information System). The conversion results in an impact estimate of 65 RAD per 1000 adults for a change of 1 $\mu g/m^3$ wear PM during a year. The estimate is used for the entire population, not separating out adults. This may result in an overestimate for the morbidity endpoint, but this effect is expected to be relatively small. Using the RAD valuation suggested in CAFE, where one RAD is valued to EUR 83, they arrive at the marginal morbidity cost for wear PM emissions of EUR 6.35 per kg. The decrease in wear PM emissions due to a charge on studded tires was estimated to 929.5 tons by Nerhagen and Li (2010). Assuming linearity in the cost function, the benefit from the reduction in wear PM is

$$B^h_{morb} = 6.35 \cdot 929\ 500 = \text{EUR 5.9 million}$$

At 2006 prices this will give 55.1Million SEKS

And

$$B^l_{morb} = \text{EUR } 0.$$

Valued in 2006 prices, B^h_{morb} is equivalent to SEK 55.1 million and B^h_{mort} is equivalent to SEK 5.551Million.

5.9 Decreases in Noise

According to Ronny et al. (2011), studies from the European road public administration in Norway uses monetary valuation of noise with respect to the number of decibels (dB). In 2005/6, the value was NOK 238 per dB per person affected per year, or NOK 524 per household which is equivalent to EUR 65.45. PM10 emissions are valued at EUR 51.25 per kg, in application to Norwegian urban areas in general, but these values are possibly higher for larger cities. For the case of Sweden, the entire population for Stockholm has being considered with a total population of 2.1 million inhabitants according to statistics Sweden (2011). Furthermore, data from the Stockholm congestion trial (2006) shows that Out of this number, the trials stated that 50 000 inhabitants are exposed to over 65 dBA of noise. Based on this data, I can now compute the Benefit associated with decrease noise level by taking into consideration the difference between the Acceptable Noise Level (ANL) required for good life and the Exposed Noise Level (ENL) currently faced by the city. Taking this difference for both indoors and outdoors values one can then estimate the Benefit associated with decrease in noise level when studded tires are charged.

According to Wärnsby and Edqvist (2014) in their study of environmental noise in urban areas, they suggested that the following noise target values should not be exceeded when planning or constructing dwellings. They stated that "an equivalent value of 30 dB (A) sound level indoors and 55 dB (A) equivalent sound level outdoors is required for every city". Now, based on studies from congestion trial (2006) Outdoor value for Stockholm is 65dB which affects 50.000 inhabitants. Based on this values one can assume indoors values for Stockholm to be 65dB-(55-30) dB. This gives 40 dB indoor values for Stockholm which is known as the Exposed Indoor Noise Levels for Stockholm. These could be presented on the table below;

Table 6: Calculations on exposed and acceptable noise level

	Outdoor Values	Indoor Values	Outdoors Amount /person (SEKS)	Indoors Amount	Outdoor Amounts Costs (*50.000)	In-doors Amount Costs (*50.000)
Acceptable Noise Level for Sweden	55 dB	30dB	1 009	444	50,450.000 SEK50.5Millions	2,220.000 SEK 2.22Millions

Exposed Noise Level.	65dB	40 dB	8 557	4 720	427,850.000 SEK 427.85M	236,000.000 SEK236Millions.
Surplus or Benefit					377.35Millions SEK	233.78Millions SEK

Source of Data: Wärnsby and Edqvist (2014); Congestion trial (2006); ASEK 5.0

From the table above, I have computed the difference between the indoors and outdoors values by taking into consideration the ANL and ENL. The Surplus or Benefit is the amount gained for the imposition of a charge. This implies that if the government imposes a charge on studded tires, it expects the noise level to fall to the legislated equivalent standard. Therefore the difference between the Exposed Noise Level (ENL) and the Acceptable Noise level (ANL) is the amount to be charged if the more than 50,000 inhabitants are willing to live a noise free exaggerating life. Therefore with this charging policy 377.35MSEK and 233.78MillionSEK will be the amount gained for both outdoors and indoors values for living a healthy noise level life.

5.10 Decrease Road maintenance costs

Furthermore, Angelov (2013) conducted a Cost Benefit Analysis on studded tires in other to investigate whether they entail a net benefit or net costs. When traffic is heavy, rutting or fallow occurs and when this goes too deep, maintenance is required. The following approximations were made as maintenance cost of replacement of wearing by studded tires use in 2001. Since it is considered here as benefit, it is seen as the health benefit that accrues for the imposition of a charge on studded tires in Stockholm city. The author gave estimates to range between *42.8 million sek* to *47.6million seks*. This is the amount gain for charging the use of studded tires.

5.11 Decrease Fuel Usage

According to Anila and Kallberg (1994), "slippery, snowy, and uneven roadway surfaces can increase fuel consumption by 15 percent over bare, dry, and even surfaces. Also according to study conducted by Scheibe (2002), fuel consumption between bare pavement and the most slippery icy road has 4% difference. Based on data presented, he suggested further that Fuel consumption with studded tires was about 1.2 percent higher than that with studless winter tires. Hence, the fuel consumption of studded versus studless tires depends on which tire creates the best traction, which is a function of the roadway condition. With this, he concluded that the relative effects on fuel consumption of snow, ice, and road surface unevenness far outweigh the effects of studs on tires". Now according to Evue (2011), there are total of 4.4 Million cars in Sweden with up to 800.000

cars placed in Stockholm city. With this using data from transek (2010), I computed the change of fuel consumption as a result of studded tires used. This formula has not being derived from anywhere, it has being self-reasoned.

Table 7: Finding the total Distance covered by cars per year in Stockholm

Descriptions	Values
Average Yearly Distant for a Car	1500km/Year
Average Daily Distant Per Car	40km/day
Total Number of Cars in Stockholm city	800.000 Cars
Total Distance KM Covered by all Cars Per Day	32.000.000KM/day
Total Distance KM covered by all Cars in Stockholm Per Year (366)	11, 712, 000.000KM/Year

Source: Electrical Vehicles in Urban Europe (Evue, 2011);

Table 8: Finding Litters of Fuel per KM for Cars Only; Fuel Consumption in Sweden.

Cars on Main Road	1.11 Litters/10KM
Cars in Town	0.71 Litters/10KM
No of Litters of Fuel used to cover the total Distance is;11, 712, 000.000KM /10 x 0.71Litters	831,522.000 Litters of Fuel used by cars in Stockholm annually.

Source of Data: Skånetrafiken (2003).

Table 9: Total Benefit associated with decrease fuel usage

Fuel cost including VAT	7.79 SEKS
Total Expenditure Associated with Fuel usage	7.79*831,522.000 =6,477,556,380 SEKS

Source: Asek 5.0 $_{2010}$ Values

Therefore, 6,477,556,380SEKs is the amount of money spent for fuel consumption in Stockholm for one year. However, this value cannot be considered as the benefit associated with decrease in fuel consumption. This is so because the values have been computed without respect for season. Now considering the study of Scheibe (2002), he stipulated that Fuel consumption with studded tires is about 1.2 percent higher than that with studless winter tires. Now assuming 1.2/100 (0.012).* 6,477,556,380 gives 77,730,676.5SEK which is the amount of revenue saved on fuel usage for charging the use of studded tires in Stockholm city. This implies with this charge the 1.2% increase in fuel consumption will be avoided.

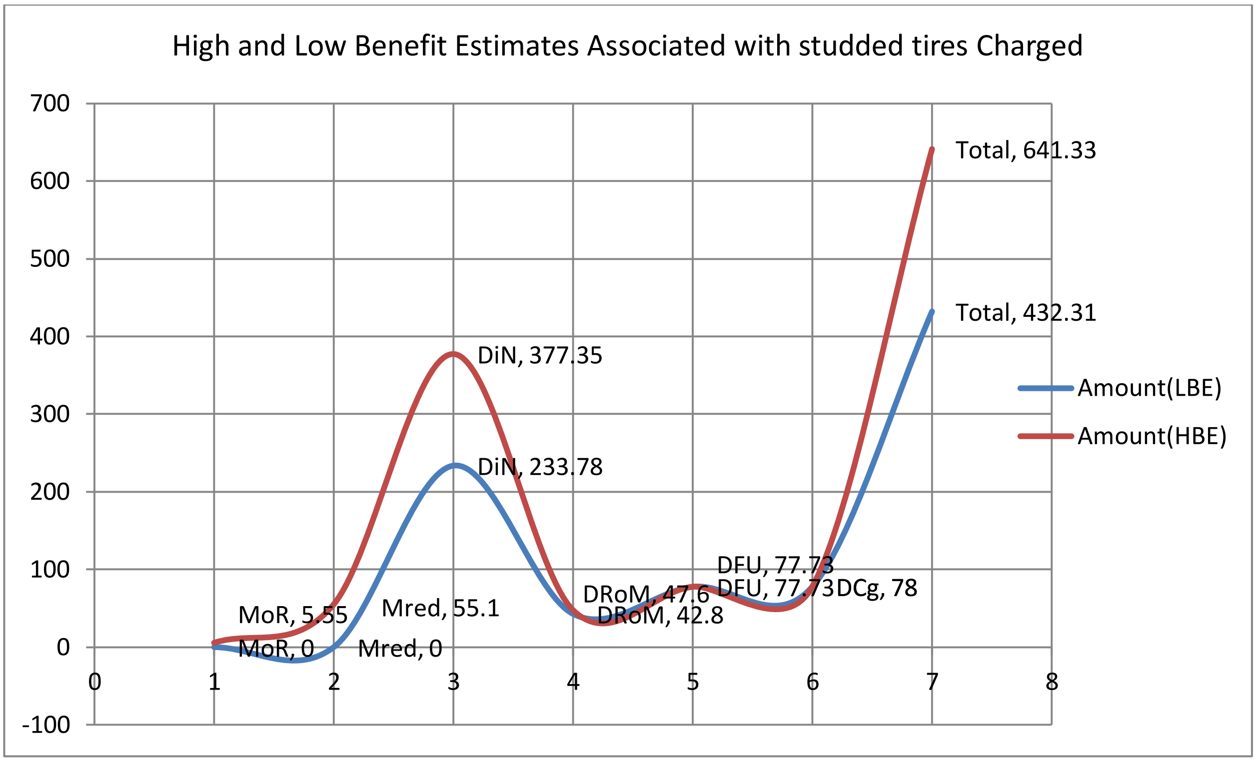
5.12 Decrease congestion.

Vehicle traffic will decline which leads to improved accessibility and when this happen reliability of travel time is achieved. It should be noted that, the value of travel time is different from reliability of travel time. With reliability of travel time, travellers were now more certain that a journey could be made within a given period. When congestion decrease individuals can actually estimate the time required travelling a particular distance. Based on this description, I didn't find any study that estimated the travel time associated with charge on studded tires but I have assumed estimates from the Stockholm congestion charging system. The reason for this is because studded tires will reduce congestion and considering that the study was conducted in the same city, using congestion benefit estimates will give us almost the same results as when studded tires congestion estimates could have resulted to. Based on Eliasson (2009), estimates of a more reliable travel times yielded a sum of 78Million SEKS. This is the benefit associated with decrease in congestion as a result of studded tires charging in Stockholm.

Table 10: Benefit Estimates for the charge of studded tires.

N	Benefit Variables	Amount (Million SEKS).
1	Mortality reduction (MoR)	0 — 5.55
2	Morbidity Reduction (MRed)	0 — 55.1
3	Decrease in Noise (DiN)	233.78—377.35
4	Decrease Road maintenance (DRoM)	42.8 — 47.6
5	Decrease Fuel Usage (DFU)	77.73
6	Decrease congestion. (DCg)	78
T	Total	432.31—641.33

Figure 2; Graphical presentation of Benefit estimates



The graph above captures the disparities between the low and high estimates due to uncertainty.

Table 11: Decision Table/CBA of charging studded tires in the low cost/high benefit scenario

Measures	Amounts (MSEK)
Cost	900.281—1,464.631
Benefit	432.31—641.33
NSB for low and High Scenes	(-467.971) — (-823.301)

The table above is out to answer the first research question of the Net Social Benefit associated with the charge. Going by the figures, we noticed that the NSB is less than Zero for the low and high costs scenarios considering that the cost is greater than the benefits associated with the charge.

6. ANALYSIS OF RESULTS

6.1 Discussions on Estimates

This work examines the cost and Benefits associated with the imposition of charge for studded tires in Stockholm. The work specifically investigates the net social benefit associated with the imposition of such a charge and whether the policy was sensible. For this goal to be accomplished, the research hypothesis assumed that the net social benefit associated with charging studded tires is less than or equal to zero. Contemporary literatures on CBA have being used in this analysis alongside Social Benefit theories such as WTP, Pareto optimum and VSL etc. Based on the cost assessments, variables such as increased travel time, increased accident risk, cost of information campaign, buying of non-studded tires, operation cost and maintenance cost of cars etc. have being quantified in monetary terms. This is because cost benefit analysis requires cost and benefit estimates to be compared so as to determine whether a policy is admissible or not. These estimates have being presented graphically as seen in figure 1 and the result shows the cost of maintenance to have higher upper bound values (520MSEK) followed by the cost associated with the purchase of non-studded tires (496.3MSEK). It should also be noted that the cost of information campaign and the cost of initial investment are onetime costs from which the present value annuity is being computed. The cost of operating the system is a yearly continuous issue but in this study the operational cost of a similar charge system-the Stockholm congestion charge has being used as a similar cost for the operation costs for charging studded tires. This was considered as an assumption since no precise study has investigations on that. The implication of these different costs will be discussed on our sensitivity analysis below.

Also, estimates of Benefits associated with the imposition of charges for studded tires used in Stockholm were being made. It should be noted that the focus is to examine health impact of such a policy. Therefore variables have being chosen to suit the health outcome effects. Mortality and Morbidity were considered as outcomes of decreased particle matter in the atmosphere and for decreased congestion, I have evaluated it in terms of declined in traffic witness by improve in reliability. In this scenario estimates from Eliasson (2009) resulting to 78million SEKS were assumed. I didn't find any study which clearly stipulate decreased in fuel consumption like the reliability estimate above. As a result, I used simple arithmetical reasoning combining studies to come up with the required quantity of 77.73Million SEK. Decrease in road maintenance was computed for indoors and outdoors values and for decreased in road maintenance the study of Angelov (2003) have being used. All these were presented in figure 2 showing high and low benefit scenarios. A total of 6 Cost and benefit estimates were derived respectively and all the variables were defined qualitatively before making quantitative assessments.

6.2 Decision, Sensitivity and uncertainty analysis.

In this sections I examined how the result relate to expectations, clearly stating why they are acceptable and how they are consistent or fit in with previously published knowledge on the topic. Based on the result, the Net social benefit associated with the imposition of a charge on studded tires in Stockholm is negative i.e. (NSB<0). This agrees with the Null Hypothesis meaning that when taking such venture the Cost incurred will be greater than the Benefit. It is important to note that all values have been computed annually even though at different prices. The first sensitive issue to highlight here is buying non studded tires and the cost of maintenance which have so high upper bound values. The two costs structures made more than ½ of the total cost. This could be an overstatement as it shows that the benefit accruing from this program can be used alone to cover the costs of these two variables. I have also considered from assumption that over stirring will leads to engine pressure. It is not always the case as this will depend on the horse power of the car. Not every person will also repair their cars; some may abandon them or buy new ones. Furthermore, the results may not be consistent with other research findings especially when the winter turns to be mild without snow. Also, if these costs are covered by insurance, then individual disposable income wouldn't be affected and therefore individuals would not have to pay as this much for maintenance. These two costs values may not have any direct impact on health even though required to know how sensible the policy was. Also despite the fact that the cost of the information campaign and the cost of initial investment are one-time cost, the result will not change if they are disregarded of and thus there is no need to extend the time horizon of the calculation, since no costs or benefits enter or exit over time. Thus the NSB will still be less than zero and it will not still change the conclusion.

On the benefit sides, reduction in morbidity and mortality rates stands as the main benefit values as far as health impact is concerned. Their estimated values stand at 0-55 Million SEKS for low and high scenes. If congestion charges are increased, the amount of vehicle km driven in the Stockholm region each year will fall and these high values of noise will be down sized. When this happen Mortality and Morbidity will fall. This means the estimates of benefits could be affected by costs in the light of when congestion charges are imposed. In this work congestion has been measured but to avoid double counting, I have not measured the variable directly but used some indicators like reliability to weigh the benefits of decongestion. Adding to this, in a previous CEA on different policies to increase the air quality in Stockholm, the debate has being on which outcome measure to be used. If the outcome measure used was the level of PM_{10} emissions the policy was chosen, while if the outcome measure used was YOLL it was not. Based on the findings in this paper, CEA using YOLL as the outcome measure is insufficient, considering morbidity and RAD is the most important cost of wear PM. YOLL is chosen with the argument that mortality is the most important health endpoint in terms of costs, but the studies covered in this paper suggests that this is not the case for wear PM. As a result, policies aimed at reducing road wear PM will always be undervalued in a CEA using YOLL as the target. On the flip side, one can argue that using level of emission as the target (e.g. the ones given in the air quality guidelines of WHO) will overvalue such policies, due to wear PM being less harmful per unit compared to the finer PM also included in PM_{10}. Finding an appropriate outcome measure for a CEA is thus difficult. Being able to correctly value different health endpoints in monetary terms and performing a CBA could be a solution to this problem, while at the same time allowing for comparisons between different sectors of the economy. However, this will require future research on the health impacts of different PM in general, and more research on how correctly value morbidity in Sweden is particular. As has been shown in this study, there is currently a great amount of uncertainty in those areas.

6.3 Conclusion, Recommendation and Areas of further research

6.3.1 Conclusion

The policy investigated in this paper is a charge on studded tires in the Stockholm region aiming at reducing the use of studded tires by 50%. The charge must be accompanied by an information campaign to create awareness among the citizens of Stockholm. The main finding of the paper is that the CBA of such a policy in the low cost/high benefit scenario, results in a negative net social benefit. This agrees with the research hypothesis. In this case, the government can not involve in the project considering the negative net social benefits.

6.3.2 Recommendations

Based on the conclusion above, I recommended that, the government should not resort to this kind of charging system as a means of environmental regulation. Instead other methods of regulations should be adopted instead of a charge considering that it will be inefficient proved by the negative net social benefits as seen above. Charging studded tires will require high cost due to the technological requirements and moral hazards due to asymmetric information associated with people's action. An ambient charge could have being another good action but it will be bias considering that PM in the atmosphere in Stockholm may also be caused by vehicles entering into the city which necessarily may not be based in Stockholm. Therefore I recommend that the government should continue with the legal control system (police check) ensuring that after winter season, all car owners should not continue with their studded tires which increase PM in the atmosphere due to friction. Secondly, the government should put a total ban on studded tires use with the possibility of ensuring that there are stand by snow clearing machines to clear snow in wintry areas of the city. Also, they can levy heavy fine on anyone caught with studded tires on densely or congested populated areas in the city. With this, the health problem of particle matters and its consequences of death will be solved.

6.3.3 Limitations and Area of further research

It would be sensible to mention some few limitations of this work and the gap that should be covered in case of further research. I have drawn the conclusion that the project will not be profitable based on one technique, the NSB which has its own limitations. Just like the Stockholm congestion system, I noticed that it was not a worthwhile investment in the short run but in the long run it may be profitable since it has a cost benefit ratio of close to 3:1. Also in the study not all the costs and Benefits valued has direct impact on health, even though they were useful in investigating the authenticity of the policy. In the analysis I neglected some of the potential costs and benefits of the policy, but based on the results and assumptions from previous studies, I have reason to believe that those would only have a small impact on the resulting CBA. It should be noted that the charge may have unwanted re-distributional effects on households, but also that the income from the charge has been suggested to be used to improve winter road maintenance which could possibly improve the efficiency of the policy. Interesting areas of research could be Areas of further research could be on the health impacts of different PM in general, and more research on how correctly value morbidity in Sweden is particular. Also investigations could be conducted on how improved road maintenance can impact the cost of the increased accident risk from imposing the charge on studded tires.

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