Lund University Master's
Programme in Environmental Science

The Human Health Cost of Development: A case study of the interaction between global warming, ground-level ozone, human health and regional development in Skåne, Sweden

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Summary

It is widely acknowledged by the scientific community that global warming is a reality. But how will this phenomenon affect people with regards to their health? In light of this question, this thesis takes a sustainability approach to evaluate the vulnerability of Skåne, Sweden's southernmost county, to impaired health due to global warming, ground-level ozone and rapid regional development. In order to accomplish this, a theoretical framework is established to support and analyse the following main concepts. Firstly, the concept of the enhanced greenhouse effect and its anthropogenic causes are evaluated and supported by scientific research from a variety of sources, including but not limited to the IPCC. Secondly, the formation of ground-level ozone and the enhancing effects of global warming/increased temperatures are assessed. Finally, ozone[1], its effects on health and ground-level guidelines are discussed.

The second section covers current and past levels of air pollutants (ozone and ozone precursors) and temperature increases in Skåne spanning nearly 20 years. It also discusses reasons for growth/development in the region, past and predicted transportation increases and infrastructural plans proposed to deal with this. In the final section, this thesis synthesizes all of these concepts using a causal-loop diagram, which shows the system dynamics. This focuses primarily on the shortcomings of regional development with regards to air pollutant production. It also offers a holistic/systems dynamic perspective of the issues involved, including the relationships between the social/health, environmental and economic factors. In conclusion, suggestions are given, particularly from a transport infrastructure perspective, to lessen possible exacerbation of transport-induced ground-level ozone production.

[1] For the purpose of this thesis, ground-level ozone and ozone are synonymous

List of figures, tables and equations

Abbreviations and Acronyms

Regional Infrastructural Transportation Plan (RTI-Plan)
Volatile Organic Compounds (VOCs)
Statistiska centralbyrån/Statistics Sweden (SCB)
World Health Organization (WHO)
Intergovernmental Panel on Climate Change (IPCC)
United Nations (UN)
General Circulation Model (GCM)
World Commission on Environment and Development (WCED)
European Environmental Agency (EEA)
Special Report on Emission Scenarios (SRES)
European Union (EU)
Causal Loop Diagram (CLD)
Forced Expiratory Volume Per Second (FEV_{-1})

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Chapter 1: Introduction

1.1 General Introduction

Over the past three centuries, the world has undergone a period of rapid industrialization and development. In many ways this period has bestowed upon the world a variety of benefits such as increases in information and its accessibility through the world wide web, faster ways of communication through the telephone and internet and, more specifically to this thesis, improvements in the way we transport ourselves and our goods. The latter has made the world a smaller place, allowing more integration of nations within their respective economies, education systems and political systems. On a much smaller and local scale, improvements in transportation have led to increased effectiveness and productivity amongst respective communities, allowing national business centres (cities) to develop supported by a somewhat constant inflow and outflow of workers. It has also increased the accessibility of education to those living outside of walking or biking distance from schools and institutions of higher education. In regards to commerce, improvements in transportation allow business to adjust and adapt more quickly to their customers demands by maintaining a relative constant stock of their respective products. Unfortunately, increases in transportation have the negative impact of increased air pollution.

Over the past three hundred years, our growth in transportation has been followed by a subsequent growth in emissions especially from cars and trucks. Many of these emissions have produced a range of negative effects such as global warming and air pollution-induced respiratory problems. Carbon dioxide, one of the main compounds in motor vehicle emissions, has the capability of contributing to the greenhouse effect and consequently raising the temperature of the Earth's surface. This increase in temperature can have effects on other pollutants such as NO_x. Under conditions of intense sunlight, high levels of NO/NO_2 and the presence of volatile organic compounds (VOCs), increased temperatures contribute to a rise in ozone (O_3) formation. Ozone in turn can have serious effects on healthy, but even more so on allergic individuals by exacerbating sensitization to allergens or by lowering their forced expiratory volume per second (FEV_{-1}). Increased cases of allergic reaction carries along with it possible increased needs for medical care creating either a financial drain on the individual in question or on society in social welfare systems such as exist in Sweden.

1.2 Geographical location and important information

Figure 1: Map of Skåne

Source: (SuperTravelNet, 2003)

Surrounded by the Baltic Sea, Skåne is the southernmost province of Sweden. It occupies an area of 11,027 km^2 (10,983 km^2 land area) with approximately 100 inhabitants per km^2. The population as of January 1, 2003 was its highest ever (1,145,090 people) signifying a continuation of its trend of increase. Skåne contains four major cities: Malmö (265,481 inhabitants), Helsingborg (119,406 inh.), Lund (100,402 inh.) and Kristianstad (74,951 inh.). Its annual average temperature ranges from 0 to -5˚C in the winter to 16˚C and above in the summer (Swedish Environmental Protection Agency, 2001, p. 27).

1.3 Statement of Problem/Purpose of Study

Global climate change is expected to have significant effects on Northern Europe. Some of these effects have already been observed in the form of increases in precipitation ranging from 10% to 50% and overall temperature increases of 0.8ºC this past century with the most significant increase from 1970 to present day (Intergovernmental Panel on Climate Change, 1998, p. 157) Expected temperature changes in the region range from winter temperature increases between 2.5-4.5ºC and summer temperature increases up to 4.5ºC in a 2XCO_2 climate (IPCC, 1998, p. 158). These temperature increases can have significant implications for human health. As temperatures exceed 26ºC, ground-level ozone formation increases and this relationship increases significantly at temperatures above 32ºC (IPCC, 1998, p. 311). Ozone has the capability of causing a variety of respiratory problems such as increased severity of hypersensitivity and has also been linked to increases in hospital admissions and premature death. Moreover, increases in respiratory illness can lead to increases in medical cost either for individuals directly or indirectly through social welfare tax. This situation is believed to be a relevant topic in the Swedish county of Skane for a number of reasons. First, it lies in Northern Europe thereby making it susceptible to the climate change mentioned above. More importantly, Skane is currently a region of high interest and development attracting more and more people to the region annually. As the population and regional development increases, so can the amount of pollutants emitted into the atmosphere thereby challenging the net benefit and stability of growth.

1.4 Aims and Objectives

The aim of this study is to access the vulnerability of the county of Skåne in regards to global warming and impaired health through the perspective of sustainability. This thesis will take into consideration how the current speed and manner of growth coupled with current environmental preservation programs and transport infrastructural plans will result in the future. More specifically, this thesis will,

- Identify the scientific basis of global warming
- Exhibit the relationship between global warming and ground-level ozone
- Highlight ozone-induced health effects
- Predict level of vulnerability of Skåne to increasing health effects due to growth
- Construct a theoretical model showing the interactions between the social, economical and environmental forces in operation in Skåne.
- Evaluate current transportation solution to reduce motor vehicle emissions.

1.5 Methodology

Acquisition of relevant information will come from a variety of sources including, but not limited to literature from the Lund University library, Lund University Hospital library, articles from Lund University's electronic database (ELIN) and various Internet sources such as the IPCC, UN and WHO. Statistical information about Skåne will be obtained primarily from the Swedish Bureau of Statistics (SCB) and various Swedish authorities. I will also consult experts in the field of global climate change and ground-level ozone-induced respiratory disorders in the region.

1.6 Scope and Limitations

This thesis aspires to take a sustainability approach at accessing the vulnerability of Skåne, Sweden to the human health effects of increased ground-level ozone due to global warming. Unfortunately, there are some concerns that, although extremely relevant, are beyond the scope of this type of study. Specific monetary values for asthmatic hospital visits and medication were unable to obtain and would require a detailed analysis that could easily make up its own separate thesis. Furthermore, improvements in medical treatment and the economic effects that they might entail are very difficult to predict and therefore are omitted from this study.

In regards to transportation, the modes of transportation that are discussed are rail and road transport. This does not imply that other modes such as air and sea transport's emissions are insignificant, but rather not a significant part of Skåne's regional transport infrastructure plan. Improvements in traditional engine construction are also not discussed due to the uncertainty and time of implementation. This thesis is primarily an analysis of vulnerability if conditions continue as they are today.

Growth, which is hypothesized as one of the main contributors to increased air pollution, is discussed primarily on a Skåne-specific basis. This is a conscious omission of the influence of emissions due to European growth on air quality in Skåne. This does not in the slightest suggest that European growth has little effect, but rather an attempt to analyse the effect of local emissions.

Finally, the actual percentage increase in ground-level ozone that can be attributed to increased temperature (i.e. global warming) is not discussed. This reaction is very complex and would require a great deal of research and resources to determine these actual values. This thesis merely attempts suggest that global warming can increase the formation of ground-level ozone and thus exacerbate and/or cause respiratory illnesses.

1.7 Sustainable Development

As stated in the Bruntland report (1987),

> "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (World Commission on Environment and Development, 1987)"

This concept is made more human specific in Rio Declaration Principle 1, stating that,

> "Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony in nature. (as cited in World Health Organization, 1997, p. 5)"

But what does this really mean and how is this exactly accomplished? According to a statement put out by the UN at the World Summit on Sustainable Development 2002 in Johannesburg, this is a very complex issue dependent on the characteristics of the region in question, but the basis in building a truly sustainable way of life must consider three key factors: economic growth and equity, conserving natural resources and the environment and social development. To some, this can be an alarming concept since traditionally economic prosperity and environmental concern is thought to result in a zero-sum trade-off (Weale, 1992, p. 31), but according to the Bruntland report, continued economic development is essential for environmental protection (Connelly and Smith, 1999, p. 57). This notion has faced some amount of criticism. One major problem is that it perhaps does not address the right issue. It usually goes along the lines of cleaner production and the reduction of waste and emissions, but the underlying problem is that regardless of the successfulness of cleaner production schemes, an increase in production will always lead to an increase in waste and emissions in the long run. According to Connelly and Smith (1999) p. 59, sustainable development calls for a reinterpretation of needs and it requires strong control of markets in order to, "…safeguard the environment and intra- intergenerational obligations." In light of the difficulty to define sustainable development in the presence of society's ever-increasing desire to expand, environmentally sound technologies and policies should be coupled with a serious investigation into our needs with a more than likely subsequent reduction in consumption.

Chapter 2: Global Climate Change Theory

2.1 Climate changes since pre-industrialization

Over the past three centuries, the temperature of the Earth has been increasing at a rapid pace with tremendous increases during the past one hundred years. According to the Working Group I of the IPCC, "…the globally averaged surface temperatures have increased by 0.6 ± 0.2ºC over the 20th century (see figure 2)." They have also projected, from models using the IPCC Special Report on Emission Scenarios (SRES), that the globally averaged surface air temperature will warm by 1.4 to 5.8ºC by 2100 compared to average temperatures for 1990 (IPCCb, 2001, p.3). In Europe alone, the average increase in annual temperature has been in the range of 0.8ºC during the 20th century (IPCCb, 2001, p. 646; ECSN, 1995; Beniston et al., 1998; EEA, 1998). This warming trend appears to be strongest in the winter than in the summer (IPCCb, 2001, p. 646; Maugeri and Nanni, 1998; Brunetti et al., 2000) except for the Fennoscandia region where the warming is opposite between 1910-1995 (IPCCb, 2001, p. 646; Tuomenvirta et al., 1998). During the 1990s, Europe has seen its most rapid increase in temperature with increases in yearly means of 0.25-0.5ºC with respect to the long-term average (IPCC, 1998, p.157). GCM-projections suggest that increases in the northern latitudes of diurnal temperature will be between 2.5-4.5ºC and 1.5-4.5ºC for southern Europe in the winter and an upper limit of 4.5ºC increase for both regions during the summer in a 2XCO_2 climate (IPCC, 1998, p. 158). In regards to European precipitation trends, studies show that during the 20th century, Northern Europe has become wetter (10-40%) and Southern Europe has become drier (around 20% drying) (IPCCb, 2001, p. 646; New et al., 1999). Looking at Sweden, the mean average temperature is expected to rise by 4ºC by the year 2100 whereas there will be a 4-5ºC rise in winter temperatures and a 2-3ºC in summer temperatures. In regards to Swedish precipitation, it is expected to rise in northern Scandinavia and lower in the south-eastern parts of Sweden (Swedish EPA, 2001, p. 145)

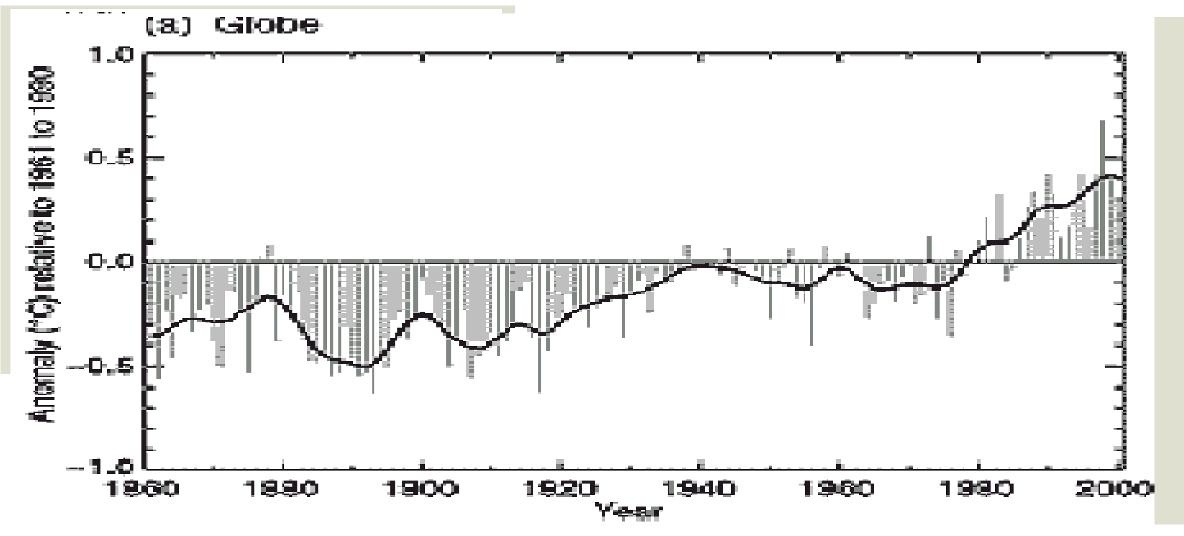

Figure 2: Annual anomalies of global average land-surface air temperature (°C), 1861 to 2000, relative to 1961 to 1990 values.

Source: (IPCCd, 2001)

Some have attributed this rapid increase to natural changes, but since this phenomenon has occurred over such a short period of time, many scientist have conclude that human activity has been the main culprit in this ever growing predicament.

2.2 The Anthropogenic source of global warming

Since the 19th century, the concept of greenhouse gases and their effects have been known, but not until 1896, has the concept been applied in a global perspective. This concept of global warming due to the greenhouse effect was first mentioned by the Swedish scientist, Svante Arrhenius. He calculated that if carbon dioxide levels in the atmosphere doubled from current levels of his time, the global average temperature would increase by ± 5 – 6 °C. This value was actually close to the values of our present understanding and is not too far off from the reality of the situation (Houghton, 1998, p. 12). Since industrialization, CO_2 levels in the atmosphere have been increasing at a rapid and alarming rate. Between the years of 1700 and present day, the levels of CO_2 have increased by around 30% shifting from 280 ppmv to 360 ppmv (Houghton, 1998, p. 24). This is a very significant figure since CO_2 is responsible for 50-60% of global warming attributed to human activity since pre-industrial times (Miller, 2000, p. 500). The majority of this human produced CO_2 is produced either through the burning of fossil fuels (70-75%) and land clearing and burning (20-25%). Most of the CO_2 produced through the burning of fossil fuels is created by the burning of coal, but motor vehicles are rapidly narrowing the gap between the two. As CO_2 is created, it stays in the atmosphere anywhere from 50-200 years (Miller, 2000, p. 500). Despite the obvious importance CO_2 has in regards to global warming, there are also other gases that play a role in the greenhouse effect such as water vapour (H_2O), methane (CH_4), nitrous oxide (N_2O), ozone (O_3) and synthetic compounds such as chlorofluorocarbons (CFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6):

- H_2O is actually the prime heat-trapping gases due to its high concentration in the atmosphere (1-5%) relative to CO_2 (0.036). Human input has little effect on its heat-trapping ability since its concentration is already high. (Miller, 2000, p. 501).

- Methane (CH_4) is a gas originating from the anaerobic breakdown of dead organic materials in moist places (e.g. swamps), the production and use of oil and natural gas (especially leaks) and the incomplete burning of organic materials. It last in the troposphere for 9-15 years and traps 20 times more heat than a CO_2 molecule. Since 1750, there has been a 151% increase and this value is continuing to increase although the annual growth in concentration slowed and became more variable in the 1990s compared to the 1980s. Around half of current emissions of CH_4 are attributed to anthropogenic sources.

- Nitrous oxide (N_2O) is a gas created from nylon production, the burning of biomass and nitrogen rich fuels (coal), catalytic converters and the breakdown of nitrogen fertilizers in soil, livestock waste and nitrogen contaminated groundwater. It last in the troposphere for 120 years and traps 200 times more heat than a CO_2 molecule. Since, 1750, N_2O has increased by 17% and continues to increase. Close to a third of current emissions originate from anthropogenic sources.

- Ozone gas (O_3) comes primarily from interactions between precursor molecules nitric oxide (NO), nitrogen dioxide (NO_2), oxygen (O_2) and sunlight, whereas, NO is mainly emitted from motorized vehicle exhaust. Since 1750, tropospheric concentrations of O_3 have increased by 36% and this increase is primarily due to increased automobile emissions.

- Chlorofluorocarbons (CFCs) are a compound that is mainly emitted from leaking refrigerators and air conditioner, the production of plastic foams, aerosol propellants and the evaporation of industrial solvents. Not only do they have the ability to trap heat more than 1,500 to 1,700 times a CO_2 molecule in the troposphere, but they also deplete the ozone layer in the stratosphere. Fortunately, this compound is being phased out.

- Perfluorocarbons (PFCs), a synthetic compound similar to CFCs, is emitted during aluminium production and remains in the atmosphere anywhere from 2,000 to 50,000 years (Miller, 2000, p. 500; IPCCa, 2001, p. 7).

The above-mentioned compounds do pose a serious threat to global warming due to the fact that they trap much more heat than CO_2, but the total of their concentrations only add up to 36%. “The much larger input of CO_2 makes it the most important greenhouse gas produced by human activities (Miller, 2000, p. 501).”

2.3 The mechanism of the greenhouse effect and global warming

As stated in Houghton 1998, p. 10

> “The basic principle of global warming can be understood by considering the radiation energy from the sun which warms the Earth’s surface and the thermal radiation from the Earth and the atmosphere which is radiated out to space. On average these two radiation streams must balance. If the balance is disturbed (for instance by an increase in atmospheric carbon dioxide) it can be restored by an increase in the Earth’s surface temperature.”

This balance can be disturbed by increasing concentrations of greenhouse gases and this is known as the enhanced greenhouse effect. As there concentrations increase, the amount of thermal radiation absorbed in the troposphere and radiated back down to the Earth’s surface increases. Another, and even more important, mode of heat transfer associated with the greenhouse effect is convection. As sunlight warms the surface of the Earth, the air closes to the surface warms up. The warm air then begins to rise because of its lower density and then cools and expands as it ascends. During this process, cooler air at higher altitudes descends thereby creating a situation of convective equilibrium (Houghton, 1998, p. 13). The reason why the greenhouse gases emit the majority of the radiation that they absorb is because it is a process dependent on temperature. The colder it is, the less radiation they emit. So, most radiation will be directed towards the Earth’s surface instead of out in space. Clouds also play a role in this process of absorbed and reflected radiation, but their net influence actually contributes to cooling the Earth’s surface (Houghton, 1998, p. 15). Some particles emitted from human activities, such as sulphates and soot, can also have a net cooling effect on the Earth’s surface by way of reflecting more sunlight than they absorb. Such cooling effects, either by clouds, particles or a combination of the two is called radiative forcing (Houghton,

p. 39; IPCCa, 2001, p. 7). In conclusion, the greenhouse effect consists of the blanketing effect of the greenhouse gases and the atmospheric phenomenon of convection.

2.3 Global warming and its effects on pollution

Studies have shown that increases in temperature can have an effect on the production and increase concentration of photochemical oxidants and this can have negative effects on the human respiratory system (IPCC, 1998, p. 310; Shumway et al., 1988; Schwartz and Docker, 1992; Dockery et al., 1993; Katsouyanni et al., 1993; Pope et al., 1995; Phelps, 1996). In particular, ozone shares a non-linear relationship with temperature whereas below 22-26 ˚C there is no effect and above 32 ˚C there is a strong positive relationship. There are also other factors aside from temperature that play a role in local ozone formation and concentration such as wind speed, relative humidity, and sky cover (IPCC, 1998, p. 311; Wakim, 1990; Korsog and Wolff, 1991) not to mentioned wind direction, dew point temperature, sea-level pressure and precipitation (IPCC, 1998, p. 311). Despite the complexity of the issue, studies done in New York, the Midwest and Southeast United States and San Francisco under constant weather conditions show that an 4˚C increase in temperature in these areas can lead to 4%, 8% and 20% increase of ozone concentrations respectively (IPCC, 1998, p. 311; Smith and Tirpak, 1989).

Chapter 3: Ground-level ozone and its effects on human health

3.1 Ground-level ozone formation

Despite the fact that ozone in the stratosphere is considered to be essential to human survival, ozone in the atmosphere's trophospheric layer can be extremely harmful at high concentrations. These effects range from lower concentration-induced tree foliage damage and increased susceptibility to stress to higher concentration-induced lung function reductions in humans as well as other animal species (Miller, 2000, p. 480). For this reason, the creation and destruction of ozone is of paramount importance to our society.

Ground-level ozone is a photochemical oxidant indirectly produced primarily by humans either through industry or the transport sector. The reaction begins with the release of nitric oxide (NO) from the burning of fossil fuels into the atmosphere usually deriving form automobile exhaust. This nitric oxide is subsequently converted into nitrogen dioxide (NO_2) through a 1:1 interaction between ozone (O_3) in the presence of sunlight or a 2:1 interaction with molecular oxygen (O_2) (National Academy of Sciences, 1977, p. 19; Miller, 2000, p. 476) (see figure 3).

$$\text{a. } O_3 + NO \xrightarrow{h\bullet\ [2]} NO_2 + O_2$$

$$\text{b. } 2NO + O_2 \rightarrow 2NO_2$$

Figure 3: Formation of NO2

[2] h● = light

NO_2 can then be broken apart by light (i.e. photolyzed) resulting in an available oxygen atom that reacts with O_2 producing ozone (O_3) (Arey, 2000, p. 59) (see figure 4).

$$NO_2 + h\bullet \rightarrow NO + O(^3P)$$
$$O(^3P) + O_2 \rightarrow O_3$$

Figure 4: Formation of ozone

In other words, the local ambient air concentrations for nitric oxide, nitrogen dioxide or ozone are dependent on the relative concentrations of the other two pollutants. In regards to ozone, equation 1 exhibits that ozone concentration stability is a direct function of the [NO_2 : NO] ratio (National Academy of Sciences, 1977, p. 19).

$$O_3 = \frac{k_1[NO_2]}{k_3\,[NO]}$$ [3]

Equation 1: Ozone concentration stability equation

As long as the ratio remains 1:1 the ambient ozone concentration remains low, but if the NO_2 concentrations starts to surpass NO concentrations the local O_3 production will increase. The later occurs in the presence of hydrocarbons, aldehydes, or other reactive contaminants. These contaminants have the capability of forming peroxy radicals that oxidize the nitric oxide creating nitrogen dioxide without ozone involvement and thus result in ozone concentration increases. Unfortunately, many of these compounds, otherwise known as volatile organic compounds (VOC) are also produced from vehicle exhaust (Bylin, 2000, p. 78). Days of strong sunlight and heat can further exacerbate the photolyzation of NO_2 to form O_3 (Miller, 2000, p. 476). Moreover, studies done by Olszyna, et al, 1997, state that, "higher temperatures enhance biogenic hydrocarbon emissions and increase the abundance of NO_x by thermal decomposition of the peoxyacetyl nitrate (as cited in Lin, Jacob, Fiore, 2000)." The same study (not to mention studies done by Jacob, et al, 1993 and Smith and Adamski, 1998) also suggests that, "temperature is a surrogate for clear skies and stagnation (as cited in Lin, Jacob, Fiore, 2000)." As ground-level ozone forms much of it drifts out to the outlying areas around cities. The reason for this is due to the less traffic in these areas, which consequently results in less NO or CO formed to consume or breakdown O_3 molecules. In general, the countryside outside of major cities has a 20% higher concentration of ozone than within the urban area (Bylin, 2000, p. 78).

3.2 Effects of Ozone on Human Health

Ozone has some very serious effects on the respiratory system and particularly individuals suffering from asthma and chronic obstructive pulmonary disease (COPD) (Van Loveren, 1996, p. 163). According to Antico, 2000, p. 323, " Studies of controlled exposure of asthmatics or rhinitics to O_3, NO_2 or to a combination of NO_2 and SO_2 show an increase in the airway response to inhaled allergens, (which last for 48 hours) (Molfino et al., 1991; Devalia et al., 1994; Tunnicliffe et al., 1994; Jorres et al., 1996; Ruxznak et al., 1996)." In addition, findings from Guidelines for Air Quality, WHO, 2002, p. 37, claim that, "O_3 toxicity occurs in a continuum in which higher concentrations, longer exposure duration and greater activity

[3] k_1 represents the rate of NO_2 disassociation by sunlight and k_2 represents the rate constant for the reaction.

levels during exposure cause greater effects." The specific way ozone affects the respiratory system is rooted in cell damage.

Ozone is responsible for significant cell damage on the upper and lower airways epithelial cells, which can lead to reductions in mucociliary activity in vitro (Devalia et al., 1993a, 1993b; Bayram et al., 1995) and in vivo (Helleday et al., 1995). This effect is further exacerbated during exercise since exercise enhances airway permeability (Broeckaert, Arsalane, Hermans, 1999). In asthmatic individuals, the effects are even more significant (Bayram et al., 2002).

3.3 Hypersensitivity

Allergic responses, or hypersensitivity is generally divided into four separate types, whereas type I is associated with an immediate reaction caused by IgE-antibodies due to inhaled allergens. Around 25% of the population express increased levels of IgE-antibodies. The reason why some people produce an IgE response to certain allergens instead of an IgG, which is the most abundant and the most adaptable of the immunoglobulin classes, is unclear. The process of allergic reactions begins with the deposition of a limited amount of allergen on the mucosal epithelium or the skin. Next, specialized cells such as Langerhans cells or other antigen presenting cells ingest the allergen. Within the antigen presenting cell the allergen is cleaved by proteolytic enzymes breaking it down into small peptides. These peptides are then presented on the surface of the cells to helper-t cells (TH0) that later differentiate into TH2 helper-t cells. These cells begin to produce cytokines IL-3, 4,5,10 along with many others and thereby stimulating the isotype switching of IgM to IgE on B-cells bearing newly formed IgM (Roitt and Rabsen, 2000, p. 123). There is also some research that suggests that this switching can also occur spontaneously without cytokine influence and without parallel production of IgM. (Niederberger, V., et al, 2002; Steinberger, P., et al, 1995; Dolecek, C., et al, 1995).

Two examples of diseases caused by type I hypersensitivity are asthma and allergic rhinitis (hay fever). Asthma is characterized by increased responsiveness of the tracheobronchial tree to a variety of allergens resulting in airway inflammation and reversible airway limitations. However, asthma may also be non-allergenic with no known sensitization to allergens. Allergic rinitis is characterized by increased responsiveness of the membranes of the nose and eyes with symptoms of congestion, itchiness and sneezing. Like asthma, allergic rhinitis involves localized IgE-mediated anaphylactic reactions to extrinsic allergens such as grass, pollens, animal danders, and the feces from house dust mites, etc (Roitt and Rabsen, 2000, p. 125).

3.4 Basis for human health guidelines

As stated before, ozone has some very serious effects on human health causing a variety of respiratory problems. The degree of severity of ozone inhalation is greatly linked to the amount of ozone in the atmosphere and the length of time these conditions persists. For this reason, the World Health Organization (WHO), the European Union (EU) and its respective countries (in this case, Sweden) have established some guidelines to guard against negative impacts on human health.

Many studies have been conducted in order to determine at what level ozone pollution can lead to significant impairment of pulmonary function for different age groups and for the most sensitive individuals in the population. Beginning with healthy exercising adults, acute single exposure concentration experiments have been conducted in ranges of 160 to 1000 µg/m^3. These experiments have shown that exposure to ozone of normal adults during moderate-to-heavy exercise for a duration of 1 to 3 hours causes a decrease in forced expiratory volume (FEV_1) at ≥ 240 µg/m^3, an increase in airway resistance at ≥ 360 µg/m^3, a decrease in forced vital capacity (FVC) at ≥ 240 µg/m^3 and an increased respiratory frequency at ≥ 400 µg/m^3. In addition, exposure to ozone of normal adults during moderate exercise for 4 to 8 hours caused a decrease of FEV_1 (≥ 160 µg/m^3), a decrease of FVC (≥ 200 µg/m^3), and an increase in airway responsiveness (≥ 160 µg/m^3). The combined result of such experiment suggest that health effects are "statistically significant at 160 µg/m^3 for 6.6 hours of exposure whereas the most sensitive subjects experienced a >10% functional decrease within 4 to 5 hours (ODRSD, 1999, p.50).

Children and young people represent a special group due to their increased susceptibility to ozone exposure. Studies have shown that similar pulmonary function reductions occur at levels lower than healthy exercising adults (120-240 µg/m^3 and higher). Furthermore, at exposure concentrations of 280-340 µg/m^3 for several hours, children or asthmatics experience changes in pulmonary function. This increased effect on children in comparison to adults is primarily due to their overall higher intake of ozone and other air pollutants. This is due to three major reasons. First, they have a higher basal metabolic rate that results in a higher breath volume per minute and a higher breathing frequency. Secondly, their respiratory tract is underdeveloped making it more susceptible to inflammation. Thirdly, their immune system is not fully developed and is under more stress than adults (ODRSD, 1999, p. 50). Other sensitive groups are patients with lung disease, smokers and individuals exercising during peak ozone concentration hours (ODRSD, 1999, p. 51).

In regards to respiratory symptoms, especially coughing, their manifestation has been associated with levels as low as 300 µg/m^3. Not only has ozone level concentrations been linked to respiratory symptoms, but also to increased hospital admissions for respiratory causes and symptom exacerbation among adults and asthmatics (see figure 5 and 6) (ODRSD, 1999, p. 50).

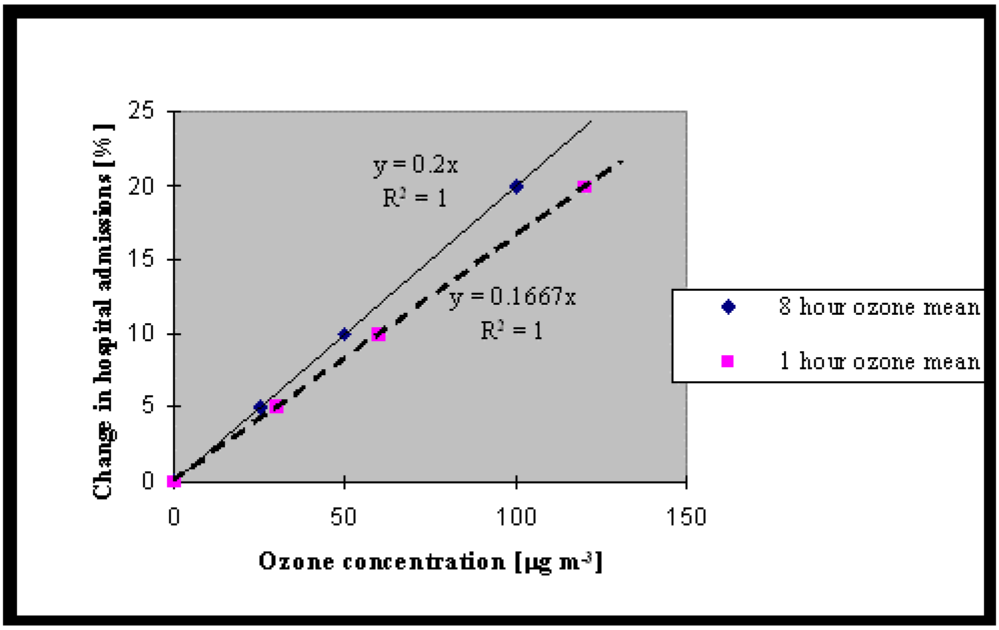

Figure 5: "Increase in hospital admissions for respiratory conditions as a function of O^3 concentration"

Source: (WHO, 2002)

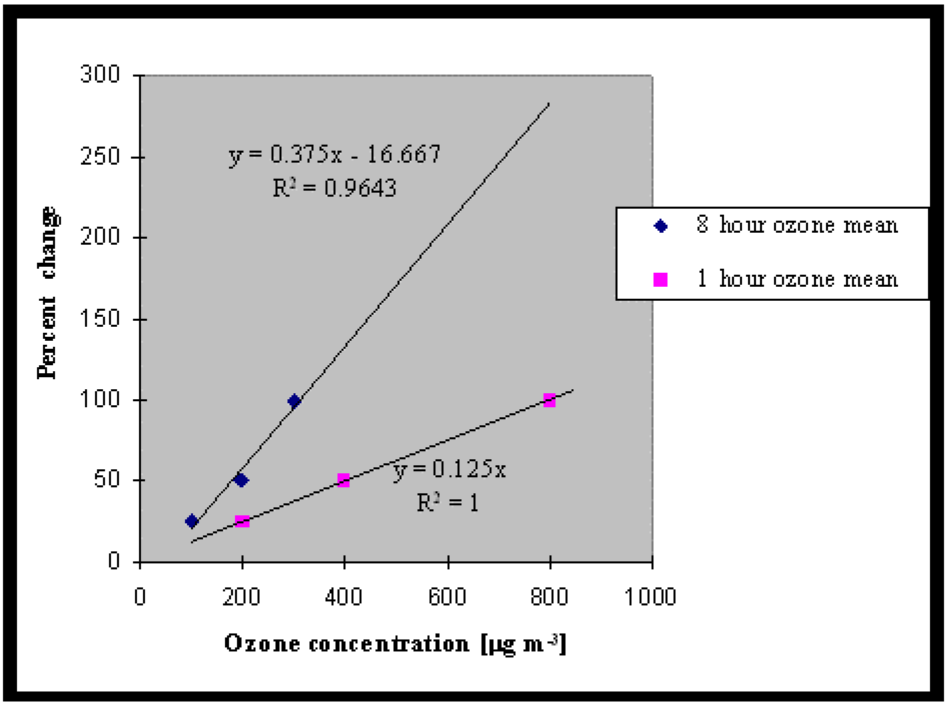

Figure 6: "Change in symptom exacerbation among adults and asthmatics as a function of O^3

Source: (WHO, 2002)

As for the latter, the level of effectiveness of ambient ozone concentration on asthmatic individuals varies greatly depending on their asthmatic severity. Nevertheless, the shear nature of this disease, being airflow limitation (obstruction) and chronic inflammation, compounded by irritants (e.g. ozone) that inflame airways results in a more pronounced effect in relation to healthy individuals. Thereby, making them an "enhanced risk group" (ODRSD, 1999, p. 51). Some studies, Thurston, et al, 1997, have also shown that all day exposure to ozone at or below national standard affects asthmatic children and adults similar to healthy individuals at much higher concentrations in controlled human studies (as cited in ODRSD, 1999, p. 52).

So far the discussion of the health effects of ozone has centred on short-term acute effects, but some studies show that there is a possibility that ozone can have some long-term effects. Rat and monkey experiments have shown a number of morphological changes in the epithelium and interstitium of the centriacinar region of the lung, including fibrotic changes (WHO, 2000 p. 37). Studies also suggest that cumulative ozone exposure is linked to increasing asthma severity and increased risk of new asthma cases (ODRSD, 1999, p. 51).

3.5 National, International and Organizational Guidelines

In order to curb the rise of ozone levels in the atmosphere and minimize/eradicate ozone's above mentioned human health effects, nations and international organizations have set guidelines to protect its respective populations. One thing important in establishing such guidelines is to determine when the effects are significant enough to warrant a health concern. In terms of respiratory function responses, the WHO deemed that ozone-related FEV_1 decreasements below 10%, which occurred at levels under 160 $\mu g/m^3$, were of no clinical significance. Due to this limit and in light of, "exposure duration to O_3 is important in controlling the response and that exposures to raised concentrations for periods of eight hours are not unlikely", the guideline for ambient air was set to 120 µg/m^3 for an eight-hour period. Below this level, acute effects on human health are likely to be small (WHO, 2000, p. 38). On the other hand, The EU according to the current directive 92/72/EEC has set a value somewhat lower than the WHO guideline (110 µg/m^3) for an eight-hour period. They have also set values for informing and warning the public of high ozone concentrations as well as levels dangerous for vegetation (see table 1). Sweden has no legislation stating limits or standard values for ambient ozone concentration additional to the values in the afore mentioned EU directive. However, the Swedish Environmental Protection Agency has set two specific goals for the country. "…Ozone concentration of 120 µg/m^3 (1-hour mean) should not be exceeded more than 12 times per year, and 150 µg/m^3 (1-hour mean) should not be exceeded at all."

Description	**Based on**	**Value**
Population information threshold	1 hour average	180 µg/m^3
Population warning threshold	1 hour average	360 µg/m^3
Health protection threshold	Fixed 8 hour means (period hours 0:00-8:00, 8:00-16:00-24, 12:00-20:00)	110 µg/m^3
Vegetation protection threshold	1 hour average	200 µg/m^3
Vegetation protection threshold	24 hour average	65 µg/m^3

Table 1: Thresholds for ozone concentrations in the air, set by the current Directive 92/72/EEC

Source: (ODRSD, 1999, p. 15)

Chapter 4: Regional ozone trends and influences

4.1 Global/Hemispherical/European ozone and precursor trends

The past few centuries has seen great changes in the amount of ozone produced and the amount that has remained in the atmosphere over the European continent. Since the 1800s, there has been a doubling in ozone concentrations. In addition, during the 1970s, ozone concentrations over Europe have grown by 1% per year. Just recently has levels appeared to have subsided (Naturvårdsverket, 2002). The reason for the rise, until recently, has been due to the rise in precursor emissions (NO_x and VOCs) and from the increasing trend in hemispheric background concentrations (Borrell, et al., 1997). In the European Union there has been a steady decrease in precursor emissions since 1990 and the European Environment Agency (EEA, 2000) estimates an annual decrease in precursor emissions by about 1.7-2.2 percent. Studies also show a 9% decrease in VOCs in EU15 countries (14 in Pan European countries) and a 8% decrease in EU15 countries (14 % in Pan European countries) since 1980 (ODRSD, 1999, p. 17). This decrease in precursors has led to a subsequent decrease in ozone concentrations although ozone concentrations up to 200 µg/m^3 are often observed in ambient air over Europe. Studies have also shown that this general trend of ozone concentration reduction in Europe occurs only in the 98-percentile. In the 50-percentile, ozone concentrations appear to be slowly rising. Possible explanations for this rise in the 50-percentile is ozone input from background values from global increases in CH_4, CO and NO_x emissions or reduced ozone titration[4] (de Leew, 2000, p. 189).

[4] Titration- "the amount of constituent in (substance) determined by using a standard reagent" (Allen, 1988)

4.2 Sweden/Skåne ozone and precursor trends

Precursor gases (NO_x, VOCs), which play a key role in ground-level ozone concentrations, have been on the decline in the past years (see figures 7 and 8). However, Skåne's ground-level ozone concentrations are not primarily a result of local precursors emissions, but dependent on long-range transports from continental Europe. Ozone formation takes time and thereby the highest levels are generally outside of city centres due to less pollution, such as NO_x and CO, to consume it or break it down

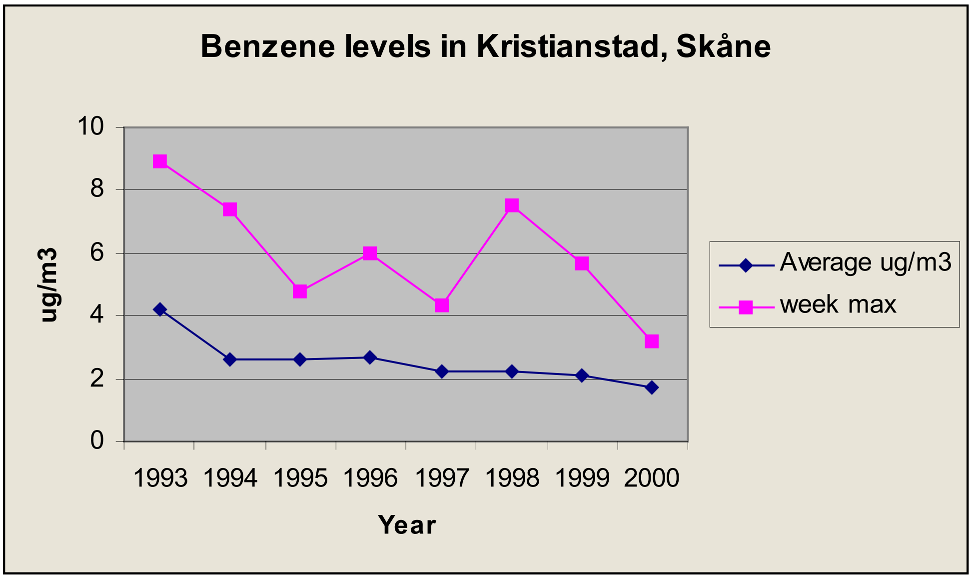

Figure 7: Benzene trends in the town of Kristianstad, Skåne from 1993-2000

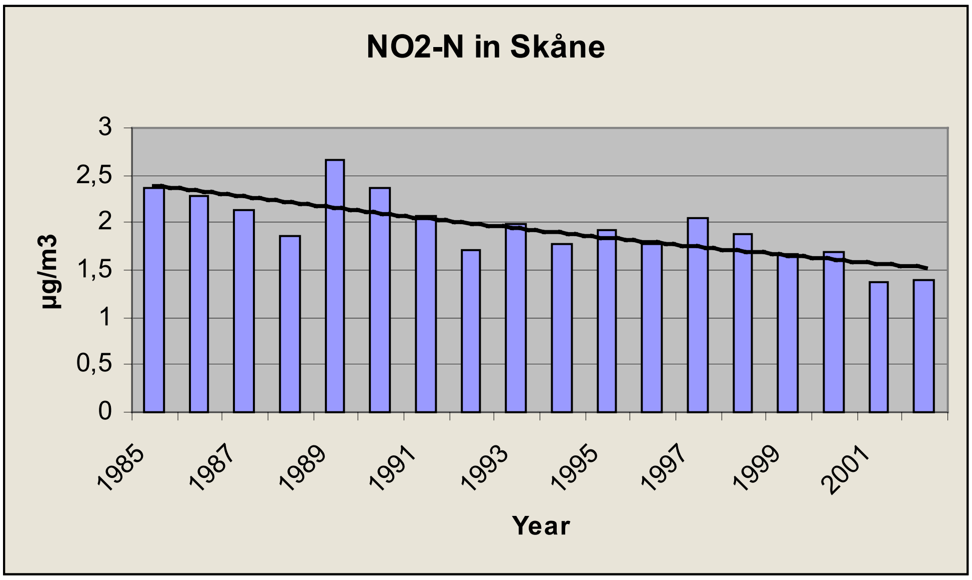

Figure 8: NO_x emissions in Skåne from 1985-2002

With aid of natural wind patterns, the ozone that is formed can be carried northwards towards Sweden. This process is reinforced by ozone's natural ability to exist in the atmosphere for considerable amounts of time. Secondly, when central Europe is covered by a high-pressure system with weak winds, the air has time to become significantly polluted. If this pollution is carried towards Sweden by the Gulf Stream, Sweden can experience a so-called ozone episode. This implies a short period of ozone concentration levels 2-3 times higher than normal. Such episodes normally occur during the summer months due to the fact that ozone building requires sunlight and is facilitated by high temperatures. On a daily scale, the maximum values usually occur during the afternoon (Naturvårdsverket, 2002).

The fluctuations in average annual ground-level ozone concentration between the years 1985 to 2002 are shown in figure 9. These results are taken from the measurements made by the Vavihill station in Vavihill, Sweden. This station is considered to be representative of all Skåne. It shows a semi-constant level of average ozone concentration (fluctuating between 50 and 70 $\mu g/m^3$) with a slight increase in latter years.

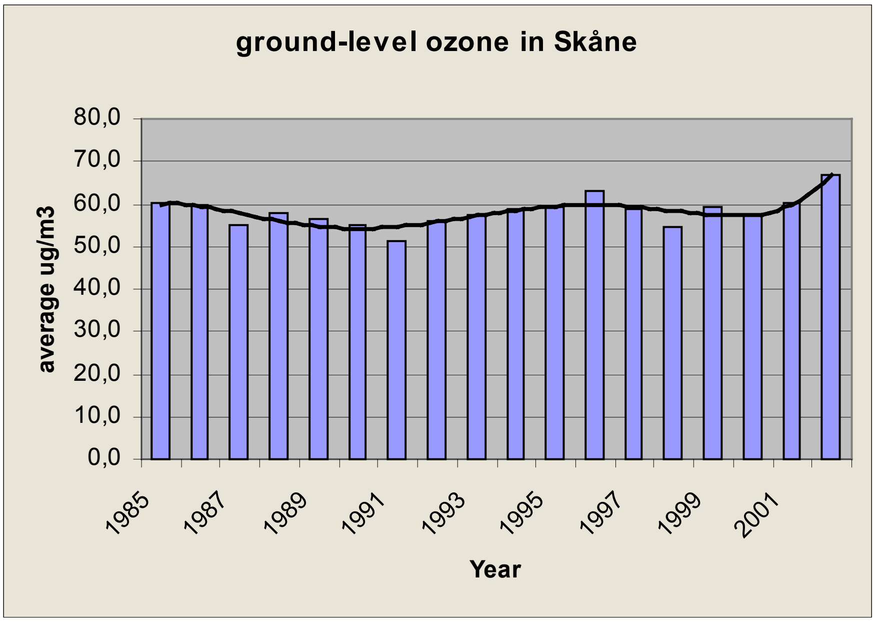

Figure 9: Average ground-level ozone concentrations in Skåne from 1985-2002

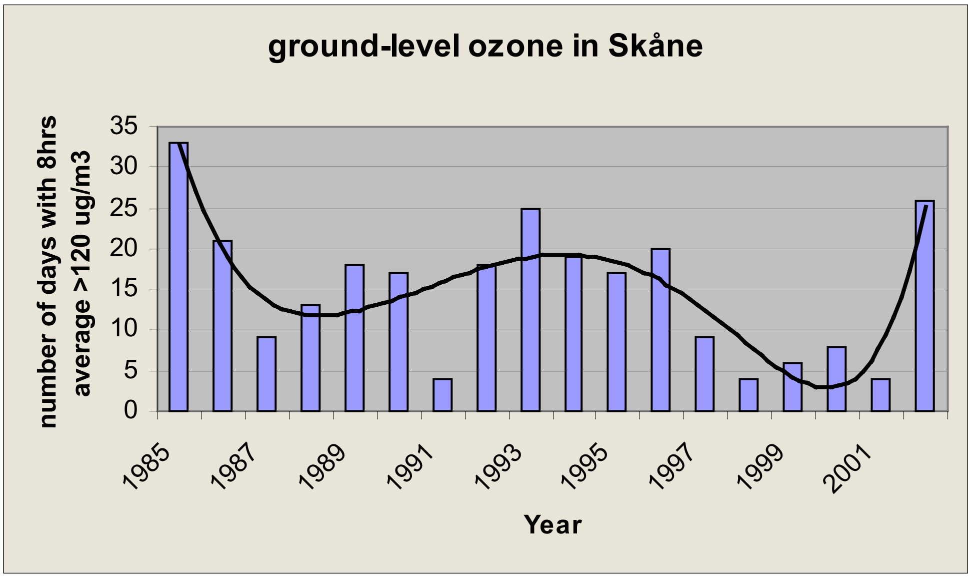

Figure 10: Number of days in Skåne with 8 hour average equal to or above 120$\mu g/m^3$ from 1985-2002

In regards to WHO standards, figure 10 exhibits the number of days that ozone levels have exceeded the WHO human health guideline of an eight-hour average of 120 µg/m^3 between the years of 1985 and 2002. This figure, similar to figure 9, exhibits a wave-like pattern, but in this case appeared to decrease except for the final year reported (2002) where values even exceed 1993 values. The wave-like pattern of both figures is most likely due to weather patterns (e.g. 1996, 2002-warm year and 1991/1998-rainy summer) (Länstyrelsen i Skåne, Miljöenhet, 2001, p. 40).

Weather, which can have a significant effect in regards to ozone formation, has also undergone some significant changes over the years in southern Sweden. Figure 11 illustrates that since 1866 the temperature in southern Sweden has been quite steadily increasing. This corresponds to annual global increases in temperature.

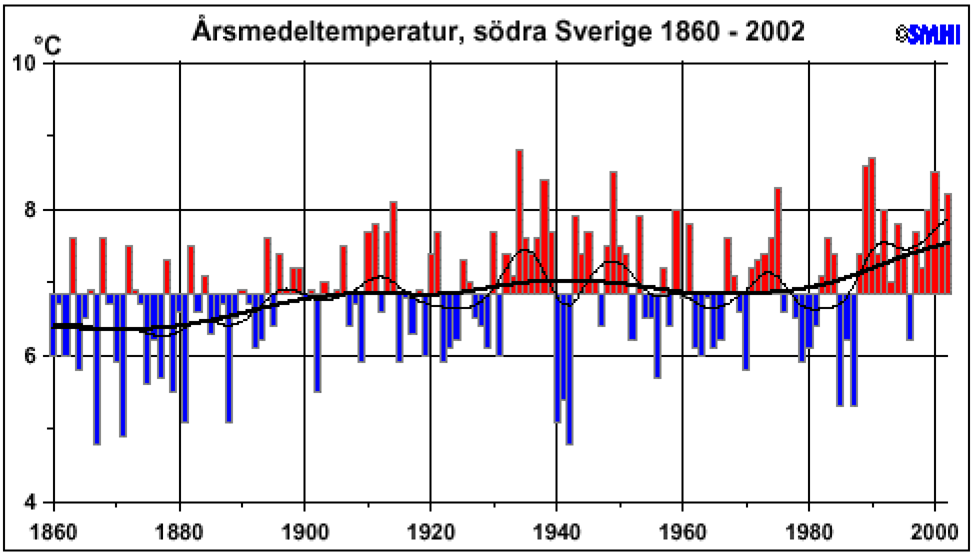

Figure 11: Annual temperature in southern Sweden from 1860-2002

Source: (SMHI, 2003)

Moreover, over the past sixteen years (shown in figure 12) there seems to be somewhat of a trend in regards to high summer days[5]. Although the values seem to fluctuate quite a bit in this seventeen-year period, it appears that the overall trend is one of wave-like increase.

[5] 24 hour period (19 o'clock – 19 o'clock) where the maximal temp is at least 25ºC

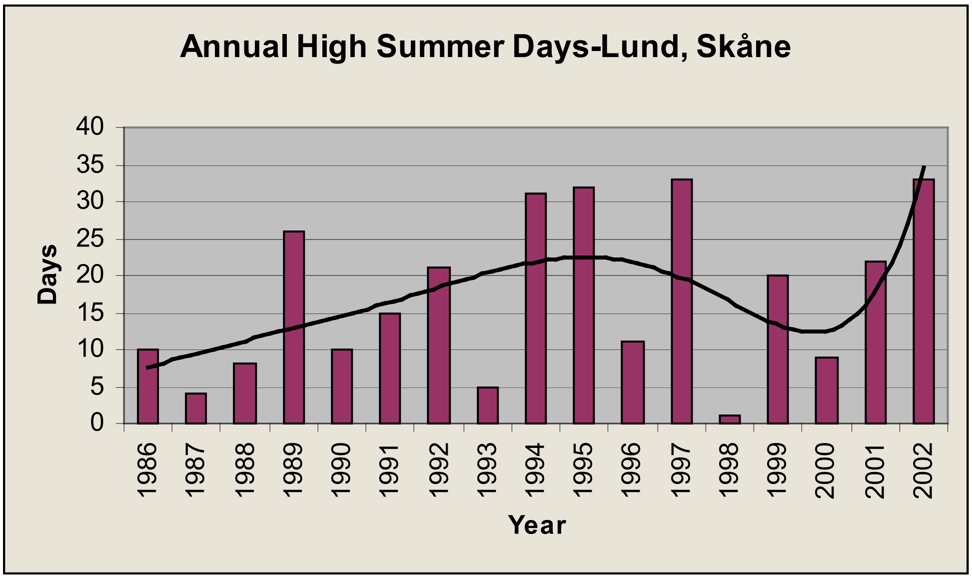

Figure 12: Annual number of high summer days in Lund, Skåne from 1986-2002

Chapter 5: Regional growth

5.1 Region Skåne-an area in transition

Skåne is a rapidly developing region striving towards four major goals according to Region Skåne's annual report 2003: growth, attract-ability, carrying capacity and balance. Growth is considered to encompass not only development in the economic sector, but also the development of knowledge, competency, environmental quality, culture, quality of life and other qualitative resources. The thought is that an improved economic situation will create money to finance social services. Skåne is very important in Sweden in this respect being that it has the most robust increase in new business start-ups in Sweden, fastest development during 2001 and 2002 in Sweden and high level of university enrolment from surrounding communities (Region Skåne, Regional Utveckling, 2002, p. 3).

Attract-ability is Region Skåne's desire of creating diversity and high quality in all that Skåne has to offer in the areas of employment, housing, education, culture, environment, communication, health care etc. In some ways Skåne has achieved this goal. First, It has the third best company conditions out of all Sweden's counties (Region Skåne, Regional Utveckling, 2002, p. 16). Tourism has been growing since 1996 (up 15% in 2001) and appears to have maintained this level in 2002 (Region Skåne, Regional Utveckling, 2002, 20-21). It is the only county in Sweden that has more immigration than emigration in all age groups between the years of 1997 and 2001 (Region Skåne, Regional Utveckling, 2002, p. 22). Finally, it has the second highest gainful employment within the fields of culture and media in the country (Region Skåne, Regional Utveckling, 2002, p. 25).

Carrying capacity, according to Region Skåne, means the long-term thinking and economical, ecological and social staying power, much similar to the concept of sustainable development (Region Skåne, Regional Utveckling, 2002, p. 29). Unfortunately, deduced from indicators such as emissions, voter turnout and life expectancy, Skåne does not fair well in this category. In regards to emissions, CO_2 production has been on a constant decline since 1980, but its production from motorized traffic sources has basically remained the same since 1990 (see figure 13) (Region Skåne, Regional Utveckling, 2002, p. 30). There has been a similar trend in regards to sulphur dioxide (SO_2) and nitrous oxides (NO_x) (see figure 14). The voter turnout has dropped below the national average since 1998 (Region Skåne, Regional Utveckling, 2002, p. 34). Finally, the average life expectancy for men is lower than the other two major most populated counties (Stockholm and Västra Götaland) and the national average (Region Skåne, Regional Utveckling, 2002, p. 38).

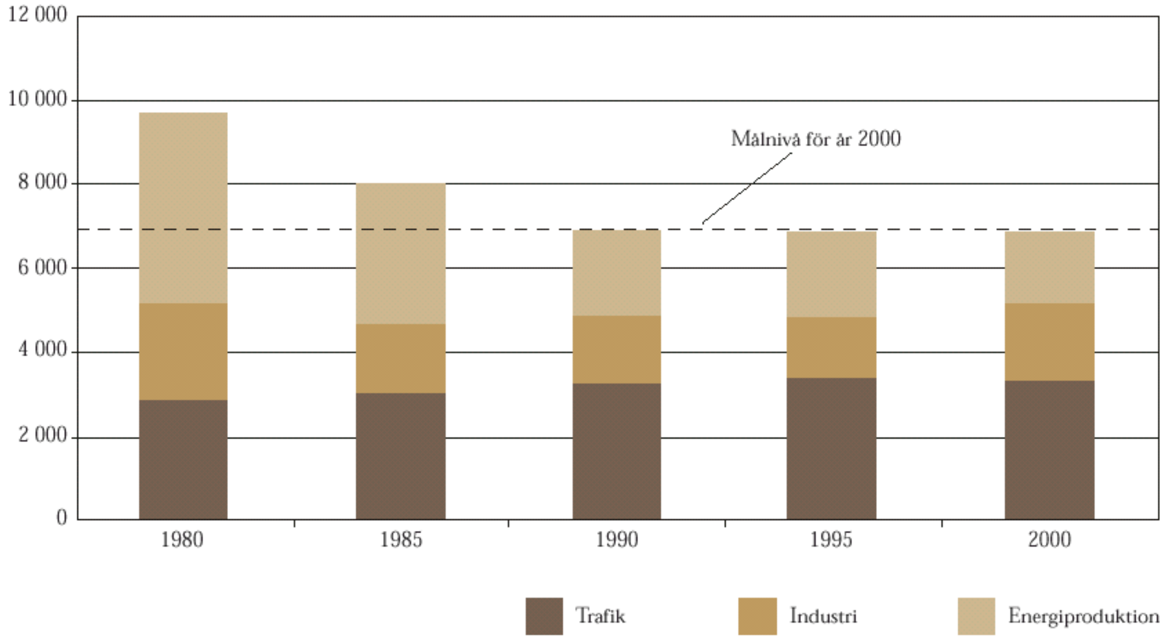

Figure 13: CO^2 emissions from the burning of fossils fuels for the years 1980, 1985, 1990, 1995 and 2000

Source: (Länstyrelsen i Skåne Län, 2003)

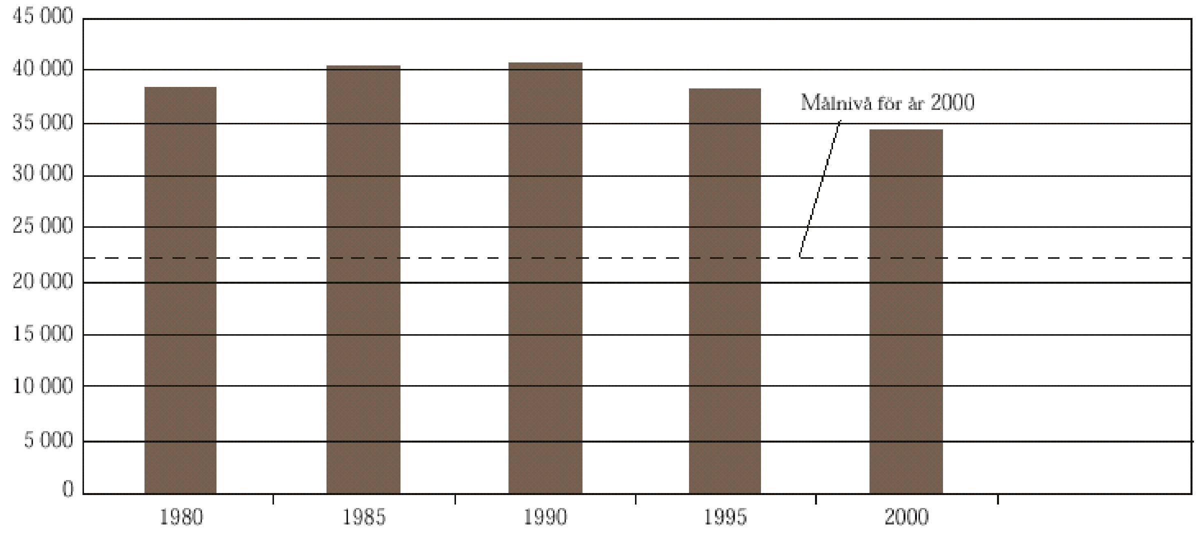

Figure 14: NO_x emissions from the traffic sector in Skåne (ton)[6]

Source: (Länstyrelsen i Skåne Län, 2003)

The term balance implies that every part of Skåne should develop under its own conditions without losing sight of the bigger picture; whereas the operative word is develop. In other words, every part of Skåne should take into consideration that they have a mutual dependence on each other resources and qualities. This concept also includes gender, racial and religious tolerance. Indicators used to determine the successfulness of this goal in Skåne are gender-specific average income, county income distribution, gender-specific unemployment rate distribution, SCB equality index, population growth and distribution, time of travel between home and work place and home and universities/colleges and distribution of immigrants (Region Skåne, Regional Utveckling, 2002, 41-55).

On average, men are paid significantly more than women in all age groups (Region Skåne, Regional Utveckling, 2002, p. 42). The average income for men 35-44 years old (highest earning group) ranges from 358,474 kronor annually in Lomma municipality and 146,385 kronor less in Tomelilla municipality (212,089 kronor) (Region Skåne, Regional Utveckling, 2002, p. 43). Unemployment in Skåne has remained around one percent over the national average since 1990 whereas the highest unemployment lies in Northeast and Southern Skåne and the city of Malmö (Region Skåne, Regional Utveckling, 2002, p. 44). The distribution of unemployment is similar for men and women, but the actual number of unemployed women is higher than the men. According to the SCB gender-equality index, which is based on a wide range of factors, Skåne is ranked 11 out of Sweden's total number of counties. The reason for this relative low ranking is probably due to low income for women, low withdrawal of parent allowance, few women in municipality and regional government. In Skåne's favour, there is relatively no imbalance between young women and men, which signifies good opportunities for women and men in regards to education and work. There is also significantly low gender-specific dominance in different fields of work (Region Skåne, Regional Utveckling, 2002, p. 46).

Over the past five years, the population of Skåne has increased on averaged by 4,400 people. This growth has not been balanced, but concentrated in the larger municipalities in Skåne

[6] Målnivå för år 2000 = Goal level for the year 2000

whereas Malmö and Lund have had the highest growth (Region Skåne, Regional Utveckling, 2002, p. 48).

Due to Skåne relatively high population density (highest in all of Sweden) and multiple centre structure, travel time to work or university is relatively low. The majority of people can reach their respective workplaces within 30 minutes by car and nearly all within 60 minutes whereas the lowest accessibility is in the northern and eastern parts of Skåne. According to the criteria[7] established by Region Skåne, the majority of communities have good access to universities and colleges excluding a few in the south eastern and north eastern parts of Skåne and small communities in between Helsingborg and Lund/Malmö. In regards to residential segregation, Skåne has one of the largest (if not the largest) in Sweden with concentrations of immigrants in a few county divisions in Malmö, Lund, Landskrona and Helsingborg (Region Skåne, Regional Utveckling, 2002, 52-55).

5.2 Population in Skåne

At present the population of Skåne is 1,145,090 people, but perhaps due to the above-mentioned campaign of growth, attract-ability, carrying capacity and balance it is expected to increase to 1,244,327 by the year 2011. Growth in the region is not exactly a new thing. In actuality, the population of the region has been on a constant incline since 1901, but not until recently has the percentage increase shown a clear growth pattern expecting to subside around one percent (see figure 15) (Region Skåne, 2003a).

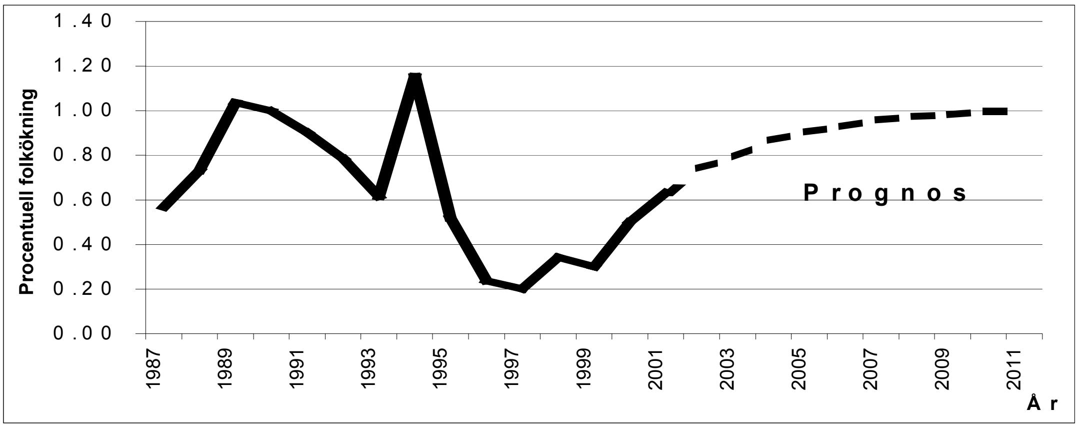

Figure 15: Estimated percentage of population increase from 1987-2011[8]

Source: (Region Skåne, Regionala Utvecklingsstaben, 2002)

Much of the growth has coincided with the opening of the Öresund Bridge, Malmö University and cross-border collaboration of the Öresund University and Medicon Valley. In regards to the Öresund Bridge, statistics show that since the bridge's inauguration in 2000, the number of Danes that have relocated to Skåne has doubled whereas the number of Swedes moving over to Denmark has only increased marginally. This occurrence is probably due to the relative low cost of living on the Swedish side in comparison to Denmark (especially Copenhagen) (Region Skåne, 2003b). This immigration to Sweden from Denmark is expected to continue to increase in the future based on current statistics and an inquiry conducted by Region Skåne, Øresundsregionens Arbejtsmarkedspolitiske Råd, and the counties of Malmö

[7] Travel time from home should take max 1 hour, including transfers, and there should be at least 10 travel opportunities in both directions during weekdays (Region Skåne, Regional utveckling, 2002, p. 55).
[8] Prognos = Prognosis, År = Year, Procentell Folkökning = Percentage of Population Increase

and Copenhagen which showed that a large number of Danes have contemplated moving over to the Swedish side of the sound. (Region Skåne, 2003a) In regards to the Öresund University and Medicon Valley, they have been marketing the region as an area of knowledge and research which in turn is expected to attract international investment and along with that an increased need for human capital, according to Boel Flodgren, former vice-chancellor of Lund University. This can in the long-term result in a positive influence on population growth on both sides of the sound.

5.3 Transportation trends in Skåne

As population grows in conjunction with regional economic development and increased total household consumption, so does the need and occurrence of increased transportation and transportation infrastructure. From the prognosis of Region Skåne's county plan for regional transport infrastructure, personal travel and goods transport will continue to increase parallel with developments in the region. Goods transport in particular is now considered to have a much stronger increase than thought before. So far, heavy truck traffic is increasing doubly as fast as personal automobile transportation. Looking at the development of traffic flow on Skåne's national highways between the years of 1990 and 2000, there has been a substantial increase ranging from 10% to 50% in some areas. This is higher than the national average, which stabilizes around 10% (Region Skåne, 2003b, p. 29).

Integration of the Öresund region through means mentioned above in *Population in Skåne* has greatly influenced the amount of traffic in the Skåne (see figure 16). With a direct link to the inauguration of the Öresund bridge, numbers of cross border travels have increased by 30% during its two years in operation in comparison to the period prior to its opening (1985-1999). There are also plans for the expansion of the Öresund train network that will not only increase Skåne's accesses to Copenhagen and the rest of the Öresund region, but by 2008 will offer fast links to Karlskrona, which lies in the Swedish county of Småland. Already has the Öresund train been extended to Sweden's second largest city, Göteborg, which lies in the county of Västra Götaland. The academic cooperation (e.g. Öresund University) is also considered to have an effect on the growth of traffic across the two borders. Generally, the higher the level of education, the higher the inclination to travel either for work or for pleasure. Not only has the transportation route between the Copenhagen and Malmö become more heavily trafficked, but even ferry traffic between Helsingborg and Helsingør has had an increasing trend. Furthermore, a new market for ferry traffic to Germany has begun to develop and this can also have significant effects on transport need in the region (Region Skåne, 2003b, 24-25).

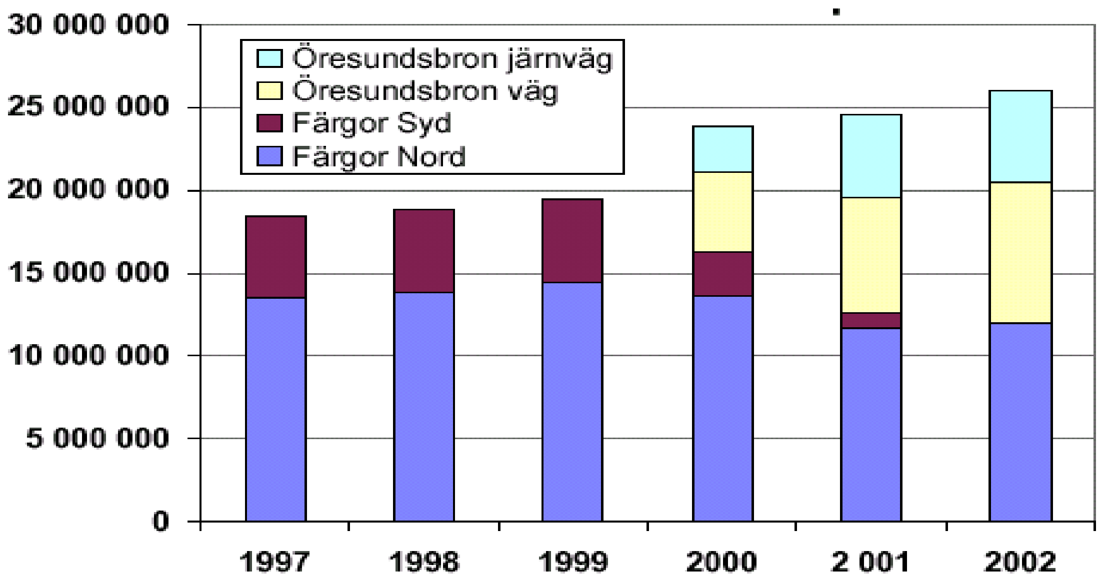

Figure 16: Travel over Öresund[9]

Source: (Öresundsbrokonsortiet, 2002 as cited in Region Skåne, 2003b)

This trend of transportation growth is expected to continue in the up coming years according to Region Skåne. Figure 17 shows the increasing trend of goods transport 1950 to 2010 divided into the respective modes of transportation.

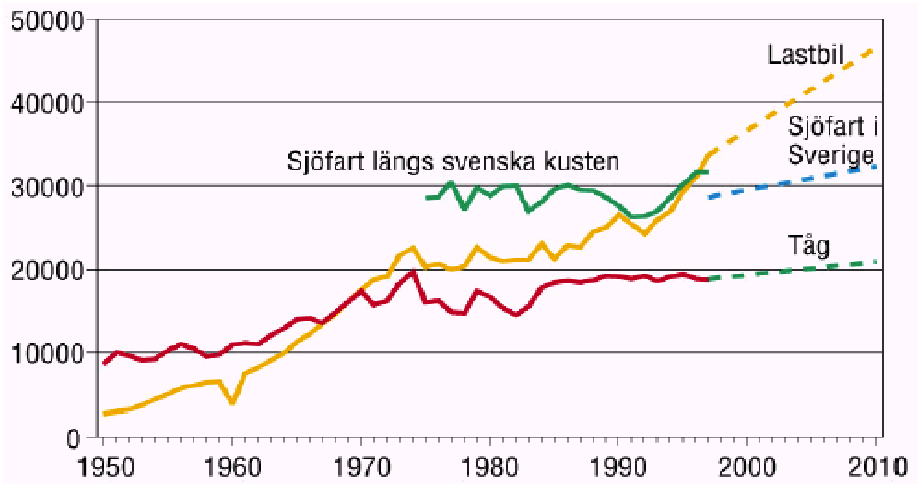

Figure 17: Goods transportation development in Sweden divided into different modes of transportation[10]

Source: (SIKA, 2002 as cited in Region Skåne 2003b)

All modes are expected to continue to increase, but the most significant growth is connected to truck transportation. Not only is the increase expected to occur in the area of goods transport, but also personal transportation. Figure 18 illustrates the estimated traffic work in Sweden from 1950 to 2010 showing a constant steep incline with no sign of leveling off.

[9] Öresundsbron järnväg = Öresund bridge railway, Öresundsbron väg = Öresund bridge road, Färgor Syd = Southern Ferries, Färgor Nord = Northern Ferries
[10] Lastbil = Lorry, Sjöfart längs svenska kusten = Shipping along the Swedish coastline, Sjöfart I Sverige = Shipping in Sweden, Tåg = Train

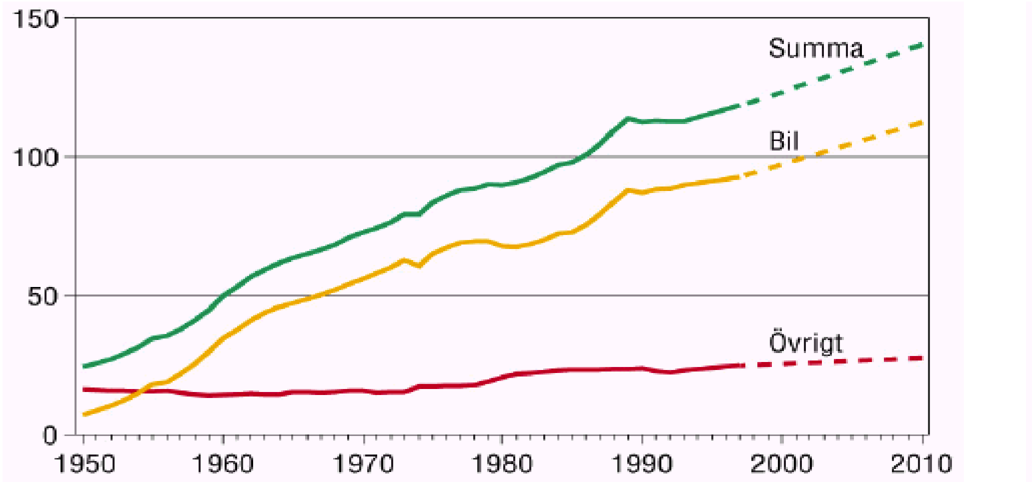

Figure 18: Estimated Traffic Works in Sweden 1950-2010 by Automobile and Other Types of Transportation. Billion Personal Kilometers[11]

Source: (SIKA, 2002 as cited in Region Skåne, 2003b)

Finally, inclusion of many eastern European countries in the European Union can also effect the transport situation in Skåne. According to Region Skåne, experience has proven that transportation between EU countries is generally greater than between a EU country and one that is not. For this reason and the fact that Skåne borders some of these future EU countries, the probable long-term consequent will be that of a transportation increase in not only a north to south direction but also from an east to west direction (Region Skåne, 2003b, p. 29).

5.4 The RTI-plan: Skåne's solution to expected growth

In light of the above-mentioned expected growth and development of Skåne, the regional administration has compiled input from several regional authorities to create a plan to deal with this up- coming situation. This plan is called the RTI-plan 2004-2015, which is an acronym for Regional Transport Infrastructure Plan. The years 2004-2015 signify the proposed beginning and duration of the plan. The creation and implementation of the RTI is very important for Skåne in reference to the belief that a functional transport infrastructure is integral to achieve the previously mentioned four main goals of the region: growth, attract-ability, carrying capacity and balance. It is meant to be used as a tool for forming and developing the future transport system in order to fulfill the needs and objectives that exists. It is also meant to be inclusive by way of taking into account the needs and desires of its citizens. In order to do this, not only could they consider economic prerequisites, but also issues such as safety and environmental impacts. Obviously, the job of planning and executing infrastructural plans require a considerable amount of investment and these funds are primarily allocated from the national government. Despite national funding, the RTI is the responsibility of Region Skåne fitting into a larger more comprehensive plan that involves national authorities including the Swedish national administration of roads and the Swedish national administration of railways. These two governmental bodies are responsible for all national/European roads (E6, E22, E4, E65) and all Swedish railways respectively. This also includes measures directed towards environmental degradation (i.e. noise pollution and water pollution) by these roads and railways (Region Skåne, 2003b).

[11] Summa = Total, Bil = Automobile, Övrigt = Other

The RTI-plan states six specific strategies to be used for the basis of proposed measures (Region Skåne, 2003b, p.5):

- Increase accessibility within the region implying increased connections to slowly developing counties
- Increase accessibility with surrounding regions
- Create a transportation system for all
- Increase safety
- Work towards environmentally adapted transport
- Decrease negative environmental impacts

Some of the proposed transportation measures that the plan suggests include road expansion and improvements, densely populated measures, so-called "directed measures", railway improvements, bike paths, collective personal transportation and specific environmental measures based on county traffic plans (see table 2) (Region Skåne, 2003b, p. 93). As stated before, these measures included in RTI are expected to ease or solve the transportation problems in Skåne, but unfortunately some of these measures are considered to possibly have negative impacts on the environment. For this reason and EU directive, "EG-direktivet, 2001/42/EG", which states that any plan, program or the like which is in danger of having a significant environmental impact must undergo a Strategic Environmental Evaluation, such an environmental evaluation has been conducted (Region Skåne, 2003b, p. 47). It has revealed an increase of CO_2 by 4.8 million kilograms from RTI projects (and 10.4 million kilograms from national road projects) whereas half comes from the road project 23 Ö Höör (Region Skåne, 2003b, p. 111). This figure is based on the assumption that all measured are carried out fully. In actuality, this may not be the case. According to a Swedish national government directive, all suggested plans should include two alternate plans whereas one receives 50% of the needed amount of investment and the other receives 150% of the needed amount (see table 2).

Alternative	**50%**		**100%**		**150%**	
	Mkr	%	**Mkr**	%	**Mkr**	%
Road Investments	**395**	22	**1275**	36	**2539**	48
Railway Investments	**0**	0	**50**	1	**50**	0.9
"Directed" Traffic Safety Measures	**230**	13	**385**	11	**472**	9
Densely Populated Measures	**100**	6	**175**	5	**200**	4
Bicycle Paths	**150**	9	**200**	6	**250**	5
Collective Traffic Measures	**150**	9	**220**	6	**275**	5
Additional Measures	**40**	2	**50**	1	**80**	2
Subsidies for Collective Traffic	**350**	20	**480**	14	**550**	10
Subsidies for the Environment and Traffic Safety	**250**	14	**480**	14	**525**	10
Aid	**96**	5	**206**	6	**340**	6
Total RTI-plan	**1761**	100	**3521**	100	**5281**	100

Table 2: Three alternative plans included in Skåne's RTI (Regional Transport Infrastructure)-plan

Source: (Region Skåne, 2003b, p. 114)

Under these circumstances, a priority system had to be created. This priority system is based on cost effectiveness in relation to the collective objective. In other words, those measures that give the most contribution to the collective fulfillment of goals are prioritized over those that offer a minimum contribution (Region Skåne, 2003b, p. 113). Obviously, the 150% plan alternative will result in the more thorough execution of the 100% plan and at a faster pace. The main point of concern is how the 50% alternative will effect the transportation situation. The expected changes in this plan are many (Region Skåne, 2003b, p. 116):

- Reductions in relative pace especially for road work
- Exclusion of many profitable socio-economic measures
- Reductions in works to promote regional balance
- Reductions in the level of execution of measures for county roads and streets
- Less investment in safety
- Fewer bike paths built and less renovations made to existing bike paths
- Slower construction and implementation of highly trafficked regional buss lines
- No partial financing from RTI-funds for the extension of the Simrishamn line

The only measures that remain somewhat unscathed are the national roads, but even this work will be done at a lower level of ambition. One clear way to see the differences in plans is to look at the length of road that will be constructed or renovated for all three plans. The difference the 50% alternative and the 100% alternative is a length of 77.6 kilometers of road. If the 150% alternative is executed, there will be an additional 29.1 kilometers of road that will be constructed or renovated (see appendix 1 for complete details on alternative plan road differences).

Moreover, potential cuts in the RTI-plan can also have serious effects on Malmö's "Citytunneln". The "Citytunneln" is a railway project that involves the construction of 17 kilometers of rail connection through Malmö and the creation of two new stations (Triangle and Hyllie). So far, construction is scheduled to begin in 2004 with a project completion date in 2009. Its purpose is to be "a communications solution" that connects the northern railroad lines of Malmö with those towards Copenhagen and the Swedish cities of Trelleborg and Ystad (Citytunnelprojektet, 2003a). It is considered to be a valuable tool in regards to development by way of allowing the citizens of Skåne and Själland, Denmark to reach their respective workplaces in under an hour (Citytunnelprojektet, 2003b). The "Citytunneln" is also believed to provide significant environmental benefits for the region. By way of shifting personal transportation away from automobiles and its comparatively lower emissions, it is believed to contribute to a reduction in CO_2 and air pollutants such as NO_2. Despite the fact that during its construction there will be increases in such gases from building machines and construction-associated transport, after construction and its subsequent operation, the level of such gases released in the atmosphere is expected to be greatly reduced (Citytunnelprojektet, 2003c). The RTI-plan affects this project in an indirect way. Although the "Citytunneln" project is not part of The RTI-plan or funded by the RTI-plan, its necessary predecessor the Simrishamn line is. The extension of this line must be completed before construction is completed on the "Citytunneln" project in order for traffic to begin. In other words, although the "Citytunnel" is not dependent on the existence of the Simrishamn line (or other future railway connections to the Malmö metro area) the expected benefits such as reduced traveling times between certain areas and increased incentive to use public transportation over automobile transportation will not exist until specific lines (e.g. Simrishamn line) are built.

For this reason, the RTI-plan has set aside a sum of 50 million crowns for the developing of the Simrishamn line in their 100% alternative (Region Skåne, 2003b, p. 101).

In order to achieve all of its specific transportation goals, Region Skåne has tentatively been allotted the amount of 3.5 billion crowns. This amount only includes measures specifically in the RTI-plan not to mention measures stated in national plans (The Swedish national roads and railway plans) that are to be implemented in Skåne. Including the last group, the total amount of investment in transportation in Skåne is estimated to about 32 billion crowns (Region Skåne, 2003b, p. 8).

Chapter 6: Health Concerns

6.1 Asthma trends

Over the past 20-30 years the prevalence of allergic illness such as asthma, hay fever and atopic eczema have doubled in Sweden. This increase includes all groups of society, but especially those between the ages of 16 and 44 years of age (Socialstyrelsen, 2001, p.129). This general increase in Sweden has led to relatively high levels of asthma (8-10%) and hay fever (21-24%) particularly in Skåne for ages between 19 and 80 by the year 1999, according to the Nationella miljöhälsoenkäten (Socialstyrelsen, 2001, p. 138). However, studies have shown some differences between gender and age groups. Women in general have had a higher prevalence of such allergic reactions than men. This is evident through figures comparing the years 1988/89 with 1996/97. Women's levels rose from 40% to 43% between these years whereas men's levels rose from 31% to 37% (Socialstyrelsen, 2001, p. 130). Although the greatest increase has been in the ages between 16 and 44, changes in levels of children under these ages should not be over-looked. The reason being that asthma is the most common childhood chronic illness in Sweden. Studies show that approximately half of all doctor visits are for asthma related illnesses. This is also particularly alarming since Sweden has a much higher prevalence than much of Eastern Europe and many underdeveloped countries (Socialstyrelsen, 2001, p. 173).

6.2 Ozone linked hospital admissions and premature deaths

From a study conducted at Umeå University by Bertil Forsberg et al, clear connections between ozone concentration and hospital admission/premature deaths have been shown for the year 2000 (see tables 3 and 4). These figures show the number of cases that are due to a maximal eight-hour concentration equal to or above 10, 60 and 80μg/m^3. In other words, it shows the estimated number of cases that would have been prevented if ozone concentrations did not exceed these levels. (Forsberg, et al, 2003, p. 21)

Area	Total number of extra hospital admissions	Number of extra hospital admissions caused by 60μg/m^3 over a 24 hour period	Number or extra hospital admissions caused by 80μg/m^3 over a 24 hour period
Malmö, Skåne	70	41	13
Lund, Skåne	21	14	5
Densely populated areas, Skåne	149	85	28
Rural areas, Skåne	65	52	25

Table 3: Number of extra emergency hospital admissions for respiratory organ illness due to ozone for the year 2000

Source: Forsberg, et al 2003, p. 21

Area	Total number of premature deaths	Number premature deaths caused by 60µg/m^3 over a 24 hour period	Number of premature deaths caused by 80µg/m^3 over a 24 hour period
Malmö, Skåne	46	27	9
Lund, Skåne	14	9	3
Densely populated areas, Skåne	96	55	18
Rural areas, Skåne	42	34	16

Table 4: Number of premature deaths due to ozone for the year 2000

Source: Forsberg, et al 2003, p. 23

Chapter 7: General Discussion

7.1 Synthesis and Vulnerability

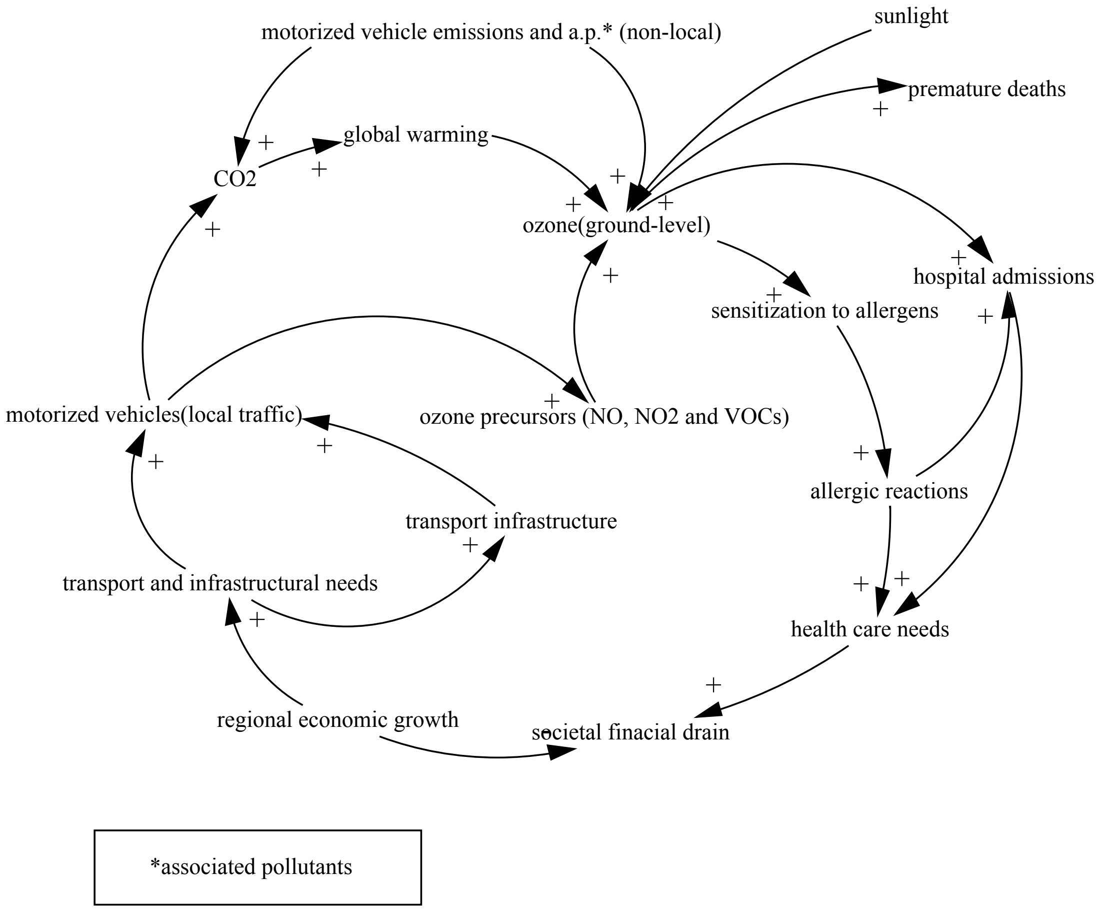

Figure 19: Global warming/Air pollution causal loop diagram

This causal loop diagram (see figure 19) shows the dynamics of the system. Beginning with regional economic growth, as economic growth increases in the region so does the need for transportation and transportation related infrastructure. The increase of these two has two outcomes. First, it results in an increase in traffic (e.g. motorized vehicle traffic) in order to satisfy the needs of economic growth. Secondly, it results in an increase in transport infrastructure to handle the increase in traffic or to handle predicted increases in traffic. As transport infrastructure increases so does the traffic that it was designed to handle. The result in increases in motorized vehicle traffic is more air pollutants such as CO_2 and ozone precursors (NO, NO_2 and VOCs). Looking at CO_2, as it increases, so does global warming and global warming has an effect on ground-level ozone. As global warming increases, so does the number of days that exceed 25ºC (temperature that increases ground level ozone formation), which increase the probability of increased levels of ozone formation. Ground-level ozone also receives other important inputs. As sunlight (a key factor in ozone formation) increases, so does the amount of ground-level ozone in the atmosphere considering ozone precursors are already present. Looking back at motorized vehicles, these precursors come from the operation of motorized vehicles. As motorized vehicle use increases, so does the amount of ozone precursors. The local amount of motorized vehicle related air pollutants in the region is also a result of long range transport from other parts of Europe especially Germany. Ozone can be transported over long distances, so as it increases abroad so does levels in the region. Moreover, internationally produced CO_2 contributes to the collected greenhouse effect and consequently global warming. So as CO_2 increase abroad so do global and local temperatures. Looking back at ozone, as it increases so does sensitization to allergens. As sensitization increases so do the cases of allergic respiratory reactions. Depending on the severity of the allergic respiratory reaction, as it increases so does the number of related hospital visits (admissions) which finally results in an increase in health care needs (resource-wise as well as financial). Increases in ozone can also contribute to other respiratory illness that consequently result in increased hospital admissions and increased premature deaths. These health care need increases result in a societal financial drain either by Sweden's state supported and heavily subsidized health care system or by the individual in question. This is hopefully offset by the taxes and revenues collected from the expected regional development and economic growth.

7.2 Transportation Increases: Not the main problem, but nonetheless problematic

As stated earlier on in this thesis, transportation has been increasing for a number of years. Not only has the increase been localized in the personal transport sector, but also, and at a greater rate, in the goods transportation sector increasing at a rate between 10 and 50% between the years of 1990 and 2000. This increase appears to be a result of the mass development that has been going on in the region ranging from infrastructural improvements such as the Öresund Bridge to ideological concepts such as Region Skåne's four-goal approach which boast of Skåne's position as the fastest developing region in Sweden during the years of 2001 and 2002. All this has coincided with a quite consistent population growth (see figure 15) that is expected to continue at least until the year 2011. One major problem is that this growth has resulted in negative impacts on the regional air quality. Although the emissions of many air pollutants/ozone precursors such as CO_2, NO_x and VOCs have diminished over the years due to serious reductions primarily in the industry/energy sector and the introduction of the catalytic converter, the total amount of CO_2 contribution from traffic has continued to increase since the 1980s, despite afore mentioned total reductions. On the other hand, average ground-level ozone has been following a different pattern whereas it fluctuates in a wave-like pattern that up until recently appeared to be constant. This most likely has to do with the nature of the gas. For one, the majority of ground-level ozone comes from the continent and more specifically, Germany and some Eastern-European counties. So, although there have been reduction in precursor gases and ozone formation in Skåne, levels can still increase or remain constant due this input from abroad. Another reason could be the initial reaction of less NO (from less NO_x emissions) to consume ozone. This could have, in some ways, contributed to the basically stagnant levels of average ground-level ozone concentrations prior to 2002, but what about the sudden increase in 2002 which reached above the extremely high 1993 levels. How can this be explained? Weather patterns are most likely the answer. Looking back at figure 11, which displays the average annual temperatures for Southern Sweden, and comparing them to figure 12, which shows the trends of annual high summer days in Lund, Skåne, one sees a clear correlation. Not only have annual average temperatures been increasing, but also the number of annual high summer days. This is significant because, as stated before, temperatures over 22˚C have a positive effect on ground-level ozone formation. Looking back at figure 10, the relatively hot summer of 2002 has resulted in over 26 days (highest since 1985) with an eight-hour average above 120 $\mu g/m^3$ and an annual average higher than it has been for the whole 17-year period (shown in figure 9). Ground-level ozone formation is also subject to other weather patterns such as wind speed, precipitation etc., but this data does suggest and show the connection with temperature and in that case, global warming and its main contributor CO_2 does play a role. As mentioned before, CO_2 emissions from the traffic sector in Skåne has continued to rise. Moreover, CO_2 emissions from Germany (the EU biggest polluter), despite huge cuts since 1990, rose by one percent between 2000 and 2001 (Daly, 2003, May 7). It is debatable how much a one-percent rise in German CO_2 emissions will affect the overall rate of global warming, but it is clear that due to CO_2 high persistence (50-200 years) in the atmosphere, such consistent or increasing input will enhance the greenhouse effect. Furthermore, any increase in motorized vehicle use will also, in the long run, enhance the greenhouse effect.

As the temperature increases and subsequently improve ozone formation, the health effects of ozone concentrations will also become more apparent. As stated before, there is evidence that increased ozone levels can and have had effects on the respiratory systems of healthy individuals and asthmatics (see figure 6) whereas the most sensitive individuals in the population being asthmatic children (enhanced risk group). This is due to their higher basal metabolic rate, underdeveloped respiratory tract and underdeveloped immune system. Moreover, the basic nature of the asthma being airflow limitations and chronic inflammation worsens the inflammation effect brought about by irritants such as ozone thereby exacerbating asthmatic symptoms. Studies have also shown that all day exposure at or below national standards affect asthmatic children (and adults) with similar symptoms that result only in higher concentrations in healthy individuals. Over the past 20 to 30 years, allergic illnesses have doubled in Sweden resulting in relatively high levels of asthma (8-10%). Children in particular appear to be very significant in this respect being that asthma is the most common childhood illness in Sweden and that approximately half of all doctor visits are for asthma related illnesses. Looking back at figure 9, it is difficult to draw parallels with annual average ozone concentrations and increasing incidences of allergic illness because not only have the levels been relatively stagnant over the past 17 years, but also the concentrations are much lower than National/WHO standards. Even the parallel between the number of days with an eight-hour average over 120 $\mu g/m^3$ and increasing allergic cases is difficult to draw since up until recently the trend had been one of decrease. This maybe has something to do with the complex and not completely understood mechanisms of how ozone actually affects the respiratory system and/or the evolution of genetic predisposition. Nonetheless, studies do show a correlation between increasing symptom exacerbation and increasing ozone level. Studies also show strong links between hospital admissions and premature deaths such as the 2000 study done by Forsberg et al. This suggests that if Skåne continues to grow and develop, and with that increase and improve its transportation infrastructure, it can contribute to the exacerbation of allergic symptoms and result in increased doctor visits and increased government funding of the health care system in the long run. In the short term, it can lead to an increased production of pollutants that consume or breakdown ozone (i.e. NO and CO), which will consequently result in less health related illnesses associated with ground-level ozone.

According to Region Skåne's four goals and past trends in the region, Skåne appears to be on a path of continuous growth that must be supported by transport infrastructure despite negative environmental impacts. To manage this predicted growth in transportation, Region Skåne has constructed an infrastructural plan for the years 2004 to 2015 that will be reviewed and decided upon by the latter part of 2003. This plan receives national funding and also works in conjunction with other national plans (the Swedish national administration of roads plan and the Swedish national administration of railways plan) whereas the national plans have, unlike before, complete authority over the transport infrastructure for national/European roads and all railways effective 2004. The RTI-plan in particular, although for the improvement and expansion of transportation infrastructure, is designed to incorporate environmental considerations as well. As stated before, a more detailed account of the specific areas addressed and the amount of investment proposed to be allocated to these specific areas are represented in table 2. Table 2 also exhibits the nationally mandated alternative plans (50 and 150%). Looking at the 50% alternative, road investment receives the highest investment (22 %) of all funding. This money is intended to go towards increasing the "trafficability" and safety problems on links in connection to large cities, the reduction of disturbing thoroughfares in densely populated areas and improving bad geometric standards on many road sections and areas where road connections do not exist. Railway investment, which is imperative for the proper functioning of the Citytunnel project, receives no investment at all. More environmentally friendly modes of transportation such as bicycle paths and collective transportation, implying handicap adaptation of collective transportation and the creation of "high class" collective bus transportation that offers a fast and comfortable commute even in areas that have not and will not be supplied with train connections, receive 9 and 29% funding respectively. Looking at the two other alternatives, the main trend is that as the total investment increases, percentage investment in roads also increases while percentage investment in collective transportation decreases (road length improvements or construction increases from 35.3 km in the 50% alternative to 142 km in the 150% alternative). From road construction alone, there is an expected 4.8 million kg increase in emissions of CO_2.

In addition to regional infrastructure planning, the national plans include huge investments in national/European roads (9.15 billion crowns) and railways (19.6 billion crowns) whereas national roads intend to improve road standards by way of shorter travel times and increased comfort offering an estimated savings of 1,018,000 hours per year and railways intend to also decrease travel times, but also readjust some tracts to handle heavier, longer and higher trains generally used for goods transport. In particular, the completion of the Citytunnel will free up the "Kontinental track" so that it can be used solely for goods transport. Similar to the regional plan, national road projects are estimated to result in an increase in CO_2 emissions by 10.4 million kg per year. In contrast, its so-called "sector work", which includes empowering different actors to act according to transport-political goals, it estimates an overall reduction in CO_2 emission by 11 million kg per year (Region Skåne, 2003b).

Despite the fact that these plans include high investment in collective transportation and bicycle path improvements and construction, which are both environmentally friendly ventures, doing this in conjunction with tremendous investment in roads can in many ways be counterproductive in regards to minimizing pollution producing transportation. This concept is known as the law of the constant travel time budget, which implies that people spend a fixed amount of their time for traveling and is well established in articles by John Allard and Frank Graham & Partners, 1987 and R. Hertz, 1985 (as cited in Pfeiderer and Dieterich, 1995, p. 29). It is not known if this concept applies to goods transportation, but "it appears that as infrastructure is improved, goods are being shipped over longer distances." (Pfeiderer and Dieterich, 1995, p. 29) The main problem is a simple matter of economics. "…Consumption increases as goods [roads] become more attractive to the consumer," thereby creating a vicious circle (see figure 20) (Pfeiderer and Dieterich, 1995, p. 29)

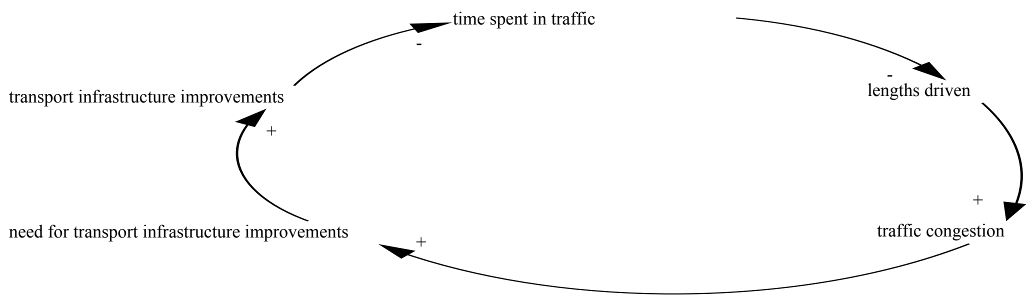

Figure 20: New roads/New traffic causal loop diagram

This in turn can lead to more road traffic and subsequently more pollution that is produced such as CO_2, NO_x and VOCs. In order for there to be a serious jump from road traffic to collective transportation there needs to be a much larger gap between the advantages of the two separate modes of transportation (e.g. a "deacceleration of road traffic") (Pfeiderer and Dieterich, 1995, p. 31)

But what if growth/development in the region produces a significant amount of tax money that can later be reallocated to environmental improvement schemes. This possibility is extremely difficult to predict and quite possibly insufficient in repairing environmental problems that are long-term or irreversible (e.g. global warming). Unfortunately, it is very difficult to make a clear empirical connection between rising temperatures, increasing ground-level ozone levels, allergic reaction cases and their financial drain on society and society's ability to cope with this drain because there are too many factors that make the issue somewhat too complicated to adequately evaluate. However this is the nature of sustainability. According to Dovers and Handmer, 1995, p.92, "The engine of human development in recent centuries, the resolving power of science, has been overrun by the macro-problems of sustainability". For this reason, the Precautionary Principle should be employed. This concept calls for decision makers to prevent serious environmental harm even without scientific certainty of, in this case, possible threats to human health (EEA, 2001, p. 13). In the case of this thesis, this implies the government's investigation into how close these connections are and possible reduction in the amount of road construction in the region. This is a radical interpretation[12] of the precautionary principle which can result in a considerable

[12] radical interpretation or approach – providing for future generations and non-human life even if our obligations can only be carried out with considerable cost.

reduction in growth in the region, but perhaps necessary in regards to possible negative future impacts.

Chapter 8: General Conclusion

At present, Skåne appears to be in a quite favorable state in comparison to many other regions in Europe (and maybe the world) in regards to their air pollution emissions and consciousness of environmental issues and impacts. Nonetheless, due to Skåne's desire to rapidly develop, the region could, in fact, be contributing to a period of serious health and economic degradation in four interconnected ways:

- Increased contribution to the greenhouse effect from traffic (assuming continued usage of today's general motor technology)
- Increased ground-level ozone precursors
- Increased health impairment due to traffic
- Increased costs for health care due to traffic

This thesis has demonstrated that CO_2 emissions from traffic is continuously on the rise and this implies that there also is an increase in motorized vehicle usage. The consequences are an obvious contribution to the greenhouse effect and the perhaps not so obvious effect of increased ozone precursor gases (i.e. NO_x and VOCs), despite statistics showing a decrease. With this increase in precursor gases, due solely to projected motor vehicle usage increases, generally the possibility of ground-level ozone formation is enhanced. This process can further be enhanced by increased days of high temperatures (above 22˚C) brought about by global warming. But there is a flipside to this process. The more traffic the more NO and CO to consume and breakdown O_3 resulting in reductions in O_3 in urban areas. However this is no justification for increasing traffic because increase traffic carries with it other problematic pollutants such as NO_2 and particles. Moreover, although O_3 levels can be reduced in urban areas by increased traffic, outlying areas are at risk for increased ozone levels. Therefore, traffic increases must be halted. Unfortunately, the possibility of road traffic reduction appears to be unlikely especially in light of Region Skåne's RTI-plan which calls for road increases and improvements over the next 11 years. Of course there is money and measures that are set aside to provide people with more environmentally friendly means of transportation, but how well will this affect those who already use roads on a regular basis? What is the incentive for these individuals and companies to switch over to a mode of transportation that will undoubtedly be less convenient? The fact is that it will not, especially if roads expand and improve. These individuals and companies will not only continue to use roads, but will in fact increase their usage in accordance to the law of constant travel time budget. Deacceleration of traffic is perhaps the best motivation for switching over to collective transportation. This of course must occur with improvements in the collective transportation system.

In conclusion, Skåne is probably not a main culprit in its regional temperature increases nor does it play a major roll in its ozone and precursor gas concentrations. On the other hand, its roll will increase in the future and this is a serious challenge to the sustainability of the region. Perhaps, economic growth can support the future health care financing needs, but the question is to what degree can this be done and for how long especially in light of incoming uncontrollable emissions from abroad. Skåne, and for that matter Sweden, must set a good example for other EU countries. It is quite unfair and unwise to continue polluting because it is the lesser of many evils. Eventually, although quite far in the future, it might begin to produce enough ozone precursors which can be converted into ozone and later affect the health of its inhabitants. In this case, exercising a little bit of precaution through transport investment reallocation from roads to collective transportation could quite possible not only be a step in the right direction, but also a necessary prophylaxis for Skåne's most sensitive individuals.

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Appendices

Appendix 1 – Road Construction and Improvement in Alternative Plans (50%, 100%, 150%)

Road number	Priority Object	Road Length	Cost 2004
17	Marieholm Passing, completion	8.5	75
11	Veberöd-Sjöbö, stage by Vomb	2.7	45
21	Hässleholm-Kristianstad, Ignaberga Section	4.8	25
21	Hässleholm-Kristianstad, Önnestad Section	6.8	30
19	Stora Herrestad Passing	3.0	40
108	Holmeja-Klågerup	4.5	80
111	Viken Passing, reimbursment	5.0	65
Total		**35.3**	**50%**

Road number	Priority Object	Road Length	Cost 2004
1950	Markaryd-Osby	20.2	95
11	Veberöd-Sjöbo, excl. Stage by Vomb	6.0	75
111	Traffic Place Brohult-Kulla Gunnarstorp	6.8	46
109	Ekeby-Kågeröd, stage 1	6.7	56
100	Höllviken-Vellinge	4.7	40
108	Stanffanstorp-Lund	3.5	65
1741	Interior Coastal Road Båstad, contract	4.3	22
16	Flädie-Lund	4.0	58
19	Bjärlöv-Hanaskog	7.0	97
11	Tomelilla-Smedstorp	9.2	21
108	Svedala Throroughway	3.0	65
108	Södervidinge-Norrvidinge	5.0	30
13	Assmåsa Passing	2.5	26
23	Ekeröd-Sandåkra	17.0	58
101	Käglinge Passage	4.5	40
119	Broby Entrance	1.5	13
1663	Viby-Fjälkinge	2.5	40
23	Ö Höör	4.5	116
Total		**112.9**	**100%**

Road number	Priority Object	Road Length	Cost 2004
1137	Löddeköpinge-Kävlinge	6.5	58
13	Ljungbyhed-Klippan	17.0	100
16	Lund-Dalby	7.5	79
119	Broby-Glimåkra	5.0	15
119	Stoby- N Sandby	6.0	15
109	Ekeby-Kågeröd, stage 2 (Kågeröd Passing)	3.2	27
108	Klågerup-Staffanstorp	7.3	87
19	Härlöv-Karpalund	2.8	39
11	Smedstorp-Ö Tommarp	6.6	15
21	Klippan-Hyllstofta	14.0	100
19	Degeverga Passing	3.4	60
23	Sandåkra-Stoby	12.3	53
13	Höör-Hörby	8.5	130
21	Hässleholm-Kristianstad	21.0	200
11	Malmö-Kyrkheddinge	10.5	120
108	Svedala-Holmeja	5.5	55
109	Ekeby-Kågeröd, stage 3 (Öster Kågeröd)	4.9	32
Total		142	**150%**

Appendix 2 – Air pollution statistics

Source: (IVL, n.d.a)

Year	Average NO2-N in ug/m3
1985	2.37
1986	2.28
1987	2.13
1988	1.86
1989	2.66
1990	2.36
1991	2.08
1992	1.72
1993	1.98
1994	1.78
1995	1.92
1996	1.77
1997	2.05
1998	1.87
1999	1.66
2000	1.7
2001	1.37
2002	1.39

Source: (IVL, n.d.b)

Year	Average ozone concentration in ug/m3
1985	60.2
1986	59.9
1987	55.1
1988	57.7

1989	56.5
1990	55.0
1991	51.3
1992	56.0
1993	57.4
1994	58.6
1995	59.3
1996	63.0
1997	58.8
1998	54.6
1999	59.1
2000	57.6
2001	60.2
2002	66.6

Source: (IVL, n.d.b)

Year	Number of days with 8hrs ozone concentration average >120 ug/m3
1985	33
1986	21
1987	9
1988	13
1989	18
1990	17
1991	4
1992	18
1993	25
1994	19
1995	17
1996	20
1997	9
1998	4
1999	6
2000	8
2001	4
2002	26

Source: (IVL, n.d.c)

Year	Average Benzene concentration in $\mu g/m^3$	Week max
1993	4.2	8.9
1994	2.6	7.4
1995	2.6	4.8
1996	2.7	6.0
1997	2.2	4.3
1998	2.2	7.5
1999	2.1	5.7
2000	1.7	3.2

Appendix 3 – High summer days in Lund (SMHI, 1986-2002)

Year	Lund-high summer days
1986	10
1987	4
1988	8
1989	26
1990	10
1991	15
1992	21
1993	5
1994	31
1995	32
1996	11
1997	33
1998	1
1999	20
2000	9
2001	22
2002	33