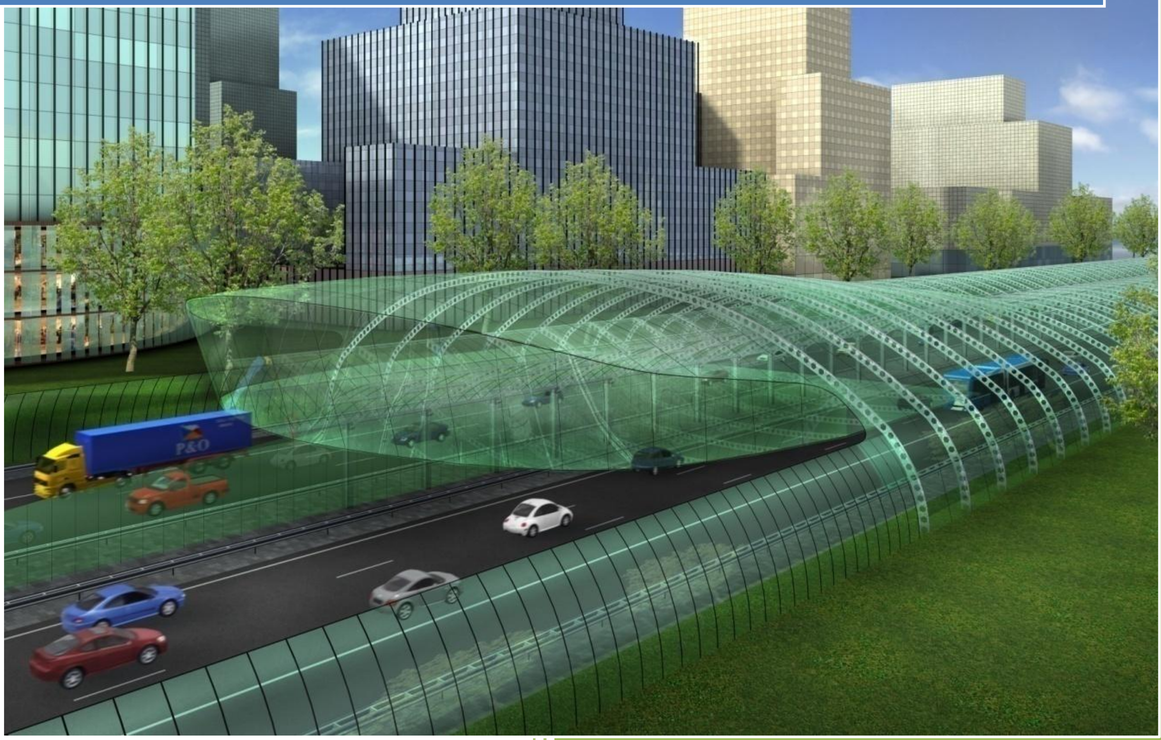
‘The Sustainable Highway’

“A realistic alternative?”



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SPM 5910 Master’s Thesis Project

Delft University of Technology

Movares B.V.

'The Sustainable Highway'

"A realistic alternative?"

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Front page illustration: Artist Impression of 'The Sustainable Highway', source: Movares B.V.

Preface

This thesis was written in conclusion of my MSc in Systems Engineering, Policy Analysis and Management at the faculty of Technology, Policy and Management of the Technical University in Delft. I was given the opportunity by Movares to perform a research project on 'The Sustainable Highway' and was welcomed into their 'Lichte Constructies' team. Spending three days a week in Movares' head office in Utrecht has helped me to comprehend every aspect of the concept. It has also given me an inside view in the frustration people experience when the worlds of technology and politics clash.

During my studies, I have always been fascinated by the interaction between technology and its environment. Working on this project has given me some firsthand experience on the difficult relation these two sometimes have. I found it both interesting and challenging to analyse both worlds and to attempt to find ways of bridging the gap. The result of this exploration is the report which lies before you now.

I would not have been able to conduct this project without the help of many people. I would therefore like to express my gratitude to the graduation committee for their valuable advice. As well as the people at Movares for their expertise and collegiality. Finally I would especially like to thank my friends and family who have successfully endured my endless stories on tunnels of glass.

I wish everyone a pleasant reading.

J.M. Kroon
Delft, January 21st 2010

Executive summary

The Sustainable Highway, consisting of a transparent canopy of cold bendable laminated glass, is a potential solution to negative effects of road traffic. It can be placed over the highway and uses several sub-systems to reduce noise nuisance, local air pollution as well as the emission of CO_2. As a consequence of this reduction, spatial development in general and more specifically the construction of houses becomes possible alongside the highway, where this previously was prohibited by environmental regulations. This research project has investigated the technological and socio-economical feasibility of the concept in addition to possible implementation strategies by answering the following research question:

To what extent can the concept of The Sustainable Highway provide a technologically and socio-economically feasible solution to the negative side effects of road traffic and how could The Sustainable Highway be successfully implemented given the institutional context?

From a technological perspective, The Sustainable Highway is a feasible concept. Technological systems which are applied in the concept are to a large extent proven and an independent second opinion endorses the advantages which Movares claims to offer with this concept. Although several technological uncertainties remain, on the whole the concept provides a technologically feasible alternative to common practices such as a noise barriers or a tunnel.

The socio-economic feasibility of the concept depends on the location in which it will be realised. The possibility for spatial development and the revenues from building land form a large component of the benefits the concept can achieve. Therefore, when The Sustainable Highway is realised on a highway running through a densely populated urban area, where local residents experience severe hindrance from noise and air pollution and where building land can be developed in the area, it is a socio economically feasible alternative.

From an institutional perspective, there has to be a window of opportunity in order to successfully introduce the concept, and the institutional context should not pose additional limitations to the concept. Gaining the support of local parties and forming a consortium of private parties which is able to realise The Sustainable Highway are the first steps towards implementing the concept into its institutional context.

The research project has lead to the following main recommendations:

- It is strongly recommended to implement the process which has been designed. A consortium consisting of private parties will greatly reduce the barriers for implementation. In addition it will create support among local governmental authorities, which is vital to the success of The Sustainable Highway. Parties supporting the concept are likely to actively attempt to realise the project. This will greatly increase the concept's chances when compared to Movares acting alone.
- Monitor the market to identify chances for The Sustainable Highway. Whenever a problem exists with expanding infrastructure, this offers an opportunity for The Sustainable Highway. Should decision makers be forced to look for alternative solutions, this opens a window of opportunity for The Sustainable Highway to be introduced. Since decision makers will then have a sense of urgency, the concept's chances are greatly increased. The market which should be monitored is not limited to the domestic market.
- Additional research has to be conducted on the technological uncertainties that surround the concept. In addition, for locations where a feasibility study is being performed, research on local factors will need to be integrated into these studies. Important local factors include: actor positions and the ability to realise benefits from building land.

Summary

The past decades in the Netherlands have been characterised by a growth in population, economic growth and an accompanying growth in mobility. Mobility is not only influenced by economic growth, it is also a prerequisite for further growth. Unfortunately, a growth in mobility and especially a growth in road traffic, leads to the increase of several negative effects. Not only do local inhabitants suffer from health problems and noise nuisance due to nearby roads, road traffic in the Netherlands is also a major contributor to the country's total emissions of CO_2. In attempting to reduce these measures, the Dutch government reaches for proven solutions such as noise barriers, tunnels and measures at the source. New, innovative solutions, often encounter resistance.

One of these new solutions is 'The Sustainable Highway'. The Sustainable Highway is specific concept, developed by Movares, which consists of a glass canopy covering the highway and thereby eliminating all noise nuisance and air pollution alongside the road. The air will be filtered, so the emission of pollutants at the canopy ends is reduced to a minimum. Heat, which accumulates under the canopy, can be used to heat nearby homes and prevent the road surface from freezing in winter. Solar panels, which can be placed between the sheets of glass, generate renewable energy. By applying this concept, building land becomes available, in places where currently environmental restrictions prohibit building next to the highway.

There are a number of uncertain factors surrounding The Sustainable Highway. The concept is an innovation and has never been realised; this inherently means uncertainty surrounds the concept. Furthermore, the concept's investment costs are substantial; it is uncertain whether socio-economic benefits can compensate (some of) the concept's investment costs. Finally, should the concept be technologically and socio-economically feasible, it is uncertain how the concept should be implemented, given its complex institutional context. Therefore, the main research question is as follows:

To what extent can the concept of 'The Sustainable Highway' provide a technologically and socio-economically feasible solution to the negative side effects of road traffic and how could The Sustainable Highway be successfully implemented given the institutional context?

In order to answer this question, the research project is divided into two parts. First, the system will be analysed from a technological and socio-economical perspective, leading to conclusions on the feasibility of the concept. Second, the institutional context of The Sustainable Highway will be the subject of analysis, providing input to formulate recommendations on how an institutional design and process design can be used to implement the concept into its institutional context.

System analysis
The concept of The Sustainable Highway intends to mitigate several of the negative effects caused by road traffic. These effects are: noise nuisance, the emission of polluting substances with adverse effects on public health and local quality of life (such as NO_x and fine particulate matter (PM)), in addition to the emission of the greenhouse gas CO_2.

The concept of The Sustainable Highway consists of a canopy of cold bendable, laminated glass (Freeformglass ®), which is placed over both carriageways of a highway. The glass panels allow daylight to enter and block all noise and air pollutants from reaching the area around the highway; by doing so, creating a noise reduction of 5 to 20dB(A) compared to noise barriers. Without additional measures, the highly polluted air would exit the canopy at both entrances. A reduction of the concentration of PM can be achieved by electrostatic filtering, whilst adsorption by active carbon cleanses the air of NO_x (and SO_x). By utilising the natural air flow caused by traffic under the canopy, in combination with innovatively shaped canopy entrances, a natural circulation of air is created. This increases the percentage of polluted air which can be filtered. By eliminating the emission of air pollutants and noise alongside the canopy, public

health and quality of life is increased. In addition, building becomes possible in locations where this was previously restricted due to environmental regulations. Since daylight can enter and vehicles emit heat, the temperature under the canopy may rise in summer, making cooling necessary. The concept accommodates this by placing heat collectors in the asphalt. These collectors cool the highway in summer, storing excess heat in the ground water. This heat can be pumped up in winter to heat the road surface and nearby homes. The natural gas which is saved by using this system to heat homes is equivalent to an emission of 1000 tons of CO_2 per kilometre per year. By using a different type of asphalt, cooling the asphalt and shielding it from weather influences, its lifespan is greatly increased, reducing road maintenance. Finally, solar panels can be placed between the sheets of glass to generate solar energy. By covering 25% of the canopy with solar panels, up to 1350 MWh of green energy can be generated per kilometre per year.

A second opinion has been performed on the concept by the engineering office of the city of Rotterdam to assess the technological feasibility of the concept. It has confirmed that the goals with regards to noise reduction, cooling, using heat, structural integrity, increased life of road surface, availability of building land and solar energy are all feasible. It has established that during operation of the concept no additional congestion is to be expected, whilst during construction a modular construction process can ensure hindrance is kept to a minimum. With regard to safety, the concept is safer than a tunnel, because of daylight entering the structure and a larger spatial profile, even though it is currently governed by tunnel law. A factor that remains uncertain is the efficiency of the filtering installations, which still remains to be proven in coverings with a larger spatial profile than a normal tunnel. Furthermore, it is uncertain how much of the air can be recirculated. In addition, the heat which is stored in the groundwater cannot be used to feed into a district heating system, although other applications are possible. Since the concept has never been constructed, it is uncertain how users will experience driving through the canopy. These factors require additional research. When the concept is compared to alternative solutions such as noise barriers and tunnels, socio-economical factors need to be evaluated. With regard to the technological feasibility of the system, it can be concluded that on the whole, the system can be considered to be technologically feasible.

Socio-economical feasibility

To assess the socio-economical feasibility of The Sustainable Highway, a cost-benefit analysis (CBA) is performed. A CBA is mandatory for special infrastructure projects in the Netherlands and by far the most common form to appraise the socio-economical costs and benefits of an infrastructure project throughout Europe. A CBA is not only part of decision making procedures; it is also used as a tool to convince other stakeholders of the socio-economical effects of a project. In order for other stakeholders to perceive the CBA to be valid, it must be transparent and objective. In order to guarantee transparency and objectivity in the use of cost-benefit analyses in the Netherlands, the OEI-guideline was drawn up by the Dutch government in the year 2000. This guideline standardises the way in which cost-benefit analyses are conducted for infrastructure projects in the Netherlands, so political decisions can be made based on the correct information regarding cost and benefits of such a project. A four-phase approach by the consulting firm BCI, based on the OEI-guideline, is used to analyse the socio-economical costs and benefits of The Sustainable Highway.

In early 2009, a CBA on The Sustainable Highway was performed by an external agency based on the second opinion of the engineering office of the city of Rotterdam. This analysis concluded that: “The Sustainable Highway can be an interesting alternative to other infrastructural solutions from the perspective of social costs and benefits” (Decisio BV, 2009). However, this analysis is very generic in nature and an additional location specific, more detailed CBA is needed. The original CBA concluded that locations, in which the building of houses close to the highway is desired, but currently not possible due to environmental regulations, would be interesting for The Sustainable Highway. Such a location has been selected within the city of Rotterdam. The location which is analysed in the CBA is a section of the A20 ring road in the north of the city. In this location, local residents experience severe hindrance from the highway. In addition, potential building land is available alongside the highway. By including the development of building land in the project, the problem is reframed as a spatial development problem rather than just an infrastructure problem.

The results of the location specific CBA show a favourable outcome for The Sustainable Highway. The Sustainable Highway is compared to common solutions to noise nuisance, being: noise barriers (10 and 15 metres high respectively, named zero and zero+ alternative,), a sunken highway and a tunnel. Of all alternatives, The Sustainable Highway has by far the most positive benefit-cost ratio (Table 1).

Table 1, resulting NPV of socio-economic costs and benefits (in millions of euros)

	Zero alternative	Zero+ alternative	The Sustainable Highway	Sunken Highway	Tunnel
Balance of direct effects	-22,0	-34,6	-9,6	-90,0	-88,2
Balance of external effects	10,1	12,2	29,0	16,2	20,3
Total	-11,8	-22,4	19,4	-73,8	-67,9

The effects that contribute most to this positive ratio are the building land benefits (39,6 million euros) and the benefits from the reduction in noise nuisance (20,3 million euros). Other contributing effects include financial benefits from marketing renewable energy and a reduction in road surface maintenance. In addition, socio-economic benefits such as emission reduction and (marginal) traffic flow effects contribute towards The Sustainable Highway's positive Net Present Value. These socio-economic benefits fully compensate the concept's high investment costs (56,7 million euros) and maintenance costs (7,1 million euros). Some of the effects are influenced by uncertainty, especially the benefits which can be obtained by marketing building land. The possibility of obtaining the revenues from building land is dependent on whether the land is currently available and owned by the party which attempts to realise The Sustainable Highway. If this is not the case, the building land will need to be obtained, carrying with it significant additional investment. However, a sensitivity analysis confirms the model is robust for changes in the starting assumptions. Therefore, it may be concluded, that in this location The Sustainable Highway is a socio-economically feasible solution.

From the first part of this research project, the conclusion can be drawn that: The Sustainable Highway can be a technologically and socio-economically feasible solution to the negative effects of road traffic in certain locations. These locations being: a highway running through a densely populated urban area, where local residents experience severe hindrance from noise and air pollution and where building land can be developed in the area.

Institutional context

Although The Sustainable Highway might be a technologically and socio-economically feasible solution, it is not being executed in a vacuum, but in a highly complex institutional context. This context may impose additional conditions on the feasible implementation of the concept. The institutional context of The Sustainable Highway is composed of four layers, as has been identified in the four-layer model by Koppenjan & Groenewegen (2008). The institutional context of The Sustainable Highway is composed of laws and decision making procedures (layer 2), stakeholders, their positions and interactions (layer 4) in addition to cultural aspects (layer 1) and the perceptions these stakeholders have of The Sustainable Highway. Institutional arrangements, which are normally present in layer 3, do not yet exist since The Sustainable Highway is a new system. This offers the possibility to design these institutions. The institutional design will later be used to coordinate the relations and responsibilities between actors[1].

[1] In this research project the term 'actors' is used synonymously with the term 'stakeholders'

When The Sustainable Highway would be part of a larger project, involving the capacity increase of a highway, it would be governed by the tracélaw. Decision making procedures are clearly outlined, but involve making a 'tracédecision', which might be a time consuming process. When The Sustainable Highway is constructed as a stand-alone project a building permit will need to be issued. The project will need to comply with the zoning plan, which it is unlikely to do, since it is a new concept. A 'project decision' will need to be taken to incorporate the project into the zoning plan. In any case, the project will need to comply with the tunnel-law, since it is likely to be over 250 metres long. Currently no exceptions to the tunnel-law exist for transparent canopies, although this has been recommended by the commission for tunnel safety. The tunnel-law currently imposes serious restrictions on the design of The Sustainable Highway.

The method of actor analysis by Enserink (2004; 2009) is used to analyse the actor field that is part of the institutional context of The Sustainable Highway. Whilst a specific location is needed to analyse actor positions in detail, actors which are a part of the general institutional context of The Sustainable Highway can be identified. A number of these actors are interviewed on their perceptions of the concept in general and specifically on its perceived feasibility. All respondents agree that the concept of The Sustainable Highway is technologically feasible, although they accede to the fact that some uncertainties still surround the concept. Most respondents state that the concept is economically feasible, although conditions which need to be satisfied for the concept to be considered as economically feasible are mentioned. The condition that is mentioned most often is private funding in the form of building land benefits. In addition, several barriers for the implementation of the concept have been identified by the respondents. A barrier, experienced by most of the respondents is the general scepticism towards a concept which is innovative and thus by nature: not proven in practice. The actors which appear to be most sceptical are the Ministry of Transport and its division Rijkswaterstaat, which are responsible for decision making on national highways. Other barriers include the concept's high investment costs, the costs coming from a different source than the benefits and the fact that the benefits from building land might be difficult to realise. These barriers can be dealt with in the design of an institutional arrangement and process design.

The institutional context is applied to the same location which is used in the analysis of the socio-economic costs and benefits of the concept: the A20 in the north of Rotterdam. The actor field is analysed in detail, which leads to the following concluding table:

Table 2, conclusion of actor analysis

	Dedicated actors		Non-dedicated actors	
	Critical actors[2]	**Non-critical actors**	**Critical actors**	**Non-critical actors**
Similar / supportive perceptions, interests and objectives	The Lower chamber Ministry of Housing Municipal authorities Municipal divisions Political parties	Province of South-Holland Urban Region Rotterdam Borough councils Rotterdam Climate Initiative Environmental groups Residents' organisations Local residents ROM-Rijnmond	Property developers Building contractors Energy companies	Housing corporations Stedin Suppliers of components Universities Research institutes Road users' organisations Road users Energy consumers Ministry of Economic Affairs
Conflicting perceptions, interests and objectives	Ministry of Transport Rijkswaterstaat Commission tunnel safety Political parties			

[2] Whenever the term 'critical' actor is used in this thesis, critical is synonymous with 'crucial' and is no indication of the actor's attitude.

Most actors which are part of the institutional context are in the top half of the table, leading to conclusions that more proponents than opponents to the solution are present. However, two critical actors currently oppose the proposed solution, making the concept difficult to implement. The city of Rotterdam, however, appears to be a good location for The Sustainable Highway. It is a city with a progressive environmental policy, which has already shown interest in an innovative solution such as The Sustainable Highway. If there is an institutional context in which The Sustainable Highway is a feasible alternative, it will be similar to that in Rotterdam. The analysis of both the institutional context and socio-economic feasibility suggests the A20 in Rotterdam as an ideal location for The Sustainable Highway. Although much is in favour of the location, a very important institutional factor is lacking: a window of opportunity. Although local residents experience severe hindrance near the A20, there are other locations in Rotterdam which receive more public attention. In other words: the sense of urgency in other locations is bigger. Furthermore, no measures reducing the negative effects of road traffic are planned for the A20, meaning no window of opportunity is present to introduce the concept. This leads to the conclusion that similar locations to the A20 in the North of Rotterdam are highly suitable for the realisation of The Sustainable Highway. However, a window of opportunity is required to introduce the concept. Even in a location where a window of opportunity exists, the concept is highly complex to implement. Therefore an institutional design and process design are needed to remove the barriers that stand in the way of a successful implementation.

Institutional design

To implement The Sustainable Highway, a number of different parties are needed which are willing to participate in a Public Private Partnership (PPP). Institutional arrangements coordinate the functioning of the actors involved in the socio-technological system and formalise relations and responsibilities. The execution of these institutional arrangements only becomes relevant when The Sustainable Highway moves past the earlier stages of planning. However, in identifying a possible institutional design now, the required parties and their functions become clear, providing information on which parties should be involved in the process. Responsibilities for the following functions need to allocated among a number of different parties: the concept will need to be designed, built, financed, operated and maintained. Designing, building and maintaining applies to the canopy, energy system, and spatial development. Furthermore, the energy system will need to be operated, while the entire concept will need to be (partly) privately financed and funded. Figure 1 shows one possible way of allocating these responsibilities.

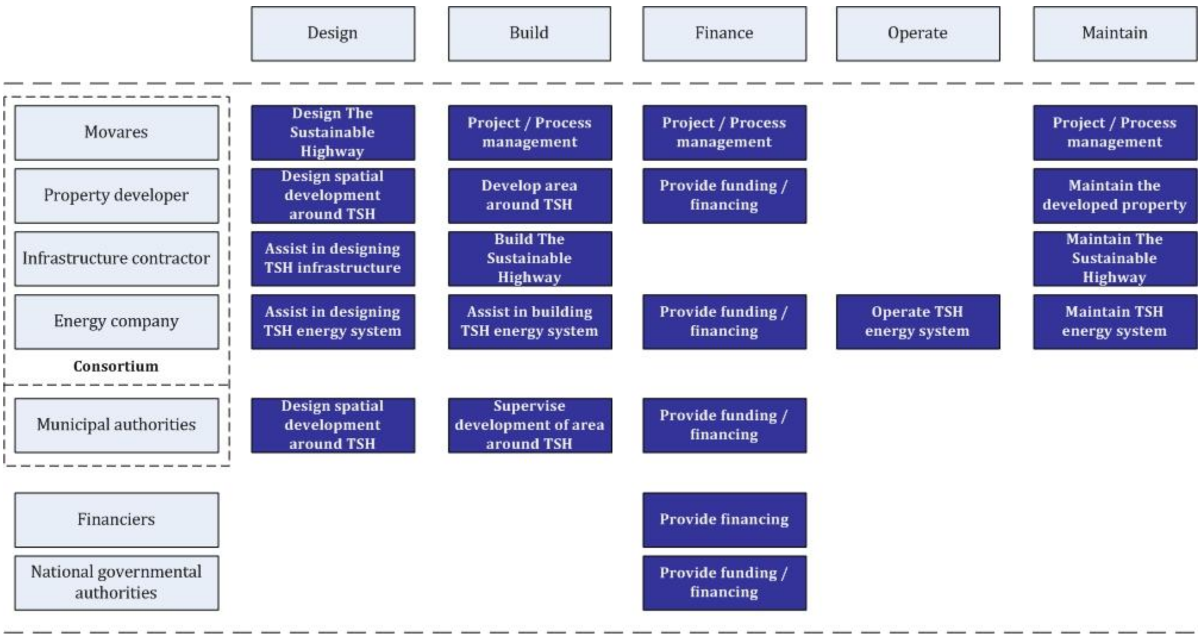

Figure 1, the roles and responsibilities in a potential Public Private Partnership

Such a Public Private partnership will require cooperation between a private consortium and local governmental authorities. Both are equally important for the feasibility of The Sustainable Highway. This consortium will need to have sufficient expertise to take on the responsibility associated with realising The Sustainable Highway. Although the institutional design in Figure 2 provides an indication, the final institutional arrangements will have to follow from a process involving all relevant stakeholders.

Process design

For the institutional design to be successful, a consortium is needed consisting of the parties shown in Figure 1. To realise such a consortium, in addition to the support of local governmental authorities, a process design can be used. The four core elements of process design are taken as boundary conditions and a starting point for the process design. These core elements are: openness, protection of core values, speed and substance. To incentivise parties to join the process, they should experience a process of gain. This means that parties feel that if they participate in the process, their position will be improved. For private parties, this can be financial gain, while for public parties, this can be the solving of a long lasting problem. Furthermore, to incentivise parties to join now rather than later, they should experience a sense of urgency. For private parties, this can be achieved by competition in the market: if a private party does not join now, a competitor might join the process before he can. When parties in the process experience a prospect of gain in addition to a sense of urgency, they will work to bring the process to a favourable outcome, bringing the realisation of The Sustainable Highway a step closer. The power of a consortium lies in its ability to arrange private funding, the ability to transfer risks from public parties to private parties, the ability to distribute costs and benefits equally and the ability to influence other actors in the network. The existence of a consortium in addition to the support of local parties greatly reduces the barriers which have been identified.

Conclusions

The previous considerations lead to the following conclusions to the main research question: from a technological perspective, The Sustainable Highway is a feasible concept. Technological systems which are applied in the concept are to a large extent proven and a second opinion endorses the advantages which Movares claims to offer with this concept. Although several technological uncertainties still exist, on the whole, the concept provides a technologically feasible alternative to common practices such as a noise barriers or a tunnel.

The socio-economic feasibility of the concept depends on the location in which it is realised. The possibility for spatial development and the revenues from building land form a large component of the benefits the concept can achieve. Therefore, when The Sustainable Highway is realised on: a highway, running through a densely populated urban area, where local residents experience severe hindrance from noise and air pollution and where building land can be developed in the area, it is socio economically feasible.

From an institutional perspective, a window of opportunity has to exist and the institutional context should not pose additional limitations to the concept. By executing the institutional and process designs, The Sustainable Highway can be implemented into its institutional context.

Recommendations

The research project has lead to several recommendations, some of which are meant to facilitate the implementation of the concept, while others are more academic in nature. Since the recommendations on the implementation of the concept were the goal of the research project, these will be presented here. For all academic recommendations, refer to Chapter 8. The most important recommendations on implementing the concept are as follows:

- It is strongly recommended to implement the process which has been designed. The existence of a consortium will greatly reduce the barriers which have been identified. The existence of a consortium binds additional parties to the concept. These parties are likely to actively attempt to realise the project. This will greatly increase the concept's chances when compared to Movares acting alone.

- Monitor the market to identify chances for The Sustainable Highway. Whenever a problem exists with expanding infrastructure, this offers an opportunity for The Sustainable Highway. Should decision makers be forced to look for alternative solutions, this opens a window of opportunity for The Sustainable Highway to be introduced. Since decision makers will then have a sense of urgency, the concept's chances are greatly increased. The markets which should be monitored are not limited to domestic markets.
- Additional research has to be conducted on the technological uncertainties that surround the concept. In addition, for locations where a feasibility study is being performed, research on local factors will need to be integrated into these studies. Important local factors include: actor positions and the ability to realise benefits from building land.

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1. Introduction

1.1 Problem context

The past decades in the Netherlands have been characterised by growth. Growth of the population, economic growth and an accompanying growth in mobility (Table 1-1). Mobility is not only influenced by economic growth, it is also a prerequisite for further growth. The role of mobility as a driver for societal and economic growth is underlined by the Dutch Ministry of Transport: "Whereas government policy previously viewed mobility as a problem or as something permissible, the assumption is now that mobility is a must. Mobility, for people as well as goods, is a prerequisite for society and the economy to function well"(Ministry of Transport, Public Works and Water Management (V&W), 2008).

Table 1-1, Causes of the growth of road traffic(Kennisinstituut voor Mobiliteitsbeleid (KiM), 2008).

	1985-2007		2002-2007	
Causes	Change in factor	Relative contribution to change in road traffic	Change in factor	Relative contribution to change in road traffic
Inhabitants 20-65 years of age	+16%	+16%	+1%	+1%
Gross Domestic Product (GDP)	+80%	+42%	+11%	+8%
Fuel prices	+17%	-3%	+20%	-3%
Capacity of main roads	+28%	+8%	+5%	+3%
Unknown		+4%		-2%
Total		+67%		+7%

Consequently, mobility fulfils a critical societal and economic function and therefore limiting mobility will limit societal and economic growth. Unfortunately a growth in mobility, and especially a growth in road traffic, leads to several negative external effects. Not only do local inhabitants suffer from health problems and noise nuisance due to nearby roads, road traffic in the Netherlands is also a major contributor to the country's total emissions of CO_2 and thus to the country's carbon footprint. The Dutch cabinet aims to reduce these negative effects: "The cabinet wants to let the economy grow and to provide space for traffic and transport while simultaneously limiting the negative effects of this traffic" (Ministry of Transport, Public Works and Water Management (V&W), the Ministery of Housing, Spatial Planning and the Environment (VROM), 2005),

Clearly these negative effects are high on the political agenda in the Netherlands. Specifically, substantial effort is put into local, regional and national plans to reduce many kinds of air pollution and noise nuisance. The European Commission has created norms for air quality and the Dutch ministry of environmental affairs has called clean air a 'condition of life'(Ministry of Housing, Spatial Planning and the Environment (VROM), 2007).

Table 1-2, Trends regarding mobility and emissions in the Netherlands(KiM, 2008)

	2002-2007	In 2007	2007-2012
Road traffic in the Netherlands	+7%	130 billion km	+11 to +14%
Road traffic on main roads	+9%	63 billion km	+9 to +12%
Loss of travelling time on main roads	+39%	68 million hours	+29 to +46%
CO_2-emissions road traffic (figures of 2006)	+7%	35 billion kg	+9 to +13%
NO_x-emissions road traffic (figures of 2006)	-19%	125 million kg	-24 to -26%
PM_{10}-emissions road traffic (figures of 2006)	-25%	8 million kg	-41 to -43%

All these efforts have resulted in a decrease of certain types of air pollution such as NO_x and fine particles (PM) (table 1-2), which are both a cause of health problems of local inhabitants. Despite this reduction, the original policy goals with regard to air quality are not met in time and it is uncertain whether the target figure for CO_2 reduction will be achieved(Algemene Rekenkamer, 2009). Norms are still being exceeded on specific locations, especially close to important national highways. Local inhabitants are experiencing significantly more hindrance from air pollution than is the average nationwide.

The discussion on emissions caused by road traffic in the Netherlands is mainly concentrated on the emissions of fine particles (PM), nitrogen dioxide (NO_2) and carbon dioxide (CO_2)(Algemene Rekenkamer, 2009). Fine particles or ‘airborne particulate matter’ (PM) is notorious for its adverse effects on public health. According to the World Health Organisation (WHO), the range of health effects is broad, but is predominantly to the respiratory and cardiovascular systems(World Health Organisation (WHO), 2006). Furthermore, all population is affected, but susceptibility to the pollution may vary with health or age. As such, the most vulnerable groups in society, such as elderly people and children are affected most. According to the WHO, the more a person is exposed to fine particles, the higher the health risks associated with it; furthermore, there is little evidence to suggest a threshold below which no adverse health effects would be anticipated. The severity of the situation is illustrated by the standards the European Union has set for the concentrations of PM_{10}. Unfortunately these standards are still being exceeded at specific locations in the Netherlands such as at certain places in Rotterdam, up to 42 days a year (DCMR Milieudienst Rotterdam, 2008).

Nitrogen dioxide is a gas which, in the Netherlands, has road traffic as its main source. In large concentrations it can cause health problems. The concentrations that exist in the Netherlands are unlikely to pose a great threat to local residents’ health in itself. However, NO_2 is also an indicator for a cocktail of other pollutants emitted by road traffic that can cause health problems. NO_2 norms are currently still being exceeded in several places in the Netherlands, especially in the vicinity of busy highways, although a downwards trend is clearly visible(Ministry of Housing, Spatial Planning and the Environment (VROM), 2008).

Another air pollutant of which road traffic is an important contributor is carbon dioxide (CO_2). The ‘Traffic and Transport’ sector in the Netherlands is responsible for 19% of the Netherlands’ total emissions of greenhouse gasses(Algemene Rekenkamer, 2009). In order to reach The Netherlands’ objective for CO_2 reduction, a substantial reduction must come from the transport sector.

Besides the emission of unwanted substances, traffic is also responsible for a large proportion of noise nuisance experienced by residents in the Netherlands. The number of people experiencing noise nuisance caused by road traffic in the Netherlands has increased from 27 percent in 1997 to 31 percent in 2008 (figure 1-1). Clearly, this is a problem which affects large numbers of the Netherlands' inhabitants. The law on noise nuisance sets 48 dB as the maximum noise load at the house front(Staatsblad, 1979), but in practice this standard is now only used as a guideline.

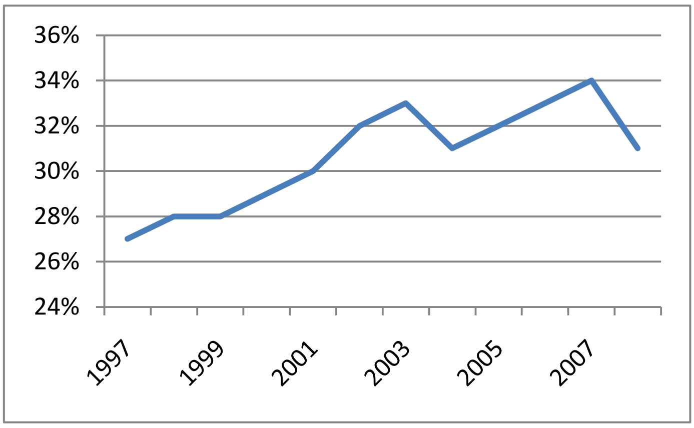

Figure 1-1, People in the Netherlands experiencing noise nuisance from road traffic (CBS), 2009)

Noise is not merely a nuisance; it can also cause health problems. At 65 dB, for example, the health of one fifth of the population is seriously affected. Furthermore, above this noise level, clinical syndromes begin to appear(Ministry of Housing, Spatial Planning and the Environment (VROM), 2004). In the Netherlands, over 400.000 households experience this noise load of over 65 dB (Table 2-1).

Table 1-3, homes on roads experiencing a noise load higher than 60dB(Algemene Rekenkamer, 2009)

	60 < x < 65 dB (not urgent)	x > 65 dB (urgent)	Total x > 60 dB
Local roads	623.683	369.641	993.324
Provincial roads	54.840	26.770	81.610
State roads	21.100	6.300	27.400
Total in the Netherlands	699.623	402.711	1.102.334

Another important consequence of all these negative effects of road traffic (besides all the effects on public health and climate change) is that obtaining permits for the expansion of infrastructure is becoming increasingly difficult due to stricter Dutch and European legislation regarding noise nuisance and air pollution. In other words: the extension of infrastructure in the Netherlands is limited by its own negative effects. This is underlined by the national mobility monitor, illustrating an additional loss of travelling time of 57 percent between 2000 and 2007 due to congestion. Capacity measures have reduced this figure by eleven percent. An additional reduction of four percent could have been achieved by measures, however these measures were not executed due to reasons regarding air quality(Stuurgroep Nationale Mobiliteitsmonitor, 2008).

Naturally, several measures which mitigate negative effects are available and commonly used. There are soot filters to reduce fine particles, screens to prevent sound from causing nuisance, and tunnels to block all traffic nuisance from reaching local residents. However, these solutions are sometimes only long-term solutions that require a lot of time to take effect, only deal with one negative effect, or are simply extremely costly to implement. Clearly, no easy solution is yet readily available; this is a situation of high technological complexity. All potential solutions contribute towards a mitigation of the negative effects, but all solutions have both advantages and disadvantages. An ideal or 'best' solution that counteracts the aforementioned negative effects has not yet been found. In an attempt to find a structural and sustainable solution to these negative side effects of road traffic, Movares B.V. has developed the concept of 'The Sustainable Highway'[3].

The concept of 'The Sustainable Highway' consists of a highway canopy of cold-bendable laminated glass. The canopy blocks almost all traffic noise to the environment and air can be filtered so that a significant reduction in air pollution can be achieved. Furthermore, excess heat that accumulates under the canopy in summer can be stored in the groundwater and be used in winter for heating homes in the vicinity of the highway or for heating the road surface to prevent it from freezing. Solar cells can be integrated in the glass to generate renewable energy and help reduce the Netherlands' carbon footprint(Vákár L. , 2008). As a positive side effect, it will become possible to build houses closer to the highway than is currently the case, because standards regarding noise and air pollution would no longer be exceeded alongside The Sustainable Highway. In densely populated areas, this will provide for many square meters of new, valuable building land. Of course, in a competitive open market such as this, there are other parties developing different types of highway coverings. However, not one of these is being built yet, or is already in place. In this respect, the concept of The Sustainable Highway is unique in the Netherlands and possibly in the world.

The Sustainable Highway certainly appears to offer opportunities, however it is also surrounded by many uncertainties. It is a technologically complex solution, of which not all effects are known or can yet be economically appraised. Furthermore, the context in which The Sustainable Highway could be implemented is characterised by a large institutional complexity. It is unsure *if* The Sustainable Highway can provide a technologically and economically viable solution to the negative effects of road traffic and *how* it could be implemented.

To Summarise: the increased mobility in the Netherlands has both its advantages and disadvantages. Many advantages are both national as well as local in nature, whilst most emissions are discharged on a local scale. The challenge is to look at solutions which mitigate the negative effects of road traffic without compromising the advantages the increased mobility offers. Current measures do not provide an integrated solution for all of these negative side effects. 'The Sustainable Highway' might provide a structural and sustainable solution.

Now that the problem is clearly identified, the objective of the research project needs to be identified. The remainder of this research proposal will discuss the proposed research project, its objective and structure.

1.2 Research description

1.2.1 Research objective and demarcation

The previous paragraph explored the problems regarding mobility in the Netherlands and presented a potential solution. However, with regard to this solution, several knowledge gaps have been identified. The objective of this research project is to fill the gaps regarding technological and institutional complexity and to identify possibilities to implement The Sustainable Highway, if it is indeed deemed to be a feasible concept. The research objective is therefore as follows:

To identify to what extent the concept of The Sustainable Highway can be a feasible solution for the negative effects of road traffic and to make recommendations on ways to successfully implement The Sustainable Highway in the institutional context.

[3] 'The Sustainable Highway' is the name of the concept which has been develop by Movares. The name is written with three capital letters.

The research objective is clearly bipartite in nature. First, it is important to look at the technological system in all its facets and to determine whether or not The Sustainable Highway is indeed as promising a solution as it seems. If The Sustainable Highway is indeed deemed to be a feasible solution, there are still many difficulties to overcome to implement it into the institutional context. If The Sustainable Highway is deemed feasible, the second part of the research project will therefore have to consist of an analysis of the institutional context. Then the compatibility of The Sustainable Highway with this institutional context can be assessed and a process for successful implementation can be designed.

To answer the first part of the research question, theory on system analysis and the appraisal of the system's effects can be used. For the second part, theory on actors and networks as well as process management and institutional arrangements can play an important role. The theoretical basis can be found in scientific literature, whilst information on the concept of The Sustainable Highway shall be provided by Movares. However, it is important to strive for independent sources of information, especially in determining the feasibility of the concept.

When referring to the concept of The Sustainable Highway, the specific concept which has been developed by Movares is meant. No other light highway coverings are the subject of analysis. In addition, when referring to negative side effects of road traffic in this research project, mainly air and noise pollution and all consequences for the environment and public health are meant as well as spatial planning issues. Of course, these are not the only negative side effects of road traffic. Congestion and safety issues are among some of the other negative side effects that road traffic causes. However, though important, these factors will not be the main subject of this research project. The Sustainable Highway is not designed to counteract these effects and therefore the effects of The Sustainable Highway on these factors will only be briefly discussed. Where The Sustainable Highway does have a possible (negative) effect on these factors, possible concerns will be discussed. However, since this will not be the focal point of this research project, the effects will be mentioned, but not analysed in depth. The emphasis will be on air and noise pollution as well as spatial planning issues and wider climatological problems.

This research project is conducted as a master thesis as a part of the System Engineering, Policy Analysis and Management Masters program of Delft University of Technology. The research project is commissioned by Movares, the designer of the concept. Movares is specifically interested in how to implement The Sustainable Highway, since explorative research on the technological side of the concept has already been conducted (to a certain extent) by Movares. A balance will need to be struck between Movares' commercial interests and the more academic interests that are in line with the TU Delft.

1.2.2 Research questions

The problem definition and research objective have been identified and demarcated in previous sections. Based on this, the main research question can be formulated as follows:

To what extent can the concept of The Sustainable Highway provide a technologically and socio-economically feasible solution to the negative side effects of road traffic and how could The Sustainable Highway be successfully implemented given the institutional context?

As in the research objective, the main research question is clearly bipartite. The sub questions that shall be used to answer the main research question will therefore be divided into two parts and the two parts, including their sub-questions, will be formulated as follows:

Part I: To what extent can the concept of 'The Sustainable Highway' provide a technologically and socio-economically feasible solution to the negative side effects of road traffic?

1. *To what extent do the sub-systems of The Sustainable Highway intend to mitigate the negative external effects of a 'normal' highway and to what extent is the concept of the Sustainable highway technologically feasible?*
    a. What does the system of a 'normal' highway look like and what are its negative external effects?
    b. Of which technological sub-systems is The Sustainable Highway comprised and what are the sub-systems' intended effects?
    c. What are technological uncertainties with respect to The Sustainable Highway's sub-systems and their effects?

2. *What should a theoretical framework, that can be used to evaluate the socio-economic feasibility of The Sustainable Highway, look like?*

3. *What are the (social) costs and benefits of The Sustainable Highway and to what extent is the system socio-economically feasible?*

Part II: If deemed feasible, how can The Sustainable Highway be successfully implemented given its institutional context?

4. *What components make up the general institutional context of The Sustainable Highway and how do these components influence the feasibility of the concept?*
    a. Of what components is an institutional context comprised?
    b. What does the general institutional context look like in relation to The Sustainable Highway?
    c. How does the general institutional context affect the feasibility of The Sustainable Highway?

5. *How can the institutional context of The Sustainable Highway be applied to a specific location, and how does this influence the compatibility of the concept with its institutional context?*
    a. What would be a suitable location to apply the general institutional context of The Sustainable Highway to?
    b. What does the specific institutional context of The Sustainable Highway look like for this location?
    c. What consequences does the specific institutional context in this location have on the compatibility of The Sustainable Highway with its environment?

6. *How can the compatibility of The Sustainable Highway with its institutional context be improved?*
    a. What role can an institutional- and process-design play in the implementation of The Sustainable Highway?
    b. What should an institutional design to implement The Sustainable Highway look like?
    c. What should a process design to implement The Sustainable Highway look like?

1.2.3 Research approach

This paragraph aims to further clarify the research questions as formulated in the previous section. The research is divided into two parts and in the first part, explicitly a neutral standpoint is taken. The first part of the research project has as its goal to determine to what extent the concept of The Sustainable Highway is a technologically and socio-economically feasible solution, from an academic standpoint. Although information from Movares will be used in the analysis of the system, the aim is to verify all information so that an unbiased conclusion on the feasibility of the concept can be drawn. In the second part of this research project, should the concept turn out to be feasible, the implementation problem around The Sustainable Highway,\ will be approached from Movares' standpoint. Again, the aim is to provide an unbiased advice; however, the analysis will be performed from the viewpoint of Movares.

The first part starts with a system analysis of a 'normal' highway with the emphasis on what negative external effects a highway generally produces. The Sustainable Highway consists of several sub-systems, using different technologies such as cold-bendable laminated glass and electrostatic filtering, which are all intended to mitigate one or more of these negative external effects. After the analysis of a 'normal' highway a detailed system analysis of the Sustainable highway and its sub-systems will follow. Some of the technologies that have been used are proven, while some uncertainty exists around other technologies. Therefore, each subsystem of The Sustainable Highway needs to be tested for technological feasibility both individually and as part of the complete system. The effects which The Sustainable Highway can have are expected to vary in strength and occurrence on different locations (Gemeente Rotterdam Gemeentewerken, 2009). Special attention will therefore be paid to location specific factors.

In order to be able to financially appraise the effects of The Sustainable Highway a theoretical framework is needed. Since the year 2000 a (social) cost benefit analysis (CBA) is a prerequisite for all infrastructure projects in the Netherlands 'of national interest', and this method will therefore be discussed and evaluated (Ministry of Transport, Public Works and Water Management (V&W) and the Ministry of Economic Affairs, 2000). There are however, different views on the appraisal of certain effects in a CBA (Brent R. J., 1996) and a discussion on the appraisal of different effects will lead to a theoretical framework to assess these effects.

With the framework from the previous section in hand, the social costs and benefits of The Sustainable Highway will be assessed. This is especially relevant since only a very general, high level cost-benefit analysis is available at the moment and no location specific, or detailed cost-benefit analysis has been done to date. With the conclusions of these three sub-questions, conclusions on the extent of the technological and socio-economical feasibility of The Sustainable Highway can be drawn. Should the concept of the Sustainable highway be deemed feasible, part II of the research project will determine how The Sustainable Highway can be successfully implemented given its institutional context.

Part two starts with an analysis of the general institutional context of The Sustainable Highway. To determine what the institutional context looks like, it is important to first review scientific literature in order to establish what is part of an institutional context. These parts can then be further analysed in order to map out the different components, together forming the general institutional context of The Sustainable Highway. Actor theory will be used here to address the dependency of Movares on other stakeholders (Enserink, et al., 2004). What this dependency actually means and the most likely consequences will be discussed from the same theoretic background. It was already established that the location in which the project would potentially be realised can have a large influence on the technological and socio-economical feasibility of the concept. The same holds for the institutional context. This part of the research project will therefore aim to analyse only the institutional context which is valid for whichever location The Sustainable Highway would be realised (with as only limitations that it is a national highway in the Netherlands). The impact of this institutional context on The Sustainable Highway can then be discussed.

Once the general institutional context has been established, value can be added to the analysis by applying the institutional context to a specific location. This will allow for a more in depth study regarding several components of this institutional context. By looking at a specific location, the compatibility of The Sustainable Highway with its environment can be assessed on a more detailed level. This can then lead to conclusions on the feasibility of the concept on such a location and conclusions on implications for other locations.

Once the compatibility of the concept with its institutional context has been established, ways on which to improve this compatibility can be studied. An institutional design can form a connection between the technological system and the institutional context. The type of institutional arrangement will have a large influence on the chance of a successful implementation, but is a very complex choice. Many (both public and private) parties will potentially be involved. Questions on whether this should be a completely publicly owned and operated project or that private parties might be interested to form a public private partnership will be addressed. Special attention will be given to the possibility of a Public Private Partnership (PPP), since PPP’s in the Netherlands are assumed to be particularly feasible in the case of ‘specific additional infrastructure’(Commissie Private Financiering van Infrastructuur, 2008). Since The Sustainable Highway is a new and innovative system, the implementation of the concept means facilitating change. Process management is often needed to successfully facilitate change in projects with a complex content (de Bruijn, ten Heuvelhof, & in 't Veld, 2008). Therefore a process design will be the final part of this thesis.

The structure of the report is demonstrated in Figure 1-2. The report is divided into two parts, each consisting of three chapters and answering three sub-questions. Part one is preceded by the introduction, and Part II is followed by the conclusions, recommendations and reflection, which shall be the final part of this research project.

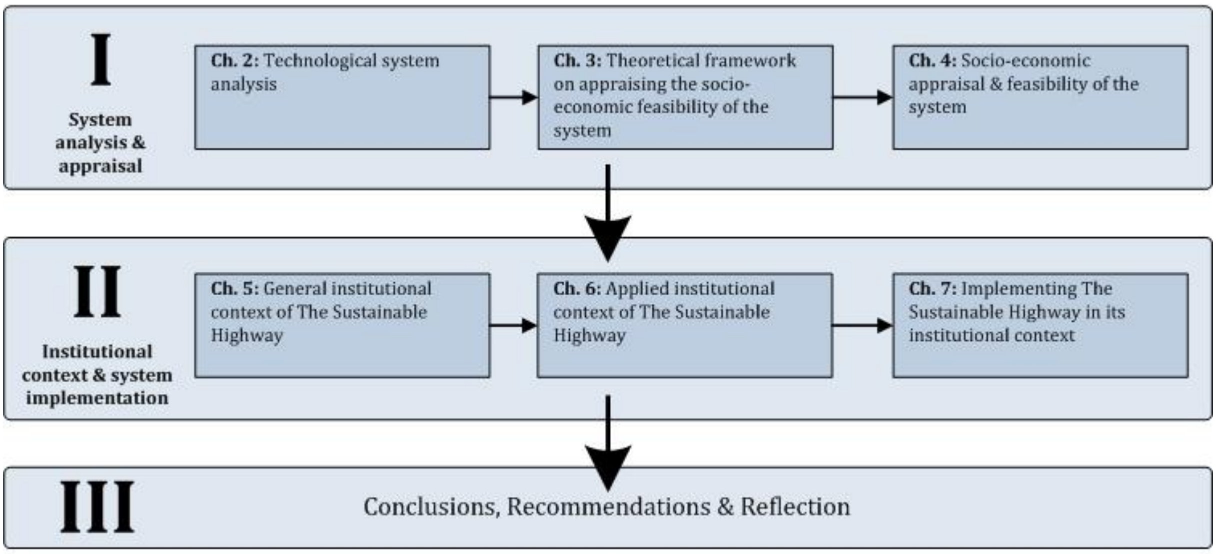

Figure 1-2, the structure of the research project

1.2.4 Research methods

Four types of research methods will be used to help answering the research questions. Here, only a brief discussion on methods and methodology will be given. At the beginning of each chapter, relevant theories, methods and methodologies will be discussed in detail. The methods used in this thesis are conceptual modelling techniques, interviews, literature study and spreadsheet simulations. Now follows a more detailed description of these research methods and of where they shall be applied.

- *Conceptual modelling techniques*: during this research project several conceptual modelling techniques will be used to analyse complex systems. Using conceptual modelling, these systems (be it technical, socio-economical or otherwise) can be split up into sub-systems which makes them easier to understand. First of all, in order to answer the first research question a system analysis will be used to understand the sub-systems of The Sustainable Highway and their effects on the environment (Enserink et al., 2009). Second of all, actor analysis will be used to answer sub-questions four and five. This will chart the network of actors surrounding The Sustainable Highway as well as their power, interdependencies and perspectives. Other conceptual modelling techniques will be discussed wherever relevant.

- *Interviews:* both oral and written interviews can provide valuable additional insights for this research project. The advice of experts will be sought wherever possible, but specifically in analysing the costs and benefits of the system. Since this is an entirely new system, information from scientific literature will be scarce, which means the reliance on expert estimations will be more important. In order to answer the third sub-question on social costs and benefits, a number of oral interviews will be conducted to gain expert input on valid starting values and assumptions. With regard to the fourth sub-question, various stakeholders will be consulted by conducting oral and written interviews to assess their position regarding The Sustainable Highway.
- *Literature study:* literature study, or desk research, is a useful tool that shall be used throughout most of the research project. However, it is especially useful to assist in constructing the theoretical framework of sub-question two. In addition, the composition of the institutional context (sub-questions four and five) will require extensive literature study. Furthermore, to answer sub-question one, the various reports that have been published regarding The Sustainable Highway shall be used as an input for the literature study.
- *Spreadsheet simulation:* the final method that shall be used will be applied to assist in answering sub-question three. A location specific social cost benefit analysis will be conducted and processed using spreadsheet simulation. This will allow a sensitivity analysis to determine the sensitivity of the model for changes in the starting assumptions and will allow testing different scenarios.

With the above described methods, clear answers to the research questions should be obtained. Data that shall be used as an input for the research methods will be gathered from different public, private and scientific sources.

Part I: technological and socio-economical feasibility of The Sustainable Highway

2. The Sustainable Highway: an analysis of the technological concept and its sub-systems

In this chapter, the technological concept of The Sustainable Highway will be analysed. The Sustainable Highway is a canopy built *over* an existing (or possibly new to construct) highway combined with several sub-systems to mitigate some of the negative external effects of road traffic. To be able to comprehend what problems are associated with road traffic, first a further elaboration on these problems will be presented in the form of a system analysis of a 'normal' highway. Next, an overview of the technological concept of The Sustainable Highway will be given and its sub-systems will be identified in conjunction with the negative effects each sub-system is intending to mitigate. Finally, the technological uncertainty surrounding The Sustainable Highway will be charted and an analysis on the technological uncertainty of The Sustainable Highway will be conducted. Both the system of a 'normal' highway and the system of The Sustainable Highway will be analysed using a 'systems approach' and a 'system diagram' commonly used in the faculty of Technology Policy and Management of the TU Delft for system analysis (Thissen, Enserink, & van der Lei, 2008). The system diagram is shown in Figure 2-1.

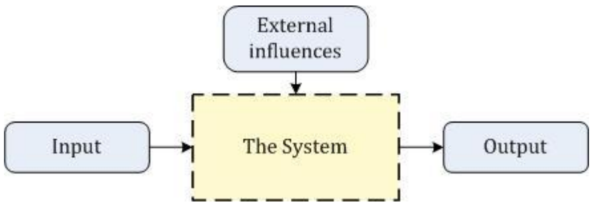

Figure 2-1, System diagram

2.1 The system of a 'normal' highway

This paragraph will deal with a system analysis of a 'normal' highway and specifically with the negative side effects that are caused by the road traffic on such a highway. First, it is important to specify what is meant by a 'normal' highway. Next, the effects of such a highway will be charted and captured in a summarised version of a system diagram. The transition of this system diagram into a version applicable to The Sustainable Highway will be the final point of discussion in this paragraph.

A 'normal' highway, as meant in this paragraph, is located in the Netherlands in an area where the highway is a hindrance to local inhabitants. This is very common since the Netherlands is a densely populated country and highways are often situated in urban areas. The hindrance itself is meant as hindrance generated by the traffic on the highway. Any mitigating measures shall therefore not be part of the 'normal' highway as it is defined here. 'Normal' in this case does not refer to any type or size of highway since this is not specifically important for which negative effects occur. It is only relevant for the extent of the effects and not so much for the nature of the effects.

In Chapter 1, the advantages of increased mobility have been clearly outlined; mobility is a driver for social and economic growth and a prerequisite for further growth. Mobility is a must and limiting mobility is limiting future social and economic growth. A normal highway contributes to mobility and therefore has many positive effects, both on a local, national and on an international scale. The Sustainable Highway however, is a measure for mitigating the negative external effects of a highway. From this point on, when referring to the effects of a highway, it is the negative effects to which is being referred. The positive effects are assumed to be known and are no further subject of study of this research project.

In a system diagram, the input, output and external influences of a system need to be defined. The output of a normal highway that will be defined here is focussed on the negative external effects. Several of these effects can be identified. The Dutch Knowledge Institute for Mobility Policy (KiM) identifies three categories of negative external effects, namely loss of travel time (congestion), traffic (un)safety and emissions (KiM, 2008). By emissions, both air pollution, noise nuisance and the emission of CO_2 is meant. This is quite similar to the negative effects of road traffic, identified by Van Wee and Dijst: "During the course of the seventies people became aware of the negative sides of mobility, such as air pollution and traffic (un)safety. Later on, congestion, global warming and noise nuisance were added" (van Wee & Dijst, 2002). Based on these definitions, the output of a normal highway (in terms of negative effects) is defined as: air pollution, noise pollution, climate change, congestion and (un)safety. Climate change can also be seen as a second order effect of air pollution, however, air pollution is defined here as pollution with a local effect (such as fine particulate matter), while climate change is defined as air pollutants with a predominantly global effect such as CO_2. The input of a 'normal' highway can be defined as all categories of traffic while an example of an external influence is the weather. The focus however, is on the output of the 'normal' highway, since those are the effects The Sustainable Highway is intending to mitigate. This is schematically represented in Figure 2-2.

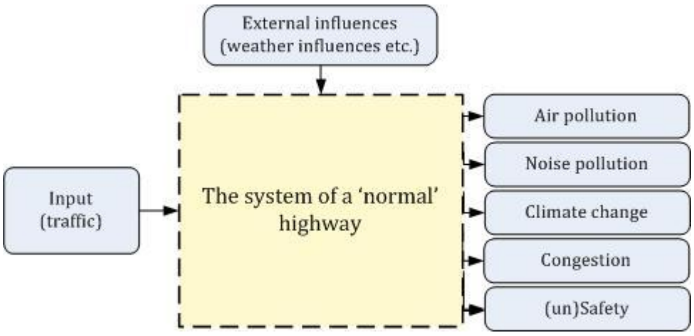

Figure 2-2 system diagram of a 'normal' highway

The system of The Sustainable Highway has been designed to counteract or mitigate some of the negative external effects of a normal highway. The Sustainable Highway will be built over a normal highway and by doing so, shield the environment from some of the negative effects that are considered to be the output of a normal highway. One system's output can become input, or an external influence to another system. For instance, when one analyses 'the weather' from a systems perspective, one of the system's outputs could be 'rain', which is an external influence to the system of a normal highway. In this way, systems are interrelated. When The Sustainable Highway is constructed, a new system comes into being which has its own inputs, outputs and external influences.

The normal highway produces certain effects, which are a given for The Sustainable Highway. So, just as rain is a given for a normal highway, these negative external effects are a given, or external influence to The Sustainable Highway. Therefore, in the system analysis of The Sustainable Highway, the negative external effects (or output) of a normal highway will be seen as external influences on the system of The Sustainable Highway. These external influences will be transformed by the sub-systems of The Sustainable Highway into more desirable outputs. Therefore, the input of The Sustainable Highway will be its sub-systems and its output the transformed external influences in addition to several by-products of The Sustainable Highway. This is schematically represented in Figure 2-3.

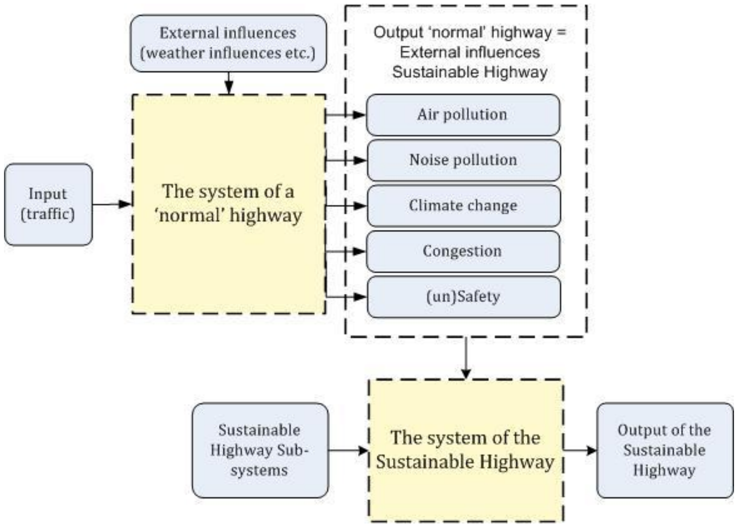

Figure 2-3, relation between the system of a 'normal' highway and the system of the Sustainable Highway

For the external influences of a normal highway to become suitable to use as external influences in a system diagram they need to be transformed into factors that are tangible. Furthermore, the external influences should be expected to be changed or transformed by The Sustainable Highway significantly, otherwise they are irrelevant for the system analysis at this stage and need to be omitted. For instance, The Sustainable Highway has not been designed to have an effect on safety and congestion. In practice, the fact that the highway is covered could cause negative effects on for example the accessibility for emergency services. However, since the highway is no longer affected by weather influences, The Sustainable Highway could also have a positive effect on safety. The same holds for congestion: some factors may slightly increase congestion, whilst others will reduce it. This makes these factors less suitable to use in the system analysis. These factors will therefore be left out of the system analysis at this stage. The assumption that The Sustainable Highway has no significant negative effects on safety and congestion will be extensively tested in paragraph 2.3.2 on technological uncertainty. Any possible effects will be discussed there and will not be used in the construction of the system diagram.

After the exclusion of two factors, three are left which require transformation into tangible factors. As discussed in Chapter 1, the discussion on air pollution in the Netherlands is mainly focussed on the emission of fine particulate matter (PM) and Nitrous Oxides (NO_x). Therefore, this factor will be split up into the emissions of these two substances. The other two factors are equally transformed leading to the schematic representation of the system of The Sustainable Highway and its external influences as shown in Figure 2-4.

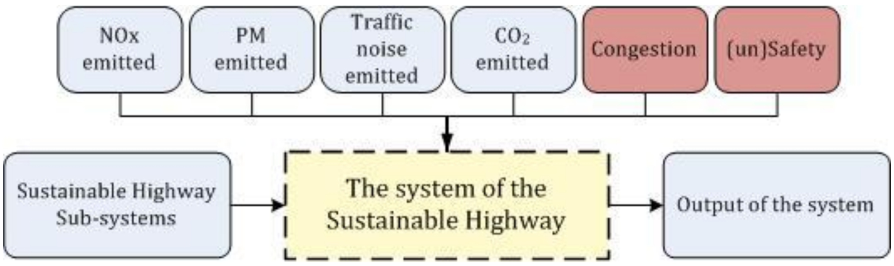

Figure 2-4, The external influences on the Sustainable highway

What remains are the four main factors The Sustainable Highway is intending to mitigate. The intended consequences of these changes are further reaching than just the improvement of the quality of life of local inhabitants. The intention is that in the highly polluted areas surrounding highways public health will increase, by preventing some of the premature deaths poor air quality causes in the Netherlands. Presently, possibly as many as 18.000 people die prematurely in the Netherlands as a consequence of poor air quality (Ministry of Housing, Spatial Planning and the Environment (VROM)). The emissions caused by road traffic are an important cause of these deaths. Other possible effects will be the reduction of the Netherlands' carbon footprint and the possibility to build closer to the highway in dense urban areas due to the reduced environmental impact of the highway when the Sustainable Highway is built. In the following paragraph the system of The Sustainable Highway will be analysed.

2.2 The concept of The Sustainable Highway and its sub-systems

In the previous paragraph the negative effects caused by a normal highway have been discussed, concluding that these effects can conceptually be seen as external influences on The Sustainable Highway. The Sustainable Highway intends to transform these negative influences into more desirable outcomes. To transform these external influences the concept of The Sustainable Highway makes use of several sub-systems, each of which intends to mitigate one or more negative effects.

The concept of The Sustainable Highway consists of a canopy of cold bendable laminated glass which can be built over any existing highway. The canopy shields the direct surroundings of the highway from the negative effects of road traffic; noise can be shielded and absorbed by the canopy and support structure. However, without additional measures the air pollution would be emitted in increased concentrations at the two ends of the canopy. To prevent this, some sub-systems are added to the canopy to complete the concept of The Sustainable Highway. On both ends of the tunnel an air return system is placed which, together with electrostatic filtering and adsorption by activated carbon, reduces the concentration of NO_x and PM_{10}. Beside these systems, asphalt heat collectors will be placed to reduce the temperature under the canopy and heat nearby houses and the road surface in winter time. Finally, solar cells can easily be placed in the canopy skin, generating solar energy to help reduce the Netherlands' carbon footprint. Based on this brief concept description, the following sub-systems can be identified:

- Canopy
- Electrostatic filtering
- Adsorption by active carbon
- Heat collectors
- Solar panels

As previously established, these sub-systems can be seen as the 'input' of the Sustainable Highway. The system diagram displayed in Figure 2-5 is an updated schematic representation of the system.

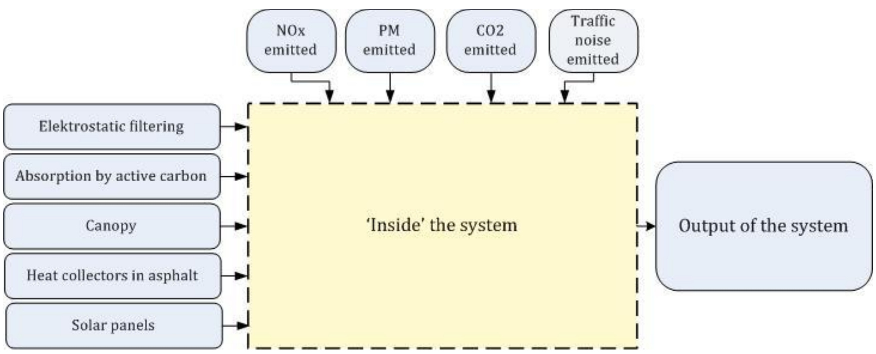

Figure 2-5, The sub-systems of the Sustainable Highway

To determine the output of the Sustainable Highway, a more in depth discussion on each sub-system is necessary. The following subsections will elaborate on each sub-system. The information is based on a number of documents provided by Movares (Vákár L. I., 2008; 2009)

2.2.1 The Canopy

The first sub-system that will be discussed is the canopy that will need to be placed over a highway. By 'the canopy', the entire object including support structure is meant. The canopy will consist of panels of cold bendable laminated glass. This glass (Freeformglass ®) is patented by Movares and relatively inexpensive compared to other materials. In addition, it greatly reduces the cost of the bearing structure that is needed, when compared to normal glass. An artist impression of the Sustainable Highway is displayed in Annex . In concept drawings, the design of The Sustainable Highway consists of a canopy over a dual carriageway highway, with each carriageway consisting of three lanes (Figure 2-6), though alternative configurations are possible. The structure is made up of arches, formed of castellated steel beams, supported on steel columns between the two carriageways. Cross beams between the arches form a framework to hold the bent beams carrying the laminated plates of glass. The entire structure is about 50 meters wide, making it large enough to accommodate all normal roadside structures comfortably.

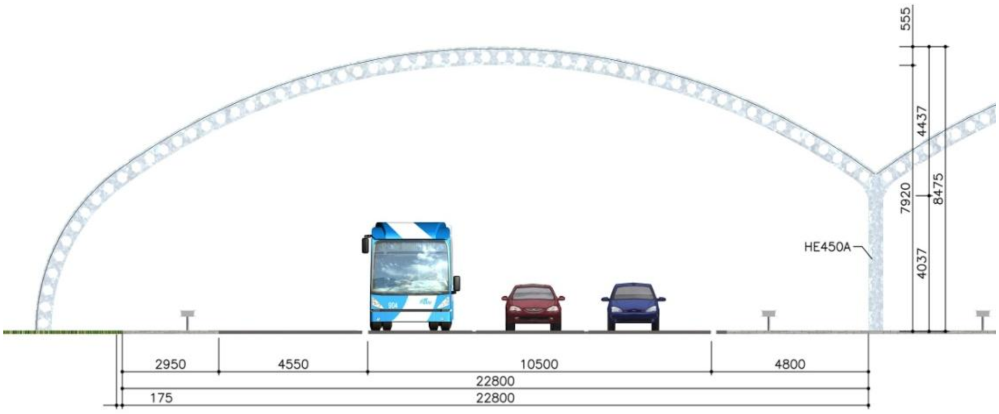

Figure 2-6, cross section of the Sustainable Highway (Vákár L. I., 2008)

The advantage of a transparent canopy is that daylight can enter, making daytime lighting superfluous and making the canopy fundamentally different from a tunnel. Furthermore, in case of a calamity, emergency services can get an overview of the extent of the calamity from outside of the structure, making it easier to control. There is ample experience with the construction of similar canopies especially in railway station construction. In 's-Hertogenbosch's central station a canopy was built in 1997 (Vákár L. I., 1998; 2000) and current construction projects such as the new bus station at Amsterdam central railway station (Vákár, Kool, & van Wolfswinkel, 2006) are also making use of this technique.

Because of the canopy, the highway is always dry and clear of snow. Weather no longer has any influence on the wear and tear of the highway, increasing its lifespan and thus decreasing the cost of road maintenance. The problems with air quality and noise nuisance next to the canopy are reduced to nearly zero. There are no more emissions anywhere parallel to The Sustainable Highway. For reasons of noise reduction in the Netherlands, mainly very porous asphalt is used, which has a theoretical life-span of around eight to twelve years in open air (IPG, 2008). However, in practice a lifespan of seven years is not uncommon. When The Sustainable Highway is constructed it becomes possible to use non-porous asphalt which is less costly and has an expected lifespan of around 20 years in open air. When this type of asphalt is covered, the lifespan can be further extended, again contributing to a cost reduction of road maintenance. This non-porous asphalt also reduces the friction of traffic on the road surface, which may lead to a slightly decreased fuel consumption.

The Sustainable Highway also has some side effects, which result in an increased importance of other factors. The temperature under the canopy may rise in summer because of the influence of sunlight and the heat produced by the traffic travelling under the canopy. Without a cooling system, the temperature rise would become unacceptable. A type of cooling system is therefore needed and provided for in the form of another sub-system, namely the asphalt heat collectors. A positive side effect of The Sustainable Highway is that due to Dutch legislation on air quality and noise nuisance, building restrictions are applied near highways. Where norms for air quality and noise nuisance are exceeded, no new construction is allowed. Since these factors are eliminated next to the highway it becomes possible to construct homes and offices close to the highway. As highways are now often located in densely populated areas, valuable building land becomes available. This factor can possibly compensate (some of the) investment costs of The Sustainable Highway.

Noise nuisance and air pollution are eliminated next to The Sustainable Highway, however, without additional measures highly concentrated polluted air will escape at each end of the canopy. Exhaust gasses will escape in concentrated form, causing the exceeding of norms on air quality. If no precautions are taken, The Sustainable Highway may not comply with legislation on this subject. Two sub-systems are used to clean the air under the canopy.

2.2.2 Electrostatic filters and adsorption by activated carbon

To improve the quality of the air exiting both ends of the tunnels it needs to be filtered. To make air circulation possible the natural air currents need to be optimally utilised. Traffic movements cause a large flow of air under the canopy and with innovatively shaped canopy entrances, part of the airflow can be directed to the other carriageway. There, the air is again caught by the natural airflow creating a circulation under the canopy. Simulations done by Movares suggest that recirculation of as much as 50 percent of the air is feasible by using these specially designed entrances. This is schematically represented by Figure 2-7.

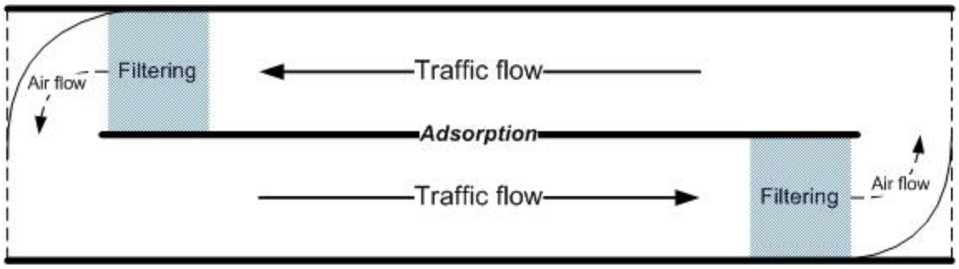

Figure 2-7, Air flow under the Sustainable Highway's canopy

The re-circulated air can be filtered of unwanted substances such as NO_x, SO_x and PM_{10} by different filtering methods. Electrostatic filtering and ionisation can be used to cleanse the air of fine particulates. These filters can be placed at the canopy entrances. Adsorption by active carbon can be used to cleanse the air of NO_x and SO_x. This technique can be employed in the central wall in the middle of the canopy. With regard to NO_x it is important to note that quite a number of different pollutants are meant by the term NO_x. For instance NO_2 is a gas that mainly has local consequences, such as adverse effects on public health, while NO mainly contributes to the forming of acid rain. Effects of NO_x are therefore both local and global in nature. Since they are both mitigated on a local scale by the adsorption by active carbon they are placed in the same category.

2.2.3 Asphalt heat collectors

The canopy placed over the highway can, on a hot day in summer act as a greenhouse, leading to increased temperatures under the canopy. This excess heat can be harvested by laying tubes in the road surface and by storing the heat in the groundwater. Because of the higher temperatures under the canopy caused by sunlight and heat emissions from vehicles passing through, in comparison with a normal highway, much larger quantities of heat can be harvested and stored. The increased asphalt temperature would in summer lead to road rutting and thus to more wear and tear of the asphalt. However, the road surface is cooled by the asphalt heat collectors keeping it on a more constant temperature, which means that less road rutting occurs. This increases the road surface's lifespan. Cooling the road in summer means large quantities of heat are stored, which can be used in winter to heat the road surface, preventing it from freezing. This eliminates the need for using salt. The stored heat can also be used to heat nearby homes. Natural gas, normally used to heat homes in winter, can be saved reducing the consumption of non renewable energy sources and thereby the Netherlands' carbon footprint. To further reduce this carbon footprint, green energy can be produced by placing solar panels in the canopy.

2.2.4 Solar panels

The Sustainable Highway provides an excellent platform to place solar panels between the glass sheets of the canopy (Annex). Although the solar panels are a non-essential part of the Sustainable Highway, they do provide a one-off chance to further increase the production of green energy; contributing to the measure of sustainability of the concept. The solar panels are protected against outside influences since they are sandwiched between the glass panels and there is no need for a separate frame to support the panels. This saves in investment and maintenance costs ensuring a shorter time to recover the investment costs. Installing a large amount of solar panels on the side of the Sustainable Highway that is most exposed to the sun, ensures the production of a maximum amount of solar energy and provides some shade, reducing the temperature under the canopy. The solar energy can be used to supply the water pumps of the asphalt heat collectors of the Sustainable Highway with power, eliminating the need to use external energy for this purpose. This will lead to an increase in the availability of green energy and a reduction to the Netherlands' carbon footprint.

2.2.5 Visualising the system

Using all additional factors and relations as explained in the analysis of The Sustainable Highway's sub-systems, a finalised system diagram can be visualised providing insight in all factors of The Sustainable Highway and the relationships between them. The system diagram is presented in Figure 2-8.

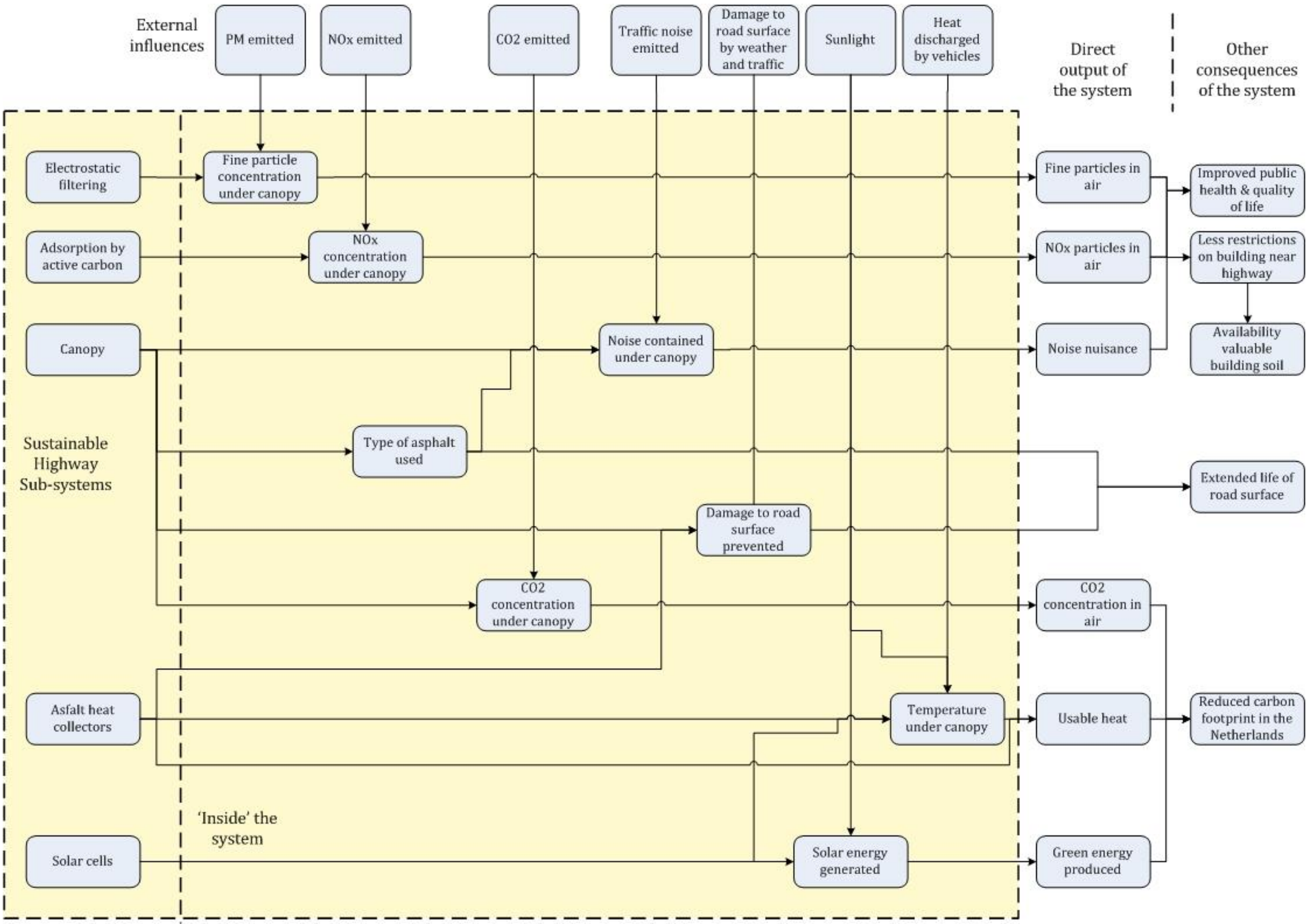

Figure 2-8, Finalised system diagram for The Sustainable Highway

On the right side of the diagram, the output of the system is shown. A clear distinction has been made between direct output of the system and second order effects caused by the system. The concentration of fine particles and NO_x will be greatly reduced (all emissions will be eliminated) next to the canopy, while filtering and adsorption reduce the emissions at both ends of the canopy. This leads to an improved public health and quality of life of all inhabitants living close to the highway. Because norms on noise and air quality are no longer being exceeded, there will be less restrictions on building close to the highway, which in its turn can lead to large quantities of valuable building land that become available. Furthermore, the elimination of noise nuisance makes it possible to use less costly asphalt with a longer lifespan (non-porous asphalt). The lifespan of the asphalt is further increased because of the elimination of damage by weather conditions and a more stable temperature of the asphalt. Usable heat and green energy is produced, reducing the need to use non-renewable energy sources and thereby decreasing the Netherlands' carbon footprint.

The potential effects of The Sustainable Highway appear to be very promising. However, there are some factors that may affect the feasibility of the concept. The construction of the system is quite costly and some technologies are not yet entirely proven. In addition to this, as was previously pointed out, no effects on safety and congestion have been described in the system diagram since no *intended* effects are present. In the next paragraph, all technological uncertainties will be mapped out with special attention for the effects the system may have on safety and congestion.

2.3 Uncertainty on the Sustainable Highway

In this paragraph, all factors related to uncertainty regarding the technological concept will be discussed. The paragraph will start off with a discussion on the techniques used in each sub-system and where possible, some effects will be quantified. Next, other possible qualitative effects will be discussed and finally, a comparison with alternative solutions will be conducted.

In April 2009, a second opinion on the concept was performed by the engineering office of the city of Rotterdam in collaboration with a range of external experts. Much of the information used in this paragraph has been taken from the report of this counter expertise (Gemeente Rotterdam Gemeentewerken, 2009). This counter expertise, together with other independent sources, has been used throughout this thesis to verify all important information on the concept which has been provided by Movares. Whenever information on the system is being contested by the counter expertise, this will be elaborated on. This will guarantee the ability to draw independent academic conclusions on the feasibility of The Sustainable Highway.

2.3.1 Technological uncertainty in sub-systems

Each sub-system of The Sustainable Highway potentially has different uncertainties associated with it. Some sub-systems are proven technologies, while others require some additional research. A system is considered to be 'proven technology' when examples of it have been successfully implemented and all effects as described in the previous paragraph have occurred in practice. All uncertainties about effects caused by the sub-systems will be dealt with here.

The canopy is a type of construction that has often been designed by Movares in the context of railway stations. Therefore, including the Freeformglass, it can be considered to be proven technology. With regard to the construction of the canopy, no uncertainties can be identified on a technological level. There are however some small uncertainties with regard to the innovatively shaped canopy entrances. Although Movares claims that 50 percent of the air can be re-circulated, no empirical examples of this exist. Additional research using a scale model of the Sustainable Highway can be used to check whether an air circulation of 50 percent is achievable. When there is no natural air circulation, because of congestion for example, additional mechanical ventilation is needed to keep the air moving. Without this backup system the temperature under the canopy may rise unacceptably, and in addition air might not be sufficiently filtered. This backup system would only need to function when the natural air circulation does not offer enough capacity. The backup system currently included in the design is a system to open parts of The Sustainable Highway, so that heat can simply escape out of the top of the canopy. This will prevent the temperature from rising, however, valuable heat will be lost. It is therefore merely a backup system in case temperatures rise above a certain threshold.

The effects which the canopy can have on the reduction of traffic noise are very positive. The canopy is approximately 5 dB(A) better at reducing traffic noise than a noise barrier of maximum effectiveness and 20 dB(A) better than a situation where noise barriers have little or no screening effect. These effects are endorsed by the second opinion.

In a tunnel, the concentrations of PM and NO_x and SO_x can reach between five and ten times the concentrations of a normal road (Cornelissen, 2007). For The Sustainable Highway, these concentrations will be comparable, making it attractive to filter the air. By utilising the natural air flows that occur under the canopy, the Sustainable Highway intends to filter the air at both ends of the tunnel. Electrostatic filtering can be used to cleanse the air from fine particles (PM) and activated carbon can be used to adsorb NO_x (and SO_x). Other types of filtering methods are also available and the efficiency of a filter depends on two factors: the percentage of the air that can be filtered and the efficiency of the filter itself. Without using mechanical ventilation the filters included in The Sustainable Highway can reach an efficiency of up to 90 percent (Cornelissen, 2007). This results in a potential reduction of 90 percent in the concentration of air pollution depending on the filtration method used. Unfortunately, the only experience with the appliance of these techniques at this time is in tunnels. The spatial profile of The Sustainable Highway is much larger than that of a tunnel, and the efficiency of the filters in The Sustainable Highway (although proven in tunnels) is still uncertain. Currently, research on the development of fine particle filters in the open air is being carried out. The TU Delft and Bam are conducting tests with electrostatically charged wires in the open air which can possibly also be applied to the Sustainable Highway (Delft, University of Technology, 2008). Additional research or perhaps a pilot project would be necessary to assess the true effectiveness of these technologies applied to the Sustainable Highway. An important uncertainty regarding the effectiveness of the filters is the legal paradox. The Sustainable Highway will be constructed to ensure the legal norms and regulations regarding air quality are met, but by doing so the air quality might decrease close to the tunnel ends if the filters do not clean the air sufficiently.

The heat collectors that will be placed in the asphalt are intended to cool the air under the canopy sufficiently. When installing this type of system, the expectation is that the difference in temperature under the canopy will not be higher than 8 degrees Celsius when compared to the outdoor temperature (Gemeente Rotterdam Gemeentewerken, 2009). The harvested heat can be used to heat nearby houses and prevent the road surface from freezing in winter. The heat will be stored in the ground water and can be pumped up in winter via heat exchangers to heat the road surface. This will keep the road surface at a more constant temperature increasing its service life. The need to scatter salt to prevent freezing of the road surface in winter is also eliminated. In addition, the large amount of energy stored in the ground water can be used for other purposes, such as to heat nearby houses. Possibly, up to 2400 homes can be heated for every kilometre of Sustainable Highway. If achieved, this will yield a reduction in CO_2 emissions of a 1000 tonnes per kilometre per year. However, this number of homes can only be achieved when the homes are modern and well insulated. If older average homes need to be heated, the amount of homes heated will be less, but the CO_2 reduction will remain the same. This sub-system consists of completely proven technology.

However, certain difficulties may arise with organising the storage and distribution. For instance, the city of Rotterdam has its own district heating system. The heat that is stored in the ground water is too cold to directly connect to the district heating system. Therefore, in the city of Rotterdam, only newly constructed homes or offices can be connected to the system. In addition to this, a party will have to be found that organises the distribution and maintenance of the system. This is an interesting dilemma since for normal infrastructure projects, such a party normally does not have to be involved. Institutionally this will make the situation more complex and thus uncertain. This issue will be extensively discussed in the second part of this research project.

Solar cells are a non-essential part of The Sustainable Highway, but offer a one off chance to generate additional green energy and utilise the canvas The Sustainable Highway offers optimally. The maximum efficiency of the solar cells can be reached when the cells are placed on the side of the canopy that faces the sun. Solar cells will be most efficient when the canopy is oriented on the south, since this will guarantee the largest exposure of the cells to sunlight. When 25 percent of the canopy is covered in solar cells they will yield 1350 MWh per kilometre per year, which corresponds to CO_2 savings of 750 tonnes per year (Vákár L. I., 2008). Solar cells can be considered proven technology and thus not many uncertainties are involved in the use of these cells. Furthermore, a cold-bendable glass shell is an ideal place to install these cells since the cells are sandwiched between two layers of glass and thus protected against any outside influences. This will ensure a long life of the cells and in addition, no additional structure is required to support the cells. This means the investment cost, although still substantial, is regained over a much shorter period of time. Nonetheless, solar cells are still considered to be costly, with prices falling as technology progresses. At the time of the specific design of The Sustainable Highway for a chosen location, a financial assessment of the costs and benefits of solar cells needs to be made. The only uncertainty regarding solar cells is on the financial side, rather than the technological side.

Other uncertainties do not relate to specific sub-systems but to the system of The Sustainable Highway as a whole. Potential issues that will need to be addressed are safety, congestion and a selection of other expected uncertainties. These will be discussed in the next paragraph.

2.3.2 Uncertainties of the system

In the introduction of this chapter, it was stated that congestion and safety would not be addressed in the system diagram, since no effects on these factors are intended to occur. However, they form important aspects of road traffic and any expected effects of The Sustainable Highway on safety and congestion will therefore be discussed.

According to the second opinion, no direct negative effects on congestion are to be expected when The Sustainable Highway is operational (Gemeente Rotterdam Gemeentewerken, 2009). During construction, some negative effects on traffic flows are to be expected, however when a modular construction process is used, these effects are very limited. Furthermore, when the construction of The Sustainable Highway is bundled with road maintenance, such as the laying of a new top-layer of asphalt, the additional effects on congestion are minimal. In the long term, The Sustainable Highway will even have a positive effect on congestion, since poor weather circumstances contribute to the forming of congestion and these circumstances are now shielded from traffic. Furthermore, the concept of The Sustainable Highway provides in the use of a more durable type of asphalt. The reduced amount of maintenance will have a positive effect on congestion. Possible negative effects include canopy maintenance and the distraction caused by the cleaning of the windows. Overall, congestion is not likely to increase after The Sustainable Highway has been constructed; on the contrary, a reduction in congestion is among the possibilities.

The safety aspect of The Sustainable Highway is a far more complex issue than congestion. The concept of 'safety' is composed of many different aspects such as the structural integrity of the construction and the ability of drivers to get themselves to safety in case of a calamity. In general, conclusions from the second opinion and by Movares state that the safety of The Sustainable Highway is comparable to that of a regular highway when a 'normal' situation is concerned. In case of a fire involving three passenger cars (9MW) the safety situation on The Sustainable Highway is still comparable to that of a normal highway when controlling the calamity and escaping are concerned. The situation on The Sustainable Highway is in this case much better than that in a tunnel. In addition, in case of a large fire (70 MW) the glass will stay in its frame for 30 minutes, giving drivers enough time to escape. In case of a large truck fire (50 – 150 MW), a hydrocarbon fire (200MW) or BLEVE (Boiling Liquid Expanding Vapour Explosion), direct contact is likely to occur between the flames and the glass. In this case, the glass will immediately break, temporarily causing the danger of falling glass in the location of the flames. However, after the glass has shattered, an open air situation is created. This will allow flames, smoke and heat to escape with no more danger than on a normal highway. The safety aspect with regard to the transportation of dangerous goods is location specific and will require further research once a final location is known.

In general, the perception of safety is expected to be much higher than in a tunnel, since the outside world is still visible for drivers. This changes in case of a calamity since fire, smoke and heat will be contained under the canopy. However, the Sustainable Highway will be two, to two-and-a-half times higher than a tunnel, which means that fire, heat and smoke will accumulate under the roof of The Sustainable Highway while at eye level the air is relatively clear. This will facilitate an easier escape, when compared to a tunnel. A condition for this is of course that sufficient escape doors are placed and that these are easy to reach and easily noticeable. In addition, the emergency services should be able to reach the place of a calamity. To facilitate this, a narrow road (or bicycle path) needs to be constructed parallel to The Sustainable Highway. As an alternative, the emergency services can approach a calamity from the opposite carriageway. A condition is the presence of doors in the wall separating the two carriageways.

It has been clearly established that The Sustainable Highway performs much better than a tunnel (often as good as a normal highway) when looking at the safety aspect. However, currently the Sustainable Highway is categorised as a tunnel due to Dutch tunnel legislation, since it is a covered road longer than 250 metres (Wet aanvullende regels veiligheid wegtunnels, 2006). This means that strict rules and regulations apply, such as the provision that drivers are not allowed to change lanes 10 seconds prior to the entry of the tunnel. Consequently, under current legislation, no on and off ramps are allowed under The Sustainable Highway. As long as The Sustainable Highway is governed by the tunnel legislation this constitutes a major uncertainty. However, an exception on tunnel legislation may be made because of the large differences in the safety aspect of The Sustainable Highway versus a tunnel.

Another aspect of safety is the perception drivers may have of the structure and how this will affect their behaviour. Since this type of structure is not yet being used to cover highways it is uncertain how drivers will react to certain aspects of the construction. Some drivers may suffer from tunnel phobia, a fear of tunnels which may also affect their perceptions of The Sustainable Highway. In addition, a stroboscopic effect may occur because the arches with glass sheets that will be used will cause a quick alternation of light and dark. This may cause problems, especially for drivers with an epileptic disorder (Tertoolen, 2008). Research carried out by Movares confirms that a stroboscopic effect is likely to occur, but can be solved by cleverly designing the construction. When the distances between the beams are increased or decreased no stroboscopic effect should be present. Additional research on whether or not drivers perceive The Sustainable Highway as a tunnel and how this will affect their behaviour would decrease this uncertainty.

To summarise, there are some safety aspects that will have to be explicitly dealt with in the design of The Sustainable Highway. The most important conclusion is that in a normal situation, the safety aspects of The Sustainable Highway do not differ significantly from a ‘normal’ highway. In case of a calamity, the system will start to adopt more characteristics of a tunnel, however its safety characteristics are in most cases much better than a tunnel. In the final part of this paragraph some additional concerns and uncertainties regarding the system of The Sustainable Highway will be discussed.

The system of The Sustainable Highway is quite flexible in the design phase. Sub-systems can be replaced by other systems or in some cases omitted and there is (practically) no limitation to the size of the structure. As technology progresses, better techniques will become available to replace the current sub-systems and the concept accommodates this. However, when the structure has been built, it is no longer possible to expand the highway that is covered by The Sustainable Highway; it becomes inflexible. This means that in the design phase it is very important to consider the possibility of building a larger canopy to accommodate future expansion of The Sustainable Highway. The designer will have to deal with the uncertainty of whether or not this expansion will be needed in the future.

Another factor is the uncertainty of the problem The Sustainable Highway is attempting to solve. Although air quality is currently a very big problem in the Netherlands, concentrations of harmful air pollutants have been steadily decreasing. This gives rise to the question of whether or not the system will still be relevant in the near or distant future. In other words, the problem is dynamic in nature. Although dynamic, most problems are likely to still exist for a significant period of time. The noise traffic produces is likely to persist and using infrastructure to generate energy and usable heat will remain interesting. Before building The Sustainable Highway, the local situation will need to be carefully assessed in order to determine whether or not the current problems are likely to persist in the future.

Clearly, where The Sustainable Highway will be built has a large impact on whether or not the system is a feasible solution to local problems. There are more factors that are very location specific. The foundation of The Sustainable Highway will need to be constructed next to the highway. A problem can arise when the land next to the highway is legally owned by a third party. This can be the case when cables, or rail infrastructure is bundled with the highway. Including another party in the construction of The Sustainable Highway will make the realisation of it more complex, slightly increasing the uncertainty of the project. Other location specific factors are possible high-rise buildings next to The Sustainable Highway causing shade and the quality of the soil, which influences investment costs.

Since the concept of The Sustainable Highway has never been carried out before in its entirety, the total costs associated with construction and maintenance of the system are not completely certain. Movares has a reasonable amount of experience in designing similar constructions, so fairly accurate estimations have been made by Movares on the investment and maintenance costs needed for The Sustainable Highway; these estimates have been confirmed by the counter expertise. Furthermore, it is unknown how big the benefits of the concept will be. Benefits do not only consist of direct financial benefits such as profits from the marketing of green energy or heat. They also consist of valuable building land which will become available next to the highway, the increased value of nearby properties and the decreased congestion due to reduced road maintenance. In addition, there are less tangible benefits such as decreased air pollution and increased public health. These benefits will generally be for a different party than the one bearing the costs. All of these factors require an in-depth study and further appraisal. In the next chapter a framework will be developed to appraise the system of The Sustainable Highway and its effects and this appraisal will be carried out in the chapter that will follow thereafter.

This paragraph has presented some uncertain factors surrounding the concept of The Sustainable Highway flowing forth from the technological analysis of the system. Most factors can be distributed among three categories namely technological uncertainties, legal or institutional uncertainties and financial uncertainties. This is summarised in Figure 2-9. Additional uncertainties are expected to come up in the socio-economical and institutional analysis respectively.

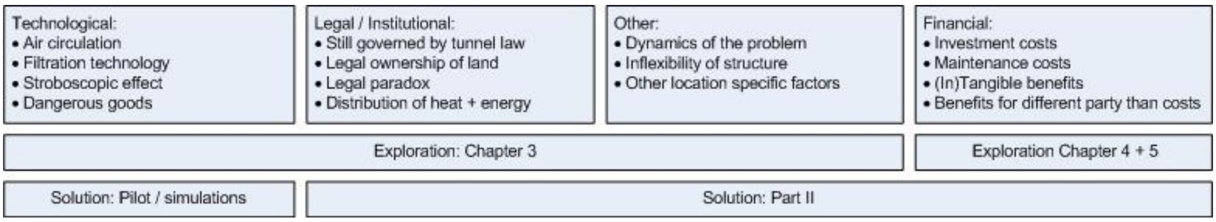

Figure 2-9, uncertain or unknown factors regarding the system of The Sustainable Highway

The technological uncertainties have been explored extensively in this chapter and can be dealt with by testing, simulating and ultimately constructing a pilot project. The legal and other uncertainties have also been discussed in depth, but their solution will be different for each specific case and potential location. Therefore, their solution is highly dependent on the (institutional) environment the system is set in. This is the subject of part II of the research project and these factors will be further discussed there. The financial uncertainties have only been briefly discussed and they will be further explored in chapters three and four. The final part of this chapter will briefly elaborate on current alternatives for The Sustainable Highway.

2.4 Alternative solutions

In the second opinion that was conducted by the engineering office of Rotterdam, The Sustainable Highway was compared to several current practices that are used to solve environmental problems related to infrastructure. The application of each of the alternatives is suitable for a different situation.

This is also the case with The Sustainable Highway. There are situations in which its benefits will be higher than in other situations. The Sustainable Highway will be compared to a ‘normal’ highway, a normal highway with noise barriers, and a tunnel. The results are presented in Table 2-1.

.

Table 2-1, Qualitative comparison of various alternatives

	Normal Highway	Highway with sound barriers	Sustainable Highway	Tunnel
Environmental				
Air quality at tunnel ends	Poor	Moderate / good	Moderate	Poor
Air quality at road side	Poor	Moderate	Good	Good
Sound	Poor	Good	Good	Good
Energy- and heat-generation	Possible in asphalt	Possible in asphalt	Possible in asphalt and canopy	Not possible
Light	Daylight	Daylight	Daylight, but stroboscopic effect	No daylight
Safety				
Escape behaviour	Good	Moderate	Moderate	Poor
Emergency services	Good	Moderate	Moderate	Poor
In- and external safety	Good	Moderate	Moderate	Poor
Driver behaviour relating to road set-up	Good	Good	Good	Moderate
Vandalism and terrorism	Good	Moderate	Moderate	Moderate
Construction				
Flexibility	Good	Modular system, adaptable	Modular system, adaptable	Poor
Construction and building process	Good	Good	Moderate	Poor
Maintenance and control	Regular maintenance	Some additional maintenance	Additional maintenance on canopy and installations, less maintenance on asphalt	Some additional maintenance
Additional investment costs	€0 mln per kilometre	€20 mln per kilometre	€60 mln per kilometre	€150 mln per kilometre

Source: based on figure 3, page 15 (Gemeente Rotterdam Gemeentewerken, 2009).

The alternatives are sorted by additional investment costs compared to a ‘normal’ highway. The Sustainable Highway appears to be most suitable for situations where normally sound barriers are applied. Next to the sound reduction, also other environmental effects will be mitigated when compared to a normal highway with sound barriers. The additional investment cost can possibly be justified when local air quality is poor and merely a reduction of noise nuisance does not suffice or when sound barriers do not provide a sufficient reduction in sound levels. Whether or not the additional investment is justified depends largely on the total benefits of the system. These are not easy to determine and will differ for each location. To determine the total feasibility of the concept of The Sustainable Highway a framework is needed to appraise these benefits. Only then a complete comparison and assessment of feasibility can be carried out.

In locations where normally a tunnel is used, The Sustainable Highway is sometimes not applicable as an alternative due to the unique nature of a tunnel. The concept of The Sustainable Highway can be applied in combination with a tunnel, for instance to re-circulate and filter the air to combat air pollution. This comparison table leaves some unique effects of the solutions out of the equation that are relevant for choosing the most feasible solution for a specific location. For instance, a tunnel allows the land on top of a tunnel to be used for other purposes, while with a normal highway (with or without sound barriers) this land is completely occupied. A very important aspect of The Sustainable Highway that is left out of this comparison to alternative solutions is the ability to build closer to the highway than is currently the case. The (financial) benefits of this aspect can be significant. There are ways to appraise these factors and make them comparable. A framework needs to be developed to appraise all effects of the aforementioned solutions in general and The Sustainable Highway specifically. Only then, it is possible to assess whether or not the additional costs of The Sustainable Highway are outweighed by the potential benefits of the system. This framework will be developed in the next chapter.

2.5 Conclusions on technological feasibility

In the first chapter, the question was posed whether or not, or to what extent, the concept of The Sustainable Highway is technologically feasible. This chapter has provided some answers to this question. There is still uncertainty around the cleansing of the air by electrostatic filtering and adsorption by active carbon. Although these technologies are expected to be further developed in the near future, presently it is unknown whether they can provide the level of filtering that is needed. These systems are vital to the success of the system, not in the least since they influence the legal paradox: attempting to solve a problem (air quality), but instead making it worse in certain places. Technological developments regarding these systems steadily progress and more research and testing will confirm whether or not these systems will provide the level of filtering that is needed. Despite the uncertainties, numerous factors are also quite certain: many proven technologies are used and similar constructions have previously been successfully designed by Movares. A second opinion on the concept generally shows a positive image of the concept and calls it ‘a promising idea to improve air- and sound-quality surrounding highways’.

Although there are some unknown and uncertain factors regarding the concept, the provisional conclusion should be that it is a technologically feasible concept. However, much depends on the costs and benefits of the concept, especially when compared to alternative solutions. The socio-economical feasibility of the concept depends largely on this comparison, which will be highly dependent on the location that is chosen for implementation. A thorough appraisal of all costs and benefits of The Sustainable Highway will need to be carried out and a framework to carry out this appraisal is necessary. In the following two chapters a framework will first be developed after which the concept of The Sustainable Highway will be appraised according to this framework.

3. Developing a framework to determine the socio-economic feasibility of The Sustainable Highway

In the previous chapter the need for an economic appraisal of all costs and benefits associated with The Sustainable Highway has been discussed. In this chapter, a framework shall be developed to carry out this appraisal. This framework shall not only be used as a blueprint to appraise the concept, but also to place the appraisal of costs and benefits into their context; the result of a cost-benefit analysis can influence decision makers and is often a prerequisite or legal obligation for implementation of a project. Therefore the first part of this chapter will consist of placing the appraisal of a project in its appropriate context, while the second part will discuss common project appraisal theory and use this to develop a framework to appraise The Sustainable Highway.

3.1 The context of project appraisal

An innovation is 'a new idea or product' (Cambridge University Press, 2008) and the Sustainable Highway classifies as an innovation according to this definition. Although the concept of the Sustainable Highway consists of a collection of (mainly) proven technologies, the combination of these sub-systems is unique. This also means that the (socio-economic) effects of the system are still quite unknown and require further research. Another consequence of the system being an innovation is that it will require substantially more effort to implement, since technical and economical feasibility still remain to be proven. In other words: the adoption of this innovation is dependent on the feasibility of the system and the acceptance of this feasibility by the stakeholders that will need to be involved in the implementation process. In order to determine the socio-economical feasibility of the concept, an appraisal of all social costs and benefits of the system will need to be conducted. For this appraisal to be effective, it should be accepted by the important stakeholders. Therefore, the appraisal will not only function as a way to assess the feasibility of the system, but should the system turn out to be economically feasible, it can also function as a tool to prove this feasibility to other stakeholders. Feitelson and Salomon (2004) have developed a political economy model of transport innovations, shown in Figure 3-1. This model shows the factors from different domains that can influence the adoption of an innovation.

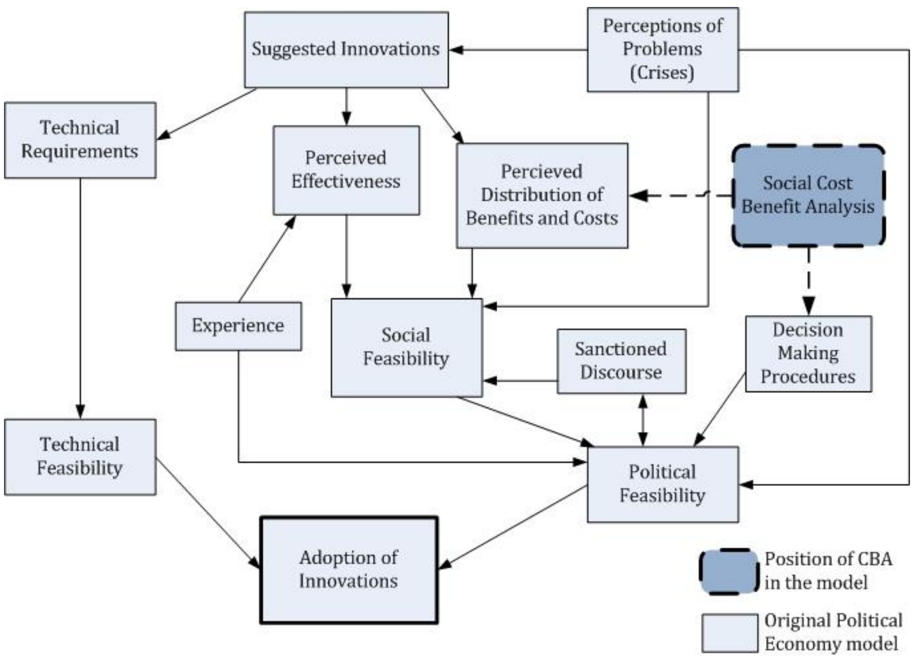

Figure 3-1, Political Economy Model of transport innovations, based on Feitelson and Salomon (2004, p. 15)

This model has been specifically developed for transport innovations and can therefore be applied to The Sustainable highway. However, it has not been specifically designed for the situation in the Netherlands and therefore requires one addition. For a transport innovation to be adopted in the Netherlands, the execution of a social cost benefit analysis (CBA[4]) is a legal obligation and an important part of the decision making procedure. In addition to this, a CBA can provide valuable insights in the distribution of costs and benefits of a transport innovation. The place of a social cost-benefit analysis in the political model of transport innovations by Feitelson and Salomon has been indicated in Figure 3-1.

According to the adapted political model of transport innovations, the adoption of innovations is in the first place dependent on the technical and political feasibility of the innovation. The technical feasibility has already been discussed in the previous chapter. Although technical feasibility is a fundamental criterion for an innovation, it is clearly not sufficient to have the innovation adopted. Many additional factors contribute towards whether an innovation will be adopted or not, such as the socio-economic feasibility of the project in question. In some economic analyses of innovations, it is argued that if an innovation can be shown to be cost effective, to provide benefits above costs, it will eventually be adopted. However, just as technological feasibility, socio-economic feasibility is a prerequisite for an innovation to be adopted, but simply satisfying a strict cost-benefit criterion is insufficient.

In addition to the technological and socio-economic feasibility of a project, there are many other factors which influence the adoption of an innovation. One of these factors is the political feasibility of an innovation, which is dependent on many different factors. The two most important ones are the political landscape (sanctioned discourse and decision making procedures, of which a CBA is a part), and social feasibility of an innovation. The social feasibility is in turn dependent on the way in which stakeholders perceive the problem and the solution, in addition to the perception on how effective the proposed solution is in solving the problem. Social feasibility is a very volatile subject, which is highly dependent on public opinion and the complex network of stakeholders surrounding the process of the adoption of an innovation. Part two of this thesis will provide an in depth discussion of the institutional context surrounding The Sustainable Highway, which will – where relevant – be linked to the Political Economy Model.

To determine the social costs and benefits of a project, some type of (social) cost-benefit analysis is needed. The result of this analysis will need to be perceived to be positive by the stakeholders involved. In practice, a slightly negative cost benefit ratio does not always lead to a rejection of the innovation. In fact, an analysis of 46 cost-benefit analyses in the Netherlands has shown that two thirds of all projects with a negative cost-benefit ratio still received a ‘go’-decision from policy makers (although often after some adjustments to the project)(Kennisinstituut voor Mobiliteitsbeleid, 2008). This shows that a negative benefit-cost ratio does not always mean a project will receive a ‘no go’-decision. However, it clearly reduces its chances of being realised in its current form. In contrast, all of the projects with a positive benefit-cost ratio received a ‘go’-decision.

Besides the ‘factual’ side of costs and benefits (the outcome of a type of cost-benefit analysis), there is the perception of these costs and benefits. This is at least as important as the actual result that is obtained from the analysis. The choices and assumptions made in a CBA strongly influence the outcome; any CBA is therefore vulnerable to criticism regarding these choices. Ultimately, the choices made can strongly influence the perception stakeholders have towards the CBA. In the following paragraphs different types of cost-benefit analyses will be discussed and the most appropriate type will be selected. This should ensure that the result of the analysis is perceived to be the true benefit-cost ratio of The Sustainable Highway. If a positive ratio is obtained using the correct method, the result is more likely to be accepted by stakeholders that are important for the realisation of the project.

[4] Whenever a cost-benefit analysis (CBA) is mentioned in this report, a social cost-benefit analysis is meant

3.2 The theory of cost-benefit analyses

Two extreme views have been opposing each other for centuries: there are scientists that look to the future with a revolutionary vision and scientists that calculate every change to see what measure yields the highest result. The contrast between these visionaries and arithmeticians was initially deepened by the emergence of social cost-benefit analyses. Nowadays, with the new developments in cost-benefit analyses, it can be the methodology that bridges the gap as long as these contrasting perspectives are kept in balance (Kennisinstituut voor Mobiliteitsbeleid, 2008). A social cost-benefit analysis can be an important tool to calculate the effects of visions and innovations and convince arithmeticians of their benefits to society.

A (social) cost-benefit analysis has as its goal to provide information on the costs and benefits of a project for society at large. Information from a CBA is needed to make decisions on whether or not certain (infrastructural) projects should be carried out. Such decisions inherently carry within them great risks which (among others) relate to future developments and effects. Under such circumstances there is a need for a reliable and policy-relevant form of information (Eigenraam C. J., Koopmans, Tang, & Verster, 2000). A cost-benefit analysis is one possible way appraise a project and to provide this form of information.

The essence of a cost-benefit analysis is that attempts are made to map all pros and cons of a project and to quantify as many of these pros and cons in monetary terms as possible (Rietveld, 2002). Cost-benefit analysis has its roots in the traditional theory of economic welfare or neo-classical economy theory (Brent R. , 1996) and is based on four main principles (Vlakveld et al., 2005):

1. *Consumer sovereignty* refers to the right of consumers to choose how to spend their income. Different consumers will make different choices; however, within the framework of cost-benefit analysis, none of these choices is regarded as more correct than another. In general, economic theory makes the assumption that consumers are perfectly rational utility maximisers. Consumers act in their own interest and one consumer's sovereign consumption choice may clash with other consumers' choices. In other words: there may be positive as well as negative external effects.
2. *Willingness to pay (WTP)* is a way to express individuals' preferences for goods and services in monetary terms, following from their utility maximisation. In existing markets, the consumers' willingness to pay shows in the demand and eventually in the market pricing. In case a market for the good does not (yet) exist, a market price cannot be used to estimate a user's WTP. To help find solutions to social problems that the market does not solve, economists study the demand for such solutions by investigating if it is possible to estimate individuals' willingness to pay for the provision of non-market goods.
3. *Maximising efficiency* is the objective of a CBA. The CBA measures efficiency increases in economic terms, usually referred to as potential Pareto improvements. In practice, a potential Pareto improvement is regarded as being attained whenever the benefits of an action are greater than the costs of the action. The objective of a CBA is thus to identify policy options that provide marginal benefits that are at least as great as the marginal costs of those options – increasing a society's efficiency.
4. *Distributional neutrality* in a CBA means that who gets the benefits and who gets the costs is not relevant, as long as an efficiency increase for society as a whole is reached. Fairness in income distribution is not the issue that CBA seeks to solve.

The basic idea behind using a CBA to assess the costs and benefits of a project is that consumer preferences should be the guiding principle for determining government policy (van Wee, 2004-2005). That is why consumers' willingness to pay is the guideline for the monetary appraisal of the effects of infrastructure projects. When these effects have been mapped in a CBA and monetarised as much as possible an overview can be given. This overview also contains costs and benefits that have not been expressed in monetary terms; these are included in the CBA as Pro Memori items (PM-posts) and are often expressed either qualitatively or quantitatively (as opposed to monetary). For as far as the costs and benefits have been expressed in monetary terms a balance is usually presented which can be positive or negative. As mentioned, the term *social* CBA is often used; this is done to indicate the analysis is performed from a societal point of view. This means that a shift in costs or benefits from one party to another has no influence on the total costs and benefits for society as a whole (distributional neutrality). When constructing an infrastructure project the costs mostly precede the benefits: the costs for construction will need to be paid prior to the usage of the infrastructure. To make the costs and benefits comparable a discount rate is used: a percentage of interest to translate future euro’s to present day euro’s. This results in an aggregated figure which can either be positive or negative.

Such a figure might give the illusion of a clear criterion on the basis of which a project can be accepted or rejected. However, such a figure can never be used to replace the decisions made by policy makers; it is merely an instrument to support decision making. A CBA is meant to be used by policy makers to ensure policy decisions are made on the basis of relevant information, using unambiguous terminology with clear foundations for appraisal (Eigenraam C. J., Koopmans, Tang, & Verster, 2000). Although a CBA can provide clear information on the costs and benefits of a project, policy makers often exercise influence on the way in which a CBA is drawn up and interpreted. Inaccurate cost forecasts by CBA’s are therefore often not the result of inadequate models and data, but inadequate institutional approaches and regimes (van Wee, Large infrastructure projects: a review of the quality of demand forecasts and cost estimations, 2007). Clearly, a CBA is not always interpreted correctly by policy makers due to its complexity or other reasons. In the next sub-section the disadvantages of CBA will be briefly discussed as well as the alternatives.

3.2.1 Criticism on- and alternatives to CBA

Cost-benefit analysis is one of the most common methods to appraise infrastructure projects. Despite the popularity of the method, there are some drawbacks to it. Many authors have dealt with the subject of criticism on CBA and below are some of the most commonly heard factors (van Wee, 2004-2005; Annema, Koopmans, & van Wee, 2002; Rietveld, 2002).

One of the most important problems associated with CBA is that for some effects there is no proper financial evaluation. A CBA is based on the principle of willingness to pay, but for some factors simply no market price is available. Although alternative pricing methods for these effects are available (such as hedonic pricing and the contingent valuation method (Wesemann & Devillers, 2008)), some authors argue that these do not always reflect the ‘true value’ of an effect. This problem mainly exists for environmental factors and effects on nature. The effects of this problem can be increased by adding the effects as PM-posts, since this provides the illusion that the effects are accounted for, without showing this in the final benefit-cost ratio. In the evaluation of a CBA, one tends to focus on effects that are expressed in monetary terms while the PM-posts receive limited attention. This is especially relevant for evaluating The Sustainable Highway, since many potential benefits of the concept fall into the environmental category. Expressing these effects in monetary terms will be one of the main challenges in order to guarantee a realistic evaluation of the concept. A second problem when appraising certain effects in a CBA relates to the spill over of economic effects to other parts of the economy, that are not directly related to the infrastructure project. Since a CBA attempts to give a full overview of costs and benefits of a project, all effects should be taken into account. Most of the time, supporters of a certain project will claim that the advantages of an infrastructure project are much further reaching than just the direct effects and that this may lead to an underestimation of the economic importance of the project. These indirect effects on the economy are often underestimated in a CBA. If however, indirect effects are taken into account, they present a risk of counting some effects twice. When conducting a CBA it might be difficult to find a balance between which effects are unique and significant and which effects are not.

A third point of criticism is that in a CBA, no distribution of income is taken into account, since this is not relevant for calculating the efficiency increase for society as a whole. This leads to the fact that someone with a higher income counts on average more than someone with a lower income. This is considered to be morally unjust by some critics. Furthermore, a project that is analysed in a CBA can lead to clear 'winners' and 'losers', since only the net benefit to society is being considered. This may lead to a situation where one region might incur costs of say 10 million and another gain benefits of 11 million. This will lead to a net benefit for society of 1 million, but one region is clearly much worse off than another. Although compensation between winners and losers is in theory possible, in practice this is often not considered. This also explains why interest groups sometimes provide heavy resistance to infrastructure projects with a clear benefit to society as a whole. They tend to represent parties that are expected to lose if the project is implemented, even though society as whole might benefit. However, as earlier explained, a CBA does not replace the process of decision making, it is merely a tool to provide clear information. A decision maker will in practice often choose an alternative with smaller differences between winners and losers, but with a slightly lower benefit-cost ratio. Even though financial compensation often does not exist in CBA's, in practice there can be a mitigation of the negative external effects of an infrastructure project. This can be seen as a form of 'winners' compensating the 'losers'. Noise barriers (or The Sustainable Highway for that matter) can be used to compensate people living in the vicinity of a new to construct highway. Often, these measures are already accounted for in a CBA and are therefore a practical (and often legally obligatory) form of compensation.

Finally, the limited accessibility of a CBA for non-economists sometimes poses a problem. A common misconception is, that in a CBA only economic effects are taken into account. This may lead to a reduced valuation by stakeholders of the analysis that was performed or of the project itself. Furthermore, policy makers do not always understand the way in which the results have come about, which further decreases their comprehension of the analysis. This can decrease support for the results and will influence the perceived costs and benefits of the project. It is therefore important to perform a CBA in a transparent way without using too many technical terms. A high measure of transparency in the analysis also limits the possibilities for the analyst to be too selective in the costs and benefits that will be analysed.

Clearly, cost-benefit analysis has its imperfections. Nevertheless, it is one of the most common tools to appraise a project. Other relatively common methods include Cost Effectiveness Analysis (CEA) and Multi Criteria Analysis (MCA). Cost-effective analysis (CEA) is closely related to CBA and may be seen as a variant of it (Vlakveld et al., 2005). In CEA, the effects on the primary goal of the measure are compared to the investment costs associated with it. This means not all effects of the measure are included in the analysis but only the main intended effect. Only the costs to obtain this effect are expressed in monetary terms. This method is common in judging measures to increase road safety. Increases in safety (such as a reduced number of traffic incidents or casualties) can be compared to the investment costs that are needed. This makes it relatively simple to compare measures' cost effectiveness on these effects. In CEA it is not possible to determine the socio-economic benefits of various alternatives nor determine indirect effects or second order direct effects. When alternatives have to be scored on several aspects and they need to be compared across different policy areas, cost effectiveness analysis is less suitable than cost-benefit analysis. In Multi Criteria Analysis, the effects of a measure are systematically compared to a set list of criteria. These criteria can be clustered into categories such as 'safety', 'accessibility' or 'the environment' and can be chosen in such a way that they form a reflection of the goals of the measure. The effects are usually expressed in their most common unit and would not be comparable. To solve this issue, a system of weights is attributed to each effect so they can be compared and aggregated. Being able to compare the effects on different criteria is a great advantage, however, it also gives the method a certain level of subjectivity. The weights can be determined relatively arbitrarily and are of great influence on the end result. Different stakeholders can, by using their own set of weights, come to an entirely different conclusion which means that 'objective' data can lead to a 'subjective' conclusion.

Despite CEA and MCA having some unique characteristics and providing some advantages over CBA, cost-benefit analysis is by far the most commonly used form of project appraisal. This has resulted in it becoming part of the policy process in many countries such as England, France, The Netherlands and on a wider European level. At this point, CBA seems to be the best alternative to analyse the costs and benefits of a project. Therefore, despite its disadvantages, cost-benefit analysis will also be used to determine the socio-economic feasibility of The Sustainable Highway.

A CBA has to be conducted in an objective, systematic and transparent way, even more so since it is often part of a political process. When a CBA is not objective, systematic and transparent, this will inevitably influence the political process and decisions might be made on the basis of beliefs rather than the facts as they were presented in the CBA. To ensure that a CBA conforms to certain standards and no discussion is needed on the form or procedures, the OEI guideline was adopted in the Netherlands. This guideline to conduct a CBA has to be used on all infrastructure projects of national importance in the Netherlands since its adoption. Therefore this guideline will also serve as a basis for the framework to conduct a CBA in this project.

3.2.2 The OEI guideline

In the nineties, several infrastructure projects were commissioned in the Netherlands based on a CBA, which later on led to much political debate. This resulted in a political discussion on how to structure the decision making process surrounding large infrastructure projects. The two most notable projects were the HSL-south and the Betuwe route. Since the decisions to construct these projects were made based on a CBA, the way in which these were carried out were also subject to discussion. In retrospect, the socio-economic benefits of these projects appeared to be much lower than was originally estimated. In other words, the benefits of the project were estimated to be too high while the costs were generally underestimated. It became apparent that the process by which to conduct a cost-benefit analysis was too loosely structured. No standard starting assumptions and procedures were available which meant that when two different agencies would be asked to carry out a CBA based on the same facts, two entirely different conclusions could be reached. This called for the need to standardise the way in which a CBA was conducted for infrastructure projects, so political decisions would be made based on the correct information regarding costs and benefits of such a project. In 1998, the Ministry of Transport, Public Works and Water Management, together with the ministry of Economic Affairs, took the initiative for the Infrastructural Effects Research Programme (OEEI). In the year 2000 this led to a guideline to conduct an Overview Effects Infrastructure (OEI) (Eigenraam et al., 2000), which standardizes the CBA methodology for infrastructure projects in the Netherlands. This guideline has since been applied to several national infrastructure projects.

Since the start of the Infrastructural Effects Research Programme, the OEI-guideline has been evaluated several times. Originally, the term Overview Economic Effects Infrastructure was used, which can put one under the impression that research is only conducted into the economic effects of an infrastructure project. This gives the wrong impression since in an OEI also, among others, effects on nature, the environment and safety are researched. That is why the choice was made to drop the term 'Economic' from the original abbreviation OEEI and speak of an Overview Effects Infrastructure. In 2002 the OEI guideline was evaluated (much of the criticism on CBA that has been earlier discussed was a reaction to the OEI-guideline) and in 2004 this has led to the Supplements to the Guideline OEI, which provides solutions for many of the problems associated with cost-benefit analysis (Ministry of Transport, Public Works & Water Management, 2004).

In an OEI, all effects of an infrastructure project on society are analysed following the CBA methodology earlier described. A distinction is made between the costs of construction and maintenance and the effects of the project on accessibility, economy, safety, nature and the environment. The OEI guideline presents an overview of how a social cost-benefit analysis needs to be carried out and reports the effects of an infrastructure project on society (Kennisinstituut voor Mobiliteitsbeleid, 2008). A cost-benefit analysis based on the OEI guideline is based on research into project alternatives, future (economic) scenarios, transport effects, external effects, indirect effects and distributive effects. The combination of these aspect studies provides the overall picture of the comprehensive social cost-benefit analysis (Eigenraam et al. 2000). A schematic representation of the structure of a CBA following the OEI guideline is presented in Figure 3-2

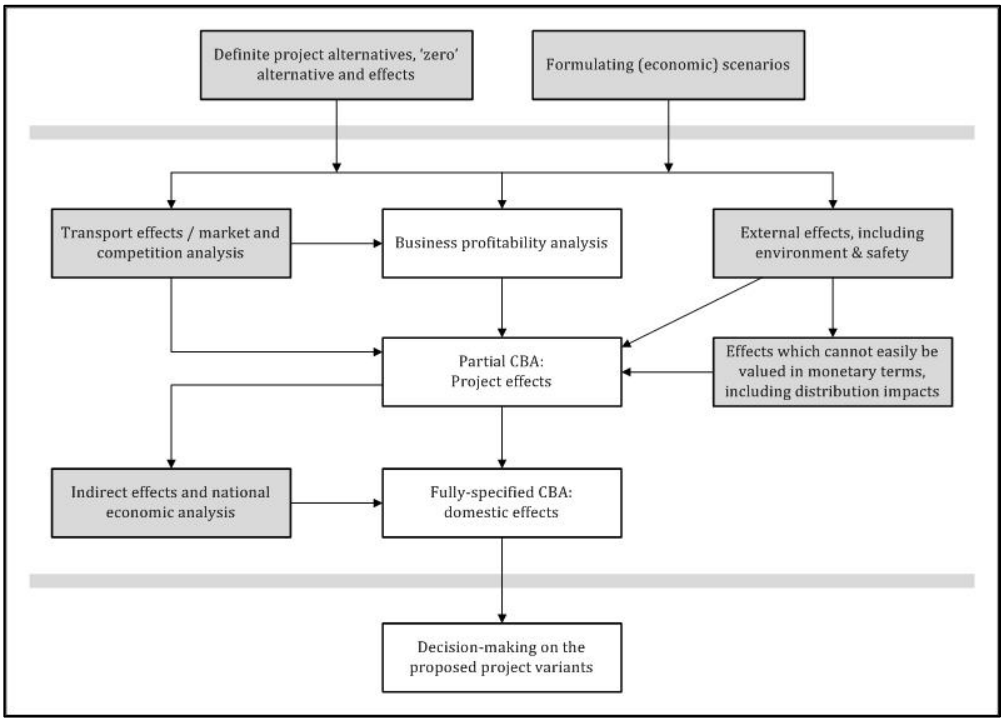

Figure 3-2, Structure of a CBA following the OEI guideline (Eigenraam et al., 2000)

Clear project alternatives and suitable scenarios (the top of Figure 3-2) are important inputs to the cost-benefit analysis. These are the starting point of the analysis and any vagueness about these items produces an additional source of uncertainty for the CBA. Therefore, the influence of the starting assumptions on the CBA model will need to be determined. This can be done in the form of complete economic scenarios or by sensitivity analyses on the most uncertain inputs to the CBA. The actual CBA (the middle part of Figure 3-2) commences with an analysis of some of the direct effects of the project: the transport effects and a market and competition analysis. These direct effects provide an input for the business profitability analysis. On the basis of the previously conducted analyses, the second type of effects: the external effects[5] (such as effects regarding the environment and safety) can be determined. These effects can be split into effects that can be expressed in monetary terms and those that cannot. These effects combined form a 'partial' CBA, which is often carried out in the earlier planning stages of a project. In the later stages, a fully-specified CBA needs to be carried out which includes the indirect effects on the economy.

The different types of effects will be defined in this thesis by using the definitions from the OEI guideline. "A direct effect is the effect of the project on the owner or operator on the users of the transport services, or externalities which stem from the infrastructure or the use thereof." Direct effects include factors such as investment and maintenance costs, but also travel time savings that result from the construction of the project. An external effect is: "a change in welfare, as a result of the project, for people other than the

[5] Although external effects can be seen as a type of direct effects, the term external effects will be used in this thesis as a separate type of effects to distinguish between direct effects of the project and external effects such as environmental & safety effects.

owner or developer and the users of the project services". External effects normally include environmental and safety effects and – in normal infrastructural projects - are often negative and unintended in nature. A distinction can be made between first order and second order direct and external effects. A first order direct socio-economic effect of covering a highway, is for instance that noise is heavily reduced next to the highway. A second order effect occurs as a result of this: building restrictions for certain parts next to this highway are lifted, which results in a value increase of all land surrounding the highway. This distinction between first and second order direct effects has already been used in Chapter 2 regarding the technological effects of The Sustainable Highway. Contrary to direct effects, indirect effects have no undisputable direct cause and effect relationship with the project and will generally take much longer to occur. An indirect effect of The Sustainable Highway might be a shift in employment towards the area where it is constructed. This will stimulate the economy in that area and is therefore an indirect socio-economic effect. The measure in which the increase in employment can be attributed to the construction of the project is often difficult to determine. In a partial CBA, effects on sectors that are directly affected by the project are included, while a fully-specified CBA also includes wider effects on the economy as a whole.

After a fully-specified CBA has been carried out, a political decision can be made on the proposed project variants. This connects well with the adapted political economy model presented in Figure 3-1. The fully-specified CBA can serve as input in the decision making procedures, as was discussed in paragraph 3.1. This will in turn influence the political feasibility of the project. In the next paragraph, the two frameworks from this chapter will be combined into a four phase approach which can be used to assess the socio-economic feasibility of The Sustainable Highway.

3.3 Integrating the frameworks

In paragraph 4.1 the place of a cost-benefit analysis in the political process of the adoption of an innovation was discussed. In paragraph 4.2 different forms of project appraisal were introduced and the choice for a CBA based on the OEI guideline was clarified. When the OEI guideline is followed, the CBA will be objective and transparent. This should ensure that the result of the analysis is perceived to be close to the true cost-benefit ratio of The Sustainable highway.

In 2007, a manual for project managers to conduct a CBA following the OEI guideline was issued by the Ministry of Transport, Public Works & Water Management (BCI, 2007). This manual provides an applied approach of the OEI guideline and is suitable for this research project. In general, as can be seen in Figure 3-2 and is explained in paragraph 3.2, an OEI is normally drawn up by conducting six different aspect studies. These studies refer to:

- The 'zero'-alternative and project alternatives;
- Conceivable socio-economic scenarios;
- Direct effects: transport effects, market- and competition analysis;
- Indirect effects;
- Direct external effects: environment and safety;
- Distributional effects.

Although in practice, the final aspect study is often not carried out or in a very limited way (BCI, 2007). Besides these aspect studies a number of research steps are identified in the OEI guideline. These research steps and aspect studies can be integrated into four process steps. This phased manner of drawing up a cost-benefit analysis is suggested in the OEI, but not prescribed. The process steps of an OEI project are depicted in Figure 3-3.

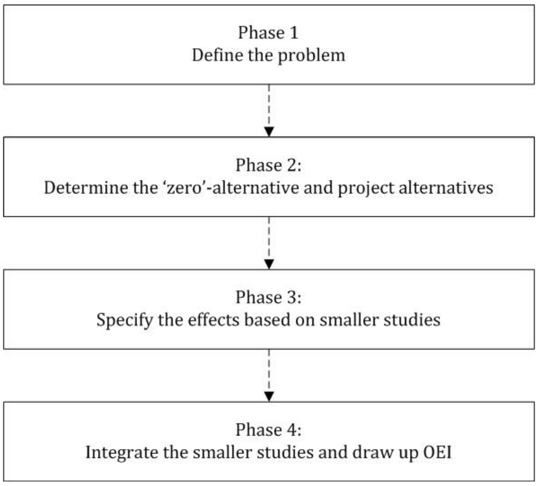

Figure 3-3, Process steps of an OEI project (BCI, 2007)

The process to draw up an OEI starts with the definition of the problem. This is a comprehensive process, most of which has already been carried out in earlier chapters. A specification of some aspects of the problem (such as geographic location) will however, require some additional attention and might need to be (re)defined for the purpose of this CBA. In phase two the 'zero'-alternative and project alternatives will need to be determined. The 'zero'-alternative will represent the most likely solution under current government policy. This is fundamentally different from 'doing nothing', since choosing a solution for the problem is often a legal obligation. The project alternatives represent different types of solutions to the problem; one of the alternatives will in this case be The Sustainable Highway. In phase three all effects of the alternatives on society will need to be defined and expressed in monetary terms for as much as possible. The aspect studies on the different types of effects need to be performed to gain insight in the full spectrum of effects. It is important that the aspect studies share the same starting assumptions and connect well. In phase four the aspect studies need to be integrated and the Overview Effects Infrastructure can be drawn up. This should include all effects from phase three and present a single outcome of the cost-benefit analysis. When this phased approach is carried out, keeping in mind the overall position of the cost-benefit analysis in the political process and the aspect studies of which an OEI is made up, a framework is formed to determine the socio-economic feasibility of The Sustainable Highway.

3.4 Conclusions on socio-economic framework

A cost-benefit analysis can be a valuable tool in determining the socio-economic feasibility of a project. It can also function as a methodology to compare different alternatives in a systematic and objective way on several criteria. A cost-benefit analysis of an infrastructure project is never carried out in isolation; it is part of a complicated political process which has certain demands on the way in which it is carried out. A CBA should be transparent, or otherwise, the understanding and valuation of the analysis by stakeholders might suffer and lead to conflicting perceptions between the analysts and stakeholders. To ensure a CBA is accepted by stakeholders the OEI guideline provides a blueprint to draw up a CBA. Drawing up a CBA according to this guideline is a legal obligation for special infrastructure projects in the Netherlands. The OEI guideline will be used to draw up the cost-benefit analysis in this research project, since this will ensure a transparent, systematic, objective and politically acceptable way to determine the costs and benefits of The Sustainable Highway. The OEI-guideline does not provide a framework on how to appraise each specific effect in detail. Each effect will therefore still require an extensive discussion on how it will need to be computed.

4. Determining the socio-economic Feasibility of The Sustainable Highway

In this chapter the concept of The Sustainable Highway will be appraised according to the framework that was developed in Chapter 3. This will lead to conclusions on the socio-economic feasibility of the concept. A limited cost benefit-analysis has already been carried out on the concept by Decisio BV in 2009 (Decisio BV, 2009). It should be noted that Decisio's Cost-Benefit Analysis (CBA) applies a rather broad perspective, not focusing on any specific location. It is however, valuable as a starting point for analysis. The CBA that will be carried out in this chapter will differ from the earlier performed CBA in several ways, which will be elaborated on later in this chapter.

The first part of this chapter will consist of a review of Decisio's CBA following the four-phase approach from Chapter 3. The second part will consist of a new CBA also following the four-phase approach. The differences in starting assumptions and their influence on the final results will be specifically highlighted. The results of the CBA will be presented in an Overview Effects Infrastructure and this will eventually lead to conclusions on the socio-economic feasibility of The Sustainable Highway.

4.1 Analysing the CBA

In Chapter 2, a counter-expertise which was performed for the municipality of Rotterdam was discussed. In this second opinion on the concept of The Sustainable Highway, the technological feasibility of the concept was researched. Since it provided no insight in socio-economical factors and left some questions regarding the concept's societal profitability unanswered, a social cost-benefit analysis was commissioned to determine the costs and benefits of the concept for society. This CBA took the counter-expertise as a starting point and analysed the costs and benefits of The Sustainable Highway for a non-defined piece of the Rotterdam ring road. Since the starting assumptions and therefore problem description are similar to that of this thesis, no further problem definition is needed to conclude phase one of the process steps of an OEI project. Decisio's 'zero'-alternative and project alternatives will now be discussed.

4.1.1 The 'zero'-alternative and project alternatives

The CBA that was performed by Decisio took the counter-expertise as a starting point. In order to provide the best possible link to the counter-expertise, the same (zero and project) alternatives were chosen for the CBA as for the counter expertise which was discussed in paragraph 2.4. The 'zero'-alternative of this CBA was a one kilometre section of the Rotterdam ring road consisting out of 2 x 3 traffic lanes. Building restrictions would apply within an area of 10 to 500 metres from the highway for residential buildings and 10 to 100 metres for office buildings due to environmental standards.

The 'zero'-alternative was compared to three project alternatives of a diverse nature. The first alternative (named the 'zero+' alternative) is common policy for problems relating to noise nuisance. In this project alternative the same highway section with 2 x 3 traffic lanes is considered, but with noise barriers of ten metres high along both sides. This alternative is focussed on solving problems with road traffic's external effects with minimal costs. As a result of construction the noise barriers, building restrictions would apply from 10 to 300 metres from the highway for residential buildings and 10 to 100 metres for office buildings. The second alternative which was considered is The Sustainable Highway, covering 2 x 3 traffic lanes with a support in the middle. Furthermore, all other technological sub-systems and attributes that have been discussed in Chapter 2 apply. This results in reduced building restrictions, allowing the construction of residential and office buildings alongside the highway. The final project alternative is a tunnel at the same location with equal highway characteristics. The same building restrictions as with the Sustainable Highway apply, however parks and green areas are allowed on top of the tunnel, increasing urban quality. Currently, it is not preferred to construct buildings on top of a tunnel, however, exceptions are made from time to time. Additional investment in the tunnel structure will then be required. In the tunnel alternative the assumption is made that building on top of the tunnel will not be allowed. To summarise: the reference (or zero) alternative will be compared to a highway with noise barriers, The Sustainable Highway and a tunnel at the same location.

4.1.2 Project effects

In phase three of the four-phase approach, first the expected effects need to be defined. In the previously executed CBA only the direct and external effects are analysed, leaving the indirect effects out of the analysis. In Table 4-1, all effects are defined; this table also shows which effects were expressed in monetary values. The top part of the table shows all direct effects, while the bottom part concerns the external effects of the alternatives.

Table 4-1, socio-economic effects evaluated by Decisio (Decisio BV, 2009)

Effects	Effects specification	Effect expressed in monetary values?
Investment costs	Construction costs	Yes
Avoided investments	Investments no longer needed as a result of project-alternative	No
Maintenance	Maintenance costs on construction	Yes
Maintenance	Maintenance costs on road surface	Yes
Traffic flow	Congestion costs as a result of road maintenance	Yes
Energy benefits	Benefits of heat and energy	Yes
Spatial effects	Square metres of building land	Yes
Urban quality effects	Value increase of existing real estate	Yes
Safety	Change in safety	No
Noise	Change in noise	Yes
CO_2	Change in CO_2	Yes
NO_x	Change in NO_x	Yes
PM_{10}	Change in fine particles	Yes
SO_x	Change in SO_x	Yes

To translate the external effects into monetary values statistical indicators were used. The external effects can be split into effects relating to infrastructure or related to traffic. The difference is that effects relating to traffic increase when traffic volume increases and effects related to infrastructure originate from the fact that the infrastructure is there. In the case of the Sustainable Highway, the CBA concerns the addition to existing infrastructure. Infrastructure related effects are less relevant in this case and are therefore not discussed. Furthermore, the costs and benefits of infrastructure related effects are normally derived from an environmental effects report (MER), which is not yet available for The Sustainable Highway. The external effects relating to traffic that are evaluated for a normal infrastructure project are similar for the effects of The Sustainable Highway and other alternatives. The external effects that will be calculated are therefore related to safety, noise and the emission of environmental pollutants.

4.1.3 The Overview Effects Infrastructure

The effects as described in the previous paragraph have been computed and combined into an Overview Effects Infrastructure (OEI). Since this CBA will only function as material for comparison, the model behind this CBA will not be discussed.

In order to make anticipated costs and benefits comparable a discount rate is used: a percentage of interest to convert a future euro to a present day euro, this is called the Present Value (PV). Using this method, the investment costs for the zero+ alternative is 26 million euro and the maintenance costs of the construction 4,7 million. For The Sustainable Highway and a tunnel these figures are 79,3 and 9,9 million euros and 189,9 and 18,0 million euros respectively. This makes the tunnel alternative the most expensive and the zero+ alternative the most inexpensive. Opposing these higher costs for The Sustainable Highway and a tunnel are the higher benefits. These mainly consist of an increase in noise reduction, a longer lifespan of the road surface, renewable energy benefits and building land benefits. When a tunnel is constructed, a park can be created on top of it. This eliminates the barrier effect of infrastructure and increases the value of real estate in the area, explaining the high benefits for urban quality effects. The results of this analysis are presented in Table 4-2.

Table 4-2, Overview Effects Infrastructure, in millions of euros, Net Present Value for entire lifespan of alternative by Decisio (2009).

Direct effects		Zero+ alternative	The Sustainable Highway	Tunnel
Construction costs		-26,0	-79,3	-189,9
Avoided investments		+PM	+PM	+PM
Maintenance costs construction		-4,7	-9,9	-18,0
Maintenance costs road surface		0,0	5,7	5,9
Traffic flow effects		0,0	0,5	0,5
Renewable energy benefits		0,0	14,4	0,0
Building land benefits		3,7	22,2	22,2
Urban quality effects		0,0	0,0	18,8
Balance of direct effects		**-27,0**	**-46,5**	**-160,5**
External effects		**Zero+ alternative**	**The Sustainable Highway**	**Tunnel**
Safety		+/-PM	+/-PM	-PM
Noise		10,5	14,0	14,0
Emissions	CO_2	0,0	0,0	0,0
	NO_x	0,0	1,3	0,0
	PM_{10}	0,0	2,4	0,0
	SO_x	0,0	0,0	0,0
Balance external effects		**10,5**	**17,7**	**14,0**
Total		**-16,5**	**-28,8**	**-146,5**

In comparison with the zero+ alternative, the most important benefits The Sustainable Highway offers are the revenues that can be achieved from building land that becomes available. Since no specific location was chosen and revenues from building land are highly location dependent, a relatively low land price was chosen. In Rotterdam, land prices range from €125 to €416 per square metre (Gemeente Rotterdam Gemeentewerken, 2009) and the low end of the range was chosen. This choice has a large influence on the final benefit-cost ratio.

The Overview Effects Infrastructure shows that the zero+ alternative has the best Net Present Value (or benefit-cost ratio). Second is The Sustainable Highway, followed by the tunnel-alternative. It is notable that all alternatives show a negative benefit-cost ratio, meaning that they all have more socio-economic costs than benefits. When looking at the chosen price for building land a change in starting assumptions can have large consequences for the ranking of the different alternatives. When a land price of €445 per square metre is assumed, the zero+ alternative will no longer have a negative BC-ratio. However, this break-even point is reached much sooner for The Sustainable Highway. The Sustainable Highway will break even at a price of €220 per square metre (the tunnel alternative requires a price of €615 per square metre), which does not appear to be unrealistic. Clearly additional research is needed on this subject.

The most important conclusion from this CBA is that although the zero+-alternative offers the best BC-ratio, The Sustainable Highway is a close second, while the tunnel alternative's costs exceed its benefits by far. Only small changes in the CBA's starting assumptions will result in significant changes in the end result, most notably the assumption of the price for building land. This factor will require additional research when drawing up a new CBA.

4.2 Drawing up a new CBA

The lessons and information from the previously conducted CBA shall be used as a starting point for the new cost benefit analysis. This CBA shall be drawn up using the four phase approach from Chapter 3. This paragraph will start with a recapitulation and reframing of the problem to conclude phase one.

4.2.1 Re-framing the problem

When drawing up a CBA it is important to be clear on what the focus of the CBA actually is. It should be defined what problem in society the proposed solutions are attempting to solve, this to prevent a misunderstanding about the results of the CBA at a later stage. Regarding this research project, the problem has already been clearly outlined in the previous chapters. These chapters can, in the current situation, be seen as the main part of phase one. However, some attention should be paid to whether all earlier problem definitions are still suitable as input for this CBA. In earlier chapters, the problem has been approached as purely infrastructural and mobility related. In addition to this, there is also the problem of spatial development in urban areas; urban density needs to be increased, but building restrictions apply near infrastructure. This gives an additional dimension to the problem: the dimension of spatial development. In this paragraph, the problem will be applied to a specific location and be reframed as being not only an infrastructural, but also a spatial development problem.

In phase one of drawing up a CBA, normally questions such as: 'What is the problem?', 'How did the problem come into being?' and 'Who's problem is it?' need to be answered (BCI, 2007). The question who's problem this is, is not that easy to answer since different aspects of the problem affect different stakeholders, whilst the first two questions have already been answered. To recapitulate: the problem is that road traffic has a variety negative external effects, some of which pollute the environment and damage public health. Limiting road traffic would decrease the problem, but would damage economic growth. A different solution needs to be found. The problem has come into being due to the expansion of road traffic and infrastructure and especially due to the tension between a growing population and growing mobility leading to an expansion of infrastructure in urban areas.

Other questions that need to be answered in this phase are: 'Do the problem and solution space need to be delineated?', 'What is the geographical span of the analysis?' and 'What are the goals of the project'. These questions have only be dealt with briefly, but are important for the CBA nonetheless. The solution space is in this case limited to infrastructural solutions. Common infrastructural solutions for the negative effects of road traffic need to be compared on their socio-economic benefits to The Sustainable Highway. Effects on a local and national scale will be taken into account.

A factor that will have a high influence on the costs and benefits of infrastructural projects in general and The Sustainable Highway in particular is the location where the project will be constructed. Not defining a location for the project will result in a more open ended CBA. The advantage is that it can be more easily applied to different situations. The disadvantage is that the analysis will be quite general and non-specific in nature. Defining a project location will reduce the uncertainty in the analysis and will provide a more detailed result for that specific location. Therefore an additional geographic demarcation needs to be made. This will allow to approach the problem not only as mobility related, but also in a much wider context as a spatial development problem.

To choose a suitable location to determine the socio-economic feasibility of the different alternatives, several factors are important to consider. The location should be in an urban environment and local residents should experience severe hindrance from a nearby highway. Simply choosing the location with the most hindrance in an urban environment is, in this stage of the analysis, not the most appropriate method. The goal of the analysis is to conclude if The Sustainable Highway is a feasible alternative from a socio-economic perspective, relative to other project alternatives. Therefore, a location in which economical considerations play an important part is, in this stage, the most suitable.

Figure 4-1, Specific location for analysis; the A20 highway near Rotterdam

In Rotterdam, serious attempts are being made to analyse whether The Sustainable Highway is a suitable alternative to deal with the city's problems with the external effects of road traffic. Stakeholders have already looked into several aspects of realising The Sustainable Highway in different locations in Rotterdam, resulting in the availability of useful information. Furthermore, the Rotterdam ring road runs through an urban area and is one of the busiest collections of highways in the Netherlands. Therefore, a location in Rotterdam will be chosen for the cost-benefit analysis. The website of ROM-Rijnmond (ROM-Rijnmond, 2009) identifies several promising locations for the concept, of which a section of the A20 in the north of Rotterdam seems to offer interesting possibilities from a socio-economic perspective. In the wide surroundings, residents experience severe hindrance from the A20, from both noise and air pollution. It is one of the busiest sections of highway in the Netherlands and runs through a highly populated area in Rotterdam. The section of the A20 highway between the Rozenlaan-viaduct and the highway exit Crooswijk, which is about 715 metres long, is identified as a promising location (Figure 4-1). Even though other locations in the Rotterdam area experience even more hindrance from the external effects of road traffic, this location is highly suitable for a socio-economic analysis. The main reason is the availability of potential building land alongside the highway. Since a location is chosen with a socio-economic perspective in mind, this criterion prevails over choosing a location in which hindrance for local residents is even worse. When ultimately a location for the project is chosen, the decision makers can choose to give priority to socio-economical, or other considerations. The goal of this analysis is however, to analyse whether The Sustainable Highway can provide a socio-economically feasible solution for the negative effects of road traffic. This location is most suitable for the purpose of this analysis.

The area that will be analysed is limited to the zones directly next to the chosen trajectory (Figure 4-2). This will reduce the complexity of the analysis, however there are some consequences of this choice that should be kept in mind. For example, when a canopy is constructed, noise and polluted air will exit at the canopy ends. This will directly influence all residents that live within a circular area around the canopy ends. This might mean additional measures will have to be taken (such as additional noise barriers where the canopy ends) depending on whether norms will be exceeded. Another example is, that when for instance a tunnel is constructed on this trajectory, the only part that will be analysed is the part of the tunnel which is completely underground. The ramps that will be used to allow traffic to descend into the tunnel will not be analysed. These ramps will add significant investment costs to the construction of the tunnel, but are not dependent on the length of the trajectory. These examples should be kept in mind when interpreting the results of the analysis, but effects outside of the area next to the trajectory will be no further part of the analysis. Also, influences from outside the area of analysis, or by other nearby infrastructure on the area of analysis will not be taken into account.

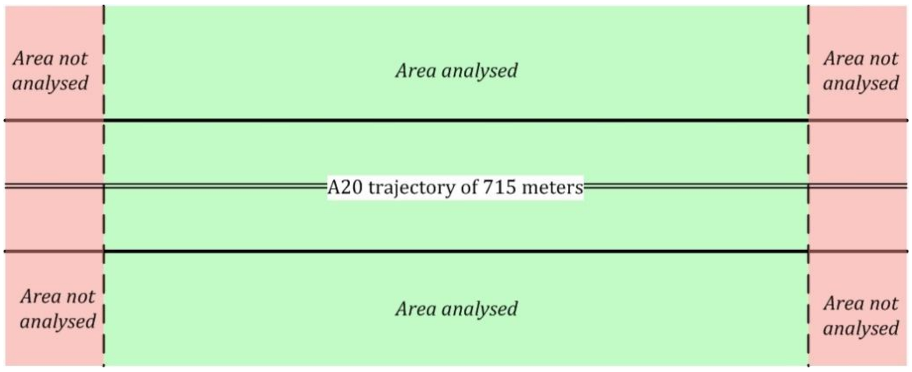

Figure 4-2, Area of analysis

Analysing the costs and benefits of the project alternatives for this location will not only provide clear and unambiguous information of the socio-economic feasibility of The Sustainable Highway for the chosen location. It can also serve as an indication for the socio-economic feasibility of the concept for other similar locations, although a location specific CBA is always advisable for each different situation.

4.2.2 The 'zero'-alternative and project alternatives

The starting assumptions – including the 'zero'-alternative and project alternatives – determine to a large extent the perception of the objectivity and transparency of a CBA. Choosing a favourable 'zero'-alternative can make the project alternatives look better or worse, depending on the chosen alternative. It is therefore important to choose a realistic 'zero'-alternative or base case. "The base case is a combination of the best other application of resources and the best possible other solution for bottlenecks. The base case is therefore something other than 'not doing anything' and is also not the 'existing policy'" (Eigenraam C. J., Koopmans, Tang, & Verster, 2000). This definition from the original OEI report was further elaborated on in 2004 in the OEI supplements (Koopmans, 2004): An OEI's zero-alternative can concern the application of minimal measures to reduce existing bottlenecks.

However, the definition of the zero-alternative is subject to discussion among CBA experts. The European commission states that, in a CBA, one: "compares the situations with and without the project. To select the best option, it is helpful to describe a baseline scenario. This will usually be a forecast of the future without the project, i.e. the 'business as usual' (BAU) forecast. This is also sometimes labelled the 'do-nothing' scenario" (European Commission, 2008). Although one can argue that using a 'do-nothing' scenario as a base case or zero-alternative is feasible, it is in the context of this thesis, not realistic. Situations in which The Sustainable Highway is considered as an alternative are characterised by norm-surpassing noise hindrance or air quality. In this case, measures have to be taken to comply to these norms. Simply 'doing nothing' is not allowed due to legal restrictions. Therefore, the zero-alternative in further analysis, will be the application of minimal measures to reduce existing bottlenecks.

The ‘zero’-alternative chosen by Decisio (a normal highway without noise-reducing measures) is therefore not suitable to use as a base case. Although justifiable since Decisio’s ‘zero’-alternative should be the same as in the counter expertise, it is simply not suitable according to the definition that has just been given. When an infrastructure project is undertaken in an urban environment, in general local inhabitants will experience noise nuisance by road traffic. The most common solution for this is to place noise barriers to mitigate the traffic noise; a ‘normal’-highway lined on two sides by noise barriers is in this case a much more suitable ‘zero’-alternative.

When considering which project alternatives to use in the analysis, the focus should be on realistic alternative solutions to both the ‘zero’-alternative and the first project alternative: The Sustainable Highway. A project alternative that was not considered in the previously conducted CBA, but is a likely solution for negative external effects caused by road traffic, is a ‘sunken road’. In this alternative the highway trajectory is dug out and the road surface is laid a few metres below ground level. This alternative is often suggested and carried out when noise barriers do not offer sufficient noise reduction. This is the case for the A73-A74 near Venlo (Cobouw, 2009) and the A1 near Muiden and Weesp (Provincie Noord-Holland, 2008). In the first case a sunken road is considered to be the most viable alternative, while in the second case the planning procedure for such a construction is already underway. In both cases, noise barriers of nine and thirteen metres respectively are needed in addition to lowering the road surface to satisfy legal norms.

The final alternative that can be considered is the construction of a tunnel. Although clearly a costly solution, a tunnel is often constructed when no other alternatives are available or feasible. This leads to the following (zero and project) alternatives:

1. *‘Zero’- alternative – Road with 10 metre high noise barriers:* a highway at ground level, consisting of 2 x 3 traffic lanes lined on both sides with noise barriers of 10 metres high. This alternative is aimed at satisfying legal conditions pertaining to traffic noise as cost effectively as possible. No further ambitions are defined for this alternative
2. *‘Zero+’- alternative – Road with 15 metre high noise barriers*: this alternative comprises the same situation as in the ‘zero’- alternative except that the noise barriers are 15 metres high. This alternative is aimed at a situation where 10 metre high barriers do not provide sufficient reduction to satisfy legal norms and higher barriers are needed.
3. *Project alternative 1 – The Sustainable Highway:* The Sustainable Highway as it has been discussed on numerous occasions in this thesis; the canopy will cover a kilometre of highway with 2 x 3 traffic lanes, consist of cold bendable laminated glass and contain additional measures to reduce air pollution and generate renewable energy.
4. *Project alternative 2 – A ‘sunken’ highway with 10 metre high noise barriers:* in this alternative the highway will be constructed below ground level with 10 metre high noise barriers lining both sides; no additional environmental measures are taken.
5. *Project alternative 3 – A tunnel:* In the tunnel-alternative the same section of highway is constructed as a tunnel. No additional environmental measures are taken. It is not possible to build on top of the tunnel, however, it is possible to construct a park or green area.

The zero- and project-alternatives will serve as input for the cost-benefit analysis. In the next phase all effects of these alternatives on the problem situation will need to be defined.

4.2.3 Project effects

In phase three all project effects need to be determined. This is normally done by conducting different aspect studies that may or may not be carried out by different parties. In this case only a partial CBA will be carried out. This means this CBA will focus on the direct and external effects, since too little is yet known about indirect and distributional effects. This paragraph will start off with the typology of all effects after which their respective magnitude will be determined. The typology of project effects will be divided into two parts; first the typology of direct effects, second the typology of external effects. The typology of these effects will follow Decisio’s definitions in some cases, but will differ significantly in other cases.

Typology of direct project effects

Direct effects of normal infrastructure projects consist of investment costs, avoided investments, maintenance costs and effects of the project on the flow of traffic. Characteristic for The Sustainable Highway is the fact that it attempts to provide an integral solution for many important negative external effects of road traffic. This means certain additional direct effects need to be taken into account. Revenues from the generation of renewable energy, spatial effects and urban quality effects will also have to be evaluated.

- *Investment costs:* the realisation of any infrastructure project will require substantial investment costs. These investment costs consist of the construction costs of the project (including costs for engineering, administration and management) and in this case also the implementation costs. When a detailed construction cost estimate is made, it will generally be applied to a specific situation and costs for implementing the project in its environment will be part of the estimate. In this case however, only the cost of building materials, engineering, administration fees and management will be taken into account, since these estimates are available. Implementing the alternative in a specific urban situation will mean incurring more costs due to the technological complexity of the local situation. Buildings might have to be demolished and land disowned to make the construction of the alternative possible. The complexity of implementing different alternatives in an urban environment differs strongly between the alternatives. It is therefore an important factor to take into account in the cost-benefit analysis. Due to the complexity of making a cost estimate for this and the early planning stage in which this CBA is performed, this effect will not be evaluated in monetary terms, but as a PM-post. The extent in which effects will occur outside the area of analysis (Figure 4-2) will also be part of the ‘implementation costs’ effect.

- *Maintenance costs:* these costs are costs that reoccur either on a yearly basis or over a longer period of time. A distinction needs to be made between maintenance costs on the construction and maintenance costs on the road surface. Both factors are likely to vary among the different alternatives.

- *Traffic flow effects:* when a CBA is executed for a normal infrastructural project (say the expansion of a highway with 2 x 2 traffic lanes to 2 x 3 traffic lanes) significant effects on the volume and flow of traffic can be expected. The proposed alternatives neither restrict nor expand the capacity of the existing highway and therefore, the expectation is that the effect of the project alternatives on the flow of traffic is negligible (Gemeente Rotterdam Gemeentewerken, 2009). However, effects on traffic flow are expected during maintenance on the road surface. This effect requires further evaluation.

- *Renewable energy:* The Sustainable Highway generates benefits resulting from renewable energy in two ways: solar cells produce solar energy and asphalt heat collectors harvest usable heat. These types of energy can both be sold at a market price. The financial benefits resulting from the sale of this energy will be calculated under this effect.

- *Spatial effects:* an important aspect of the project alternatives is that additional building land can become available alongside the section of highway where the project alternative will be constructed. Because of the possibility to build on this land, its productivity is increased, which causes the value of the land to rise. The new functions that become possible for the building land can be used as a starting point to determine its value.

- *Urban quality effects:* infrastructure in urban areas often divides an area in two separate areas between which limited interaction is possible. This is called the barrier-effect, since the infrastructure serves as a barrier that can only be crossed at certain points. Accommodating infrastructure below ground level eliminates this barrier effect. This does not only positively influence the quality of life in the surrounding areas, it will also result in an increased value of all property around the infrastructure. These effects can be clustered under urban quality effects.

Typology of external project effects

To translate external effects into socio-economic costs and benefits, valuation methods that were mentioned in Chapter 3 can be used. In this CBA statistical indicators commonly used in the European Union shall be used to express the external effects into monetary terms. Paragraph 4.1.2 mentioned that no MER is yet available for these alternatives, which means the infrastructure related effects will not be quantified. The following external effects can be identified:

- *Safety:* In Chapter 2 the effects of The Sustainable highway on safety have been discussed in depth. Like The Sustainable Highway, all project alternatives have an effect on road safety. The design or characteristics of an alternative can influence road safety and the chance of accidents directly or indirectly. All aspects of safety as they have been discussed in Chapter 2 should be taken into account.

- *Noise:* All project alternatives have the common goal to reduce noise nuisance along infrastructure. However, not all alternatives are equally effective in attaining this goal. In addition to the direct influence of an alternative on noise, an indirect influence can occur when the traffic volume increases as a result of the project.

- *Emissions:* In Chapter 2, several emissions by road traffic were identified. Since some alternatives have as their objective to reduce these emissions, they are an important part of the CBA. The emissions of CO_2, NO_x and PM_{10} will be evaluated in the CBA. SO_x will not be part of the analysis since no significant benefits are to be expected due to the already very low emission of SO_x by road traffic. The emission of fine particles and NO_x can have great effect on local air quality and public health of residents. However, for the emissions of CO_2 it is of no consequence for local residents on what location they are emitted. For the other emissions however, the damage that is caused is dependent on the location of emission.

Although this list of effects is similar to that of the previously conducted CBA, there are some important differences. Implementation costs is added as an effect, while the emission of SO_x is deliberately left out of the analysis. Furthermore, the location where the effects will be analysed is now specified as well as the alternatives that are used. Especially these two points will have large consequences for the way in which the CBA is carried out and the results which will be obtained. Finally, there are significant differences in the computation of several effects such as noise nuisance and spatial effects. The following paragraph will elaborate on the way in which all effects are computed.

Computing the effects

Now that all effects which will be analysed are known, they can be computed. For the calculations, on some occasions, the model used in the CBA by Decisio will be used as a starting point. However, on most points there will be significant deviations regarding their methods of calculation. It will be discussed why and where this is done. The model will be applied to the location that was specified in paragraph 4.2.1 and to each of the alternatives that were identified in paragraph 4.2.2.

Some costs or benefits occur immediately when an alternative is realised, such as investment costs, or benefits from the development of building land, while others return periodically. Since present day euros are more valuable than euros in a future moment in time, costs that occur in the future need to be discounted to their current value. The method that is generally used in social costs-benefit analyses is the calculation of the Present Value (PV) of effects. The Net Present Value (NPV) of an alternative can then be calculated by subtracting costs from the benefits. In the OEI guideline the NPV is defined as follows:

> *“(NPV is) a profitability or decision criterion used in cost-benefit analysis. The amount which is derived from deducting the present value of the expected costs of an investment from the present value of the expected return. In a CBA, the NPV is calculated by using the social discount rate. If the NPV is positive, it would, from an economic point of view, seem feasible to implement the project.”* (Eigenraam et al. 2000)

The NPV is to a large extent determined by the chosen discount rate. For cost-benefit analyses in the Netherlands following the OEI guideline a standard ‘real’ ‘risk-free’ discount rate of 2,5% should be used. A risk-charge is added to this base-rate to obtain the full discount rate. When no suitable method is available to determine an effect specific risk charge, the standard risk charge of 3% may be used (Werkgroep Lange Termijn Discontovoet, 2009). Therefore, the total discount rate that will be used for further analysis is 5,5%. The prices that will be used in the calculations are all current (2009) and the intended start of construction will be in 2010. Therefore, the Present Value of effects will be calculated for the year 2010.

<u>Computation of direct effects</u>
In this paragraph, the computation of the direct effects will be discussed for each effect and each alternative. Annex 3 will contain a more elaborate clarification and show some computation tables from the spreadsheet analysis.

Investment costs
The investment costs of the ‘zero’-alternative, The Sustainable Highway and a tunnel have been determined by Movares and confirmed by other external experts on previous occasions (Gemeente Rotterdam Gemeentewerken, 2009; Decisio BV, 2009). The investment costs of the other two alternatives have been determined by Movares as well. Although no estimates from other sources are available, since the investment costs for three out of five alternatives have been verified, the other two estimates are also assumed to be correct. The costs are estimated per metre or square metre and are rough estimates. As a result, all construction costs have been increased by 30 percent for engineering costs, legal dues and unforeseen costs. Various experts have stated that these costs are realistic estimates (Gemeente Rotterdam Gemeentewerken, 2009; Decisio BV, 2009).

- The zero alternative will cost roughly €10.000 per metre (or €1000 per square metre) which amounts to approximately seven million euros for each side of the highway, excluding the additional 30% charge (expert estimation movares, Decisio BV, 2009).
- The zero+ alternative will cost approximately €15.000 per metre (or €1050 per square metre), which amounts to eleven million euros for each side, excluding the additional 30% charge (expert estimation Movares).
- The Sustainable Highway will cost approximately €43 million euros for the entire trajectory, excluding engineering and risk costs. Since the construction costs are composed of several specific elements, the cost calculation is shown in

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- Table 4-3 (expert estimation Movares; (Gemeente Rotterdam Gemeentewerken, 2009; Decisio BV, 2009).

Table 4-3, construction costs of The Sustainable Highway

	Length	Width (if applicable)	Unit price	Costs (X 1.000.000)
Foundation	715		€4.000,0	€2,86
Canopy	715	50	€740,0	€26,46
Installations	715		€10.000,0	€7,15
Renewable energy system	715		€10.000,00	€7,15
Engineering & Risk			30%	€13,08
Total				**€56,70**

- The costs of a sunken highway with noise barriers are based on that of an open tunnel construction of 2,5 metres deep, with noise barriers of 10 metres high on each side. Since the noise barriers can be founded on the concrete side panels of the open tunnel construction, no additional foundation is needed. Therefore the barriers will be slightly less expensive than the noise barriers in the zero alternative. The total construction costs excluding risk are spread over two years and estimated to be €65 million. This cost estimate is obtained by consultation with experts of Movares B.V.. No second opinion on this estimate is sought, since earlier estimates for other alternatives by the same experts have been confirmed by second opinions (expert estimation Movares).
- The costs of the tunnel alternative are also spread over two years and are in total €107 million. As previously stated, this does not include any costs for the ramp to allow traffic to enter the tunnel (expert estimation Movares, Decisio BV, 2009)

The resulting total costs of each alternative, including risk and engineering costs are displayed in Table 4-4. All costs are calculated in their Present Value, which equals the total construction costs for most alternatives. For the tunnel and sunken highway, the construction is expected to take over a year in which case the construction costs are spread over two year, resulting in slightly lower Present Value costs.

Table 4-4, Construction costs (X 1.000.000)

	Zero alternative	Zero+ alternative	The Sustainable Highway	Sunken Highway	Tunnel
Construction costs	€-18,59	€-29,28	€-56,70	€-84,58	€ -139,43
PV	€-18,59	€-29,28	€-56,70	€-82,38	€ -135,79

The second part of the investment costs consists of the implementation costs. These will be expressed in as PM-posts to illustrate to what costs each alternative can be implemented in the selected environment. Both the zero- and zero+ alternative can be implemented fairly easily. Not much space is required for foundations and there is much experience with the implementation of noise barriers in an urban environment. The Sustainable Highway will also require little room for foundation, however, the construction process is slightly more complicated. This might result in some additional costs. Both the sunken highway and tunnel alternatives however, require much more implementation costs. It will be difficult to implement either one of these alternatives in an urban environment. The highway might need to be (partly) closed for a certain period of time. In addition, the tunnel or sunken highway might need to be constructed on a parallel trajectory to the existing highway. This might require additional land to be purchased or disowned. This will lead to substantial additional costs which are not yet part of the budgeted construction costs. Table 4-6 shows the PM-posts for each alternative. The implementation costs give an indication of the complexity of constructing a tunnel in an urban environment.

Table 4-5, Implementation costs (PM)

	Zero alternative	Zero+ alternative	The Sustainable Highway	Sunken Highway	Tunnel
Implementation costs	PM+	PM+	PM+/--	PM--	PM--

Maintenance costs
In addition to the construction costs, each alternative will require maintenance costs. As discussed in paragraph 0, these costs can be divided into the maintenance costs of the construction itself and the costs to maintain the road surface. Construction maintenance costs differ significantly for each alternative, depending on the complexity of the structure. For noise barriers, the maintenance costs are assumed to be approximately one percent of their construction costs per year. Several experts have confirmed the realism of this estimation (Gemeente Rotterdam Gemeentewerken, 2009; Decisio BV, 2009). For a tunnel, the maintenance costs are estimated to be between the 0,6 and 1,5 million euros per kilometre per year. The average of these costs is approximately 0,5% of the construction costs of a tunnel; the same cost estimation will be used for a sunken highway. The maintenance costs of The Sustainable highway can be estimated in detail. The construction will need to be cleaned twice a year and painted once a year. Maintenance on the installations and energy system are estimated at one percent of construction costs. These estimates have also been confirmed. Previous considerations lead to the following yearly and Present Value costs:

Table 4-6, construction maintenance costs (X 1.000.000)

	Zero alternative	Zero+ alternative	The Sustainable Highway	Sunken Highway	Tunnel
Maintenance per year	€-0,19	€-0,29	€-0,39	€-0,42	€-0,75
PV	€-3,36	€-5,30	€-7,12	€-7,65	€-13,59

In Chapter 2 it was explained that covering the highway, with either a tunnel or canopy will allow a different type of asphalt to be used, which is less costly and more durable. This will result in lower costs (or higher benefits) for alternatives which utilise some type of covering. In paragraph 2.2.1 the lifespan of these types of asphalt is discussed. This lifespan determines when the top-layer of the asphalt needs to be replaced and therefore when the costs associated with this action need to be made. Highly porous asphalt (ZOAB) which is common in the Netherlands for all non-covered road surfaces within has a lifespan of around eight years (IPG, 2008). Non-porous asphalt (DAB) is likely to have a lifespan of around 24 years, when it is covered. The costs to replace the top-layer of asphalt are €3,5 and €3,7 million per kilometre for DAB and ZOAB respectively. Table 4-7 shows the consequences for periodic and Present Value costs when this is applied to the current situation. The Present Value is calculated in relation to the zero-alternative.

Table 4-7, maintenance costs of the road surface (X 1.000.000)

	Zero alternative	Zero+ alternative	The Sustainable Highway	Sunken Highway	Tunnel
Maintenance / period	€-2,65	€-2,65	€-2,50	€-2,65	€-2,50
Road surface lifespan	8 years	8 years	24 years	8 years	24 years
PV compared to zero alternative	0	0	€4,11	0	€4,29

The tunnel alternative has slightly higher benefits since the construction process will take two years, which means all maintenance costs are pushed back one year in relation to the other alternatives. Both The Sustainable Highway and the tunnel offer a significant reduction in road surface maintenance costs.

Traffic flow effects

Effects on the traffic flow are directly related to the frequency and duration of maintenance works on the road surface. When maintenance is carried out, significant congestion will appear leading to effects on the flow of traffic. Since in some alternatives a different type of asphalt is used, which requires less maintenance, traffic will face congestion less frequently leading to certain benefits. Calculations by Decisio show that traffic flow effects for one kilometre of highway in the Netherlands total up to €350.000 every time road maintenance is carried out. This corresponds to approximately €250.000 for the analysed location. The benefits regarding traffic flow due to less frequent road maintenance are displayed in Table 4-8.

Table 4-8, Traffic flow effects (X 1.000.000)

	Zero alternative	Zero+ alternative	The Sustainable Highway	Sunken Highway	Tunnel
Traffic flow effects when road maintenance is carried out	€-0,25	€-0,25	€-0,25	€-0,25	€-0,25
Road surface lifespan	8 years	8 years	24 years	8 years	24 years
PV compared to zero alternative	0	0	€0,37	0	€0,39

Less frequent road maintenance leads to social benefits for The Sustainable Highway and tunnel alternatives, even though the benefits are very slight. The difference between the two alternatives is again caused by the longer construction process of a tunnel in relation to The Sustainable Highway.

Renewable Energy

Benefits caused by the generation of renewable energy are only applicable to the construction of The Sustainable Highway. In the current setup, no other alternatives contain measures to generate renewable energy. Benefits from renewable energy generation originate from two sources: solar panels generate electricity and a system to harvest usable heat generates heat suitable for heating homes in the vicinity of The Sustainable Highway. Direct financial benefits can be achieved by marketing the energy and heat, in addition socio-economic benefits are generated by the reduced usage of non-renewable energy sources. The first type of benefits will be computed here, while the second type will be computed under 'external effects'.

The Sustainable Highway can generate approximately 1350 MWh of electricity per kilometre, or 1,35 MWh per metre. This corresponds with an energy generation of 965 MWh for the chosen trajectory of 715 metres. At a price of €76,- per MWh (Senternovum, 2009), this results in benefits out of electricity generation of over €70.000 per year. This does not include any government subsidies for which the concept might be eligible. Revenues from marketing heat amount to over €450.000 every year and are based on the price that would normally be paid for an equivalent gas consumption. This amount corresponds to a more detailed calculation done by Movares in a feasibility study of The Sustainable Highway on the A10 (Movares B.V., 2007). The total benefits from renewable energy are displayed in Table 4-9.

Table 4-9, Benefits from marketing renewable energy

	Zero alternative	Zero+ alternative	The Sustainable Highway	Sunken Highway	Tunnel
Renewable Energy per year	€0,00	€0,00	€0,53	€0,00	€0,00
PV	€0,00	€0,00	€10,14	€0,00	€0,00

All other alternatives than The Sustainable Highway do not generate renewable energy and therefore do not receive any benefits from this effect. For the chosen location, it is yet uncertain if the generated heat can be used. Rotterdam has a city heating system and the heat generated by The Sustainable Highway is not warm enough to feed directly into the system. Therefore the heat’s temperature needs to be increased, otherwise it is only suitable to heat buildings that have yet to be built and are not yet connected to the city heating network. Since building land may come available when The Sustainable highway is constructed, the real estate that will be developed might be suitable to connect to The Sustainable Highway’s heat generating system. This however, is institutionally quite complex and will be further discussed in Part II of this thesis.

Spatial effects

Chapter 2 has provided an in depth discussion regarding the way The Sustainable Highway influences building restrictions. Since noise nuisance and emissions are shielded from the surrounding area, building restrictions can be reduced or are no longer applicable. This results in the possibility to develop plots of building land in an urban environment that were previously unsuitable for the construction of residential buildings. With regard to building restrictions, three possible scenarios are identified (Decisio BV, 2009):

- ‘Flexible’ scenario: flexible norms and regulations regarding noise and air-pollution as well as safety govern the area, which means that without any countermeasures, it is only allowed to construct houses 200 metres from the highway and offices 10 metres from the highway.
- ‘Middle’ scenario: without any countermeasures, it is only allowed to construct houses 350 metres from the highway and offices 50 metres from the highway.
- ‘Restrictive’ scenario: without any countermeasures, it is only allowed to construct houses 500 metres from the highway and offices 100 metres from the highway.

Near the A20 and the trajectory of analysis, houses have been built within 200 metres of the highway. Currently many buildings exist within the limits set by all three scenarios. In an environment such as this, the flexible scenario is the most realistic. For the flexible scenario, building restrictions are displayed in Table 4-10.

Table 4-10, building restrictions per alternative

Alternatives	Building restrictions
Zero-alternative	No residential buildings between 50 – 200 metres, no office buildings within 10 metres
Zero+-alternative	No residential buildings between 50 – 200 metres, no office buildings within 10 metres
The Sustainable Highway	No residential buildings within 10 metres, no office buildings within 10 metres
Sunken highway	No residential buildings between 50 – 200 metres, no office buildings within 10 metres
Tunnel	No residential buildings within 10 metres, no office buildings within 10 metres

Within the current building restrictions, the construction of office buildings is already possible. For further analysis the construction of residential buildings is assumed, since the objective of this CBA is to measure the change in social costs and benefits when an alternative is constructed. Constructing office buildings does not constitute a change of the current situation. Residential construction will only be possible if the city council will allow the construction of residential buildings in that area.

Three separate locations with possibilities to develop residential buildings can be identified within the area of analysis. These locations are displayed in Figure 4-3. All locations have different characteristics which influence the ease in which the location can be developed. No areas where currently residential buildings exist have been selected. Area A has been specifically mentioned in earlier explorations by the municipality of Rotterdam as a potential location to develop residential buildings (ROM-Rijnmond, 2009). It is stated that Area A can be used as a development location for approximately 500 apartments (of approximately 120 m^2 gross floor space) in high-rise apartment complexes of five to six floors. Area's B and C are mentioned as potential development locations, however, no statements on the number of apartments are made. However, there is no reason to assume fewer apartments per square metre can be realised on these locations. Therefore, the number of apartments is scaled in relation to the square metres of building land that become available.

Figure 4-3, possible locations for residential development

In Rotterdam, land prices are determined by the function the land will fulfil after it has been developed. Land prices are therefore not determined per square metre of land, but by the number of square metres of apartment space (or office space for that matter) that will be realised (Ontwikkelingsbedrijf Rotterdam (OBR), 2008). An assumption needs to be made on the number of apartments, number of square metres of apartment to be realised and the price per square metre of apartment. When these factors are known, the potential revenues from the development of building land for this location can be calculated.

This method to calculate building land revenues is fundamentally different from the method that was used in the previous CBA. The previous model assumed a flat rate per square metre of building land, which is suitable for very rough approximations. This may be realistic in some cases, however in Rotterdam, prices of building land are not determined in this way. Estimating the building land benefits on the basis of a flat rate might cause a gross underestimation of the benefits and therefore the method of functional residual pricing (such as the city of Rotterdam's method) will be used to obtain the building land benefits in this analysis. This method takes the function the land will fulfil after it has been developed as a starting point. For instance, the land price in case of apartment construction will be determined as follows: the final selling price of each apartment is determined and multiplied by the number of apartments that will be realised on the chosen plot. This results in the total benefits for the developer. Costs for building the apartments as well as other costs (such as realising parking spaces, making the land suitable for building etc.) are subtracted from this amount, together with the reasonable rate of return for the property. The residual amount that is left is used as the apparent price for the building land. The higher the market price of the real estate, the higher the land price will be. An example of such a residual calculation done by the appropriate agency in Rotterdam is shown in Annex 4 for the area around the A20 national highway.

To determine how many apartments can theoretically be constructed on areas B and C their surface area needs to be calculated. A rough estimation of the measurements and surface area of all three plots is displayed in Figure 4-4.

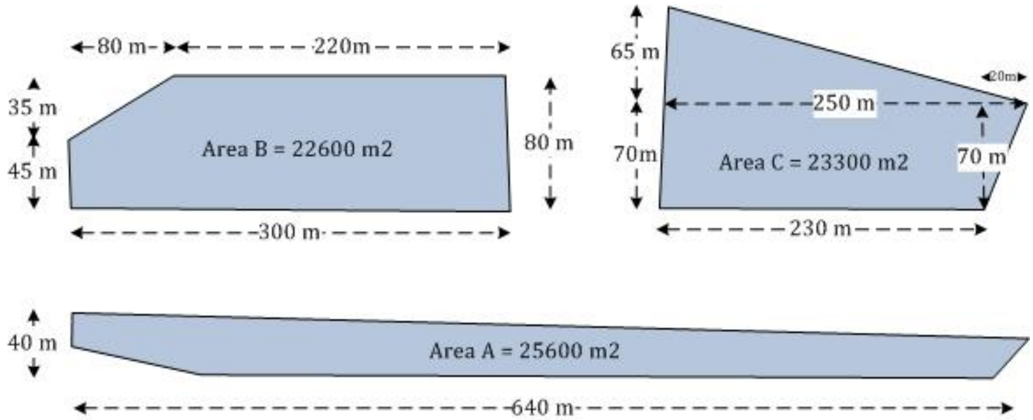

Figure 4-4, surface area of building plots

With the given estimation that Area A can accommodate approximately 500 apartments, area B and C are assumed to be suitable for the development of 441 and 455 apartments with a gross floor space of 120 m^2 (see Annex 3 for full calculations). Expert interviews within Movares confirm this as a realistic estimate, with the annotation that sufficient parking space needs to be available (either below or above ground) to accommodate the increased number of local residents.

The OBR (Land Development Agency Rotterdam), which is responsible for the distribution of building land and determining the respective prices in Rotterdam, was asked to provide an estimation of the possible revenues per square metre of apartment space for this specific location. For apartments within the 'medium' price category (guide price of €225.000) a building land price of €300 per square metre of apartment space was quoted (Annex 4, quote only available in Dutch). This is valid for apartments with a net user space of 100 square metres (equivalent to a gross floor space of 120 square metres). This leads to the following building land revenues for each of the given areas:

Table 4-11, potential building land revenues

	No. of apartments	Floor space per apartment (m^2)	Total marketable floor space (m^2)	Price per m^2 Gross floor space	Revenues (X 1.000.000)
Area A	500	120	60000	€220,00	€18,00
Area B	441	120	52969	€220,00	€15,89
Area C	455	120	54609	€220,00	€16,38
Total	1396				**€50,27**

Besides revenues by marketing these plots, costs will need to be made to make the area liveable and suitable for building. These costs are estimated by Decisio (2009) at €51 per square metre of building land. However, this does not include costs to acquire the land in case the commissioner of the project is not the owner of the land. Even if the commissioner is the owner, the land is in most cases used for other functions which cannot easily be ceased. Significant investments will need to be made to relocate companies or residences in order to develop high-rise apartments. These costs are very difficult to estimate and additional research is needed to make a realistic estimation of the costs of acquiring the land or relocating present users. This will be especially relevant for areas B and C, since currently companies are located on these plots. Area A does not contain many activities and additional costs will therefore be substantially less.

Pricing experts from Movares state that the revenues stated in Table 4-11 are only realistic when sufficient parking space is available in the area. However, it is unlikely that enough parking space for residents of almost 1400 apartments is readily available in a dense urban environment. Therefore, parking spaces will need to be integrated into the new developments. According to guidelines issued by OBR (Annex 4), one parking space per apartment should be available. This will result in a discount of €5000 per apartment on the land price. These costs will need to be subtracted from the potential revenues together with the costs to make the area liveable and suitable for building. The benefits that are left after subtracting these costs will be used the benefits from marketing building land.

Not all alternatives will result in the possibility to develop building land. All three potential building areas are within a 200 metre range from the highway which means that on the basis of Table 4-10 only The Sustainable Highway and tunnel alternative qualify for these benefits. No areas further than 200 metres from the highway can be developed into residential areas, mostly since the areas further than 200 metres away are already residential. This leads to the following benefits for each alternative:

Table 4-12, benefits from marketing building land

	Zero alternative	Zero+ alternative	The Sustainable Highway	Sunken Highway	Tunnel
Building land benefits	€0,00	€0,00	€39,64	€0,00	€39,64

Table 4-12 clearly shows a substantial benefit for The Sustainable Highway and the tunnel alternative on this location. Several things need to be kept in mind when interpreting these results. First, these figures are dependent on the ability to construct high-rise apartment buildings on the chosen locations. Second, no costs are calculated for obtaining the land or relocating present users. Acquiring the land and relocating users is likely to require significant investments, which are currently not accounted for. The benefits of this spatial effect can change significantly when either of these conditions changes.

Urban quality effects

The tunnel alternative is the only project alternative which can result in significant urban quality effects. A tunnel eliminates the barrier effect and opens the possibility to turn a highway trajectory into a park or other green area. The urban quality effects can be determined by computing the value increase of real estate in the area in case a tunnel will be constructed. A value increase of 2,5 percent for all properties within 500 metre range of the highway appears to be realistic.

Starting point is that buildings up to 500 metres away from the highway will be affected by the construction of a tunnel. Assuming an average plot size of 100 m^2 and an occupation of 50%, around 3500 houses and offices are estimated to be affected by the urban quality effects. In Rotterdam, the average price of a house is €189.000 (NVM, 2009), which results in urban quality effects to the extent of approximately €16,89 million for the tunnel alternative.

<u>Computation of external effects</u>

Safety

In Chapter 2, all safety aspects of several alternatives have been discussed. Table 2-1 summarises several safety aspects of a road with noise barriers, The Sustainable Highway and a tunnel. Safety will not be expressed in monetary values, since this is difficult and time consuming and is not expected to add great value to the analysis. Chapter 2 has presented an elaborate qualitative description of safety, which in this case consists of many different sub-aspects. Some of these sub-aspects will have a positive effect on safety, while other will be negative. For instance, The Sustainable Highway encloses the road, just as a tunnel having a negative effect on safety. However, the road is shielded from weather influences increasing visibility and reducing the chance of accidents. When all these safety aspects would need to be expressed in monetary value an extensive study would be required. Therefore, PM-values are used based on the qualitative analysis of Chapter 2.

No significant deviation in safety aspects is expected to occur when the height of noise barriers is increased, which results in a similar PM-post for these alternatives. The sunken highway shares, due to its position below ground level, safety aspects with a tunnel. It also shares safety aspects with a road with noise barriers, since road users will not feel trapped as they would in a tunnel. This results in the following safety effects:

Table 4-13, safety values of all alternatives

	Zero alternative	Zero+ alternative	The Sustainable Highway	Sunken Highway	Tunnel
Safety	PM+/--	PM+/--	PM+/--	PM+/--	PM--

Noise

The valuation of noise nuisance in a social cost benefit analysis is a difficult subject. Many different methods are available resulting in substantial differences in the final results. The method that will be used here is hedonic pricing by means of the 'Noise Sensitivity Depreciation Index' (NSDI) which is defined as the average percentage change in property prices per decibel as a result of noise nuisance (Nijland & van Wee, 2008). In this method to value noise reduction, no effects on public health are taken in to account since people are generally not aware of the damage noise can have on their health. The true damage of these effects can therefore not be reflected by house prices. This method is different from the model Decisio uses, which is based on traffic intensities. That method however, is solely based on the volume of traffic without taking the environment in which the highway is set into account. Therefore the NSDI is used in this thesis.

Figure 4-5, noise load study area (DCMR, 2007)

The NSDI can be used to calculate the current depreciation in a house's price. Alternatively, the NSDI can be used to calculate the potential rise in house prices if an alternative is constructed. The current noise load on the chosen location is shown in Figure 4-5. The marked area shows the spatial delineation of the area of analysis. Noise nuisance next to the trajectory, within a distance of 500 metres of the highway will be taken into account.

The area shows a wide variety of noise loads, which makes it challenging to determine an average noise load for the entire area. Furthermore, the noise loads in Figure 4-5 show the average noise loads for a 24-hour period (Lden). Noise nuisance depends not only on average noise loads, but also on noise loads during peak hours. Noise loads are furthermore strongly influenced by weather conditions and wind directions, making much higher noise loads under certain conditions at different times of day very likely. Although the map shows some areas with noise loads of lower than 50dB, it is likely that much higher noise loads will occur in reality and therefore influence house prices in the entire area.

When applying the NSDI, in general, a threshold below which noise nuisance has no influence on house prices is assumed. Nijland et al. (2002), assume a threshold of 55dB while other studies assume a threshold of 45dB (Wolfert, 2007) or 50dB (Howarth, 2001). The reason this threshold is sometimes lowered is that noise annoyance already occurs from 45dB Lden (24-hour period) and therefore effects on house prices are to be expected. All previous considerations lead to the rough assumption that an average noise reduction of maximum 10dB can be achieved for the entire area and a noise reduction of up to 10 dB will contribute to benefit house prices. In practice, in some parts of the area, a 10 dB reduction will not be possible, or influence house prices. In other areas, a noise reduction far greater than 10dB is possible, for instance in close proximity to the highway. A reduction of 10 dB is assumed to be a realistic average. More research will need to be done on potential noise reduction by the different alternatives for this location to show whether an even greater (or smaller) noise reduction is possible. The area should be analysed in more detail and influences on house prices should be calculated at a much more detailed scale. For this analysis however, this rough estimation will suffice.

Studies show NSDI rates ranging from 0,08% to 2,22% per dB, while the average is assumed to be somewhere in the lower part of this range (Nijland & van Wee, 2008). In general a NSDI rate between 0,2% and 0,4% is considered to be realistic (Nijland et al., 2002; Howarth, 2001). Therefore, the rate at which house prices are assumed to depreciate (the NSDI) is chosen to be 0,3% per dB in this analysis. The noise load reduction each alternative can achieve is different. In Chapter 2, it was already mentioned that The Sustainable Highway is far more effective than noise barriers in reducing noise nuisance. The difference can increase to up to 20dB. The difference is even greater when noise barriers are compared to tunnels. In this analysis, after consulting with experts in noise and noise reducing measures within Movares, the average reduction of the noise load of noise barriers is assumed to be 5 dB for the chosen area, however, this is a very rough estimate. Other measures are assumed to be increasingly effective in reducing the noise load in the area, up to the earlier determined maximum of 10dB for both the tunnel alternative and The Sustainable Highway. When comparing the noise reduction potential of a tunnel to that of The Sustainable Highway, a tunnel will decrease noise loads to zero, while for The Sustainable Highway no such guarantee can be given. However, when the average reduction in noise load for an area of 500 metres wide is being considered, the effective reduction will be nearly the same and noise nuisance negligible. No significant differences in noise reducing potential are to be expected at greater distance from the highway. The same number of residential units is assumed as in the calculation of urban quality effects, which leads to the following benefits.

Table 4-14, benefits caused by noise reduction (X 1.000.000)

	Zero alternative	Zero+ alternative	The Sustainable Highway	Sunken Highway	Tunnel
Increase in property value	€10,14	€12,16	€20,27	€16,22	€20,27

The method to determine benefits from noise reduction is different from the method used in the previous CBA. There, the damage caused by traffic is calculated by using index numbers which are subsequently reduced by a percentage to signify the effectiveness of the different alternatives. This is a valid method, however, the method used in this analysis offers the possibility to calculate the value of each decibel of noise reduction and uses actual noise loads rather than the intensity of traffic. In practice, the achieved values are only slightly different for noise barriers. However, larger differences can be seen when the alternatives turn out to reduce the noise load more.

Emissions

Emissions are only reduced by the construction of The Sustainable highway. Other alternatives offer no reduction in the emission of polluting substances. Although constructing a tunnel will shield its environment from polluting substances along its trajectory, the pollutants will exit the tunnel in highly concentrated form and no reduction for the larger environment will occur. The Sustainable Highway reduces emissions in two different ways. The first is directly by filtering the emitted pollutants by traffic from air that is trapped under the canopy. The second is indirectly by producing renewable energy which reduces the need for the use of non-renewable energy sources.

The pollutants that are emitted by traffic on a yearly basis are not only related to the volume of traffic but also to the speed of traffic, the age of the average vehicle, possible congestion, etcetera. Average emission factors are known which show the emissions an average car or truck produces when it travels one kilometre. Emission factors for highway traffic in the Netherlands on highways with a maximum speed of 80 km/h (such as on the A20 Rotterdam) are shown in Table 4-15.

Table 4-15, emission factors 2010 (Planbureau voor de Leefomgeving (PBL), 2009)

	Emission factor 2010 passenger car (g/km)	Emission factor 2010 truck (g/km)
CO_2	163,00	164,00
NO_x	0,20	3,90
PM_{10}	0,03	0,16

The Traffic and Shipping division (DVS) of the Ministry of Transport, Public Works and Water management monitors traffic intensities of all parts of the Dutch highway network. Total emissions by road traffic can be calculated by using the traffic intensities for the chosen part of the A20 (Division Traffic and Shipping (DVS), 2007) in combination with the emission factors of Table 4-15. When the total emissions are multiplied with the external costs per gram of emitted substance, it shows that for this part of the A20, without additional measures, the external costs of all emissions are a little over two million euros every year. When The Sustainable Highway is realised, the following reductions are possible:

- CO_2: 0
- NO_x: 10% - 50%
- PM_{10}: 40% - 75%

When the average of these reduction percentages is used, the following yearly benefits of emission reduction are to be expected:

Table 4-16, yearly benefits of direct emission reduction

Type of emission	Yearly benefits (X 1000)
CO2	€0
NOx	€101
PM10	€407
Total	€508

The indirect emission reduction by producing renewable energy is based on the non-renewable energy that would normally have been consumed instead. Shadow-prices of the emissions that would normally occur can then be used to calculate the benefits of the indirect emission reduction. This lead to the following additional benefits:

Table 4-17, yearly benefits of indirect emission reduction

Type of emission	Yearly benefits (X 1000)
Emissions saved by solar energy generation	
CO2	€12,4
NOx	€1,4
Emissions saved by heat generation	
CO2	€13,9
Total	€27,7

On the one hand, it is interesting to note that the benefits from indirect emission reduction are greatly exceeded by the emission reduction that can be achieved from filtering the air. On the other hand, the generation of renewable energy also causes direct financial benefits from marketing the energy. From a socio-economic point of view however, the benefits from indirect emission reduction are marginal compared to the emission reduction by filtering the air. The total yearly benefits from emission reductions and their present values are displayed in Table 4-18. Since emissions by road traffic are expected to gradually reduce, the benefits are assumed to decrease from 2020 by two percent each year.

Table 4-18, benefits of emission reduction (X 1.000.000)

	Zero alternative	Zero+ alternative	The Sustainable Highway	Sunken Highway	Tunnel
CO2 benefits per year	€-	€-	€0,03	€-	€-
PV CO2	€-	€-	€0,43	€-	€-
NOx benefits per year	€-	€-	€0,10	€-	€-
PV NOx	€-	€-	€1,67	€-	€-
PM10 benefits per year	€-	€-	€0,41	€-	€-
PV PM10	€-	€-	€6,60	€-	€-

The reduction of PM_{10} emissions provides by far the greatest contribution towards the total benefits of emission reduction. This is due to the detrimental effects PM_{10} can have on the public health and quality of life of local residents.

4.2.4 The Overview Effects Infrastructure

The smaller studies to determine each separate effect can now be integrated into an Overview Effects Infrastructure for the different alternatives on the A20 near Rotterdam. All summarised effects can be found in Table 4-19. It is important to note that these numbers are influenced by some uncertainties. The exactness of the numbers in the table suggests a high measure of certainty. However, the numbers are only an indication. Much more important is the ranking of alternatives and the relative differences between them. Although the actual numbers might be subject to uncertainty and change based on the different assumptions that were made, the ranking and dimensions of the numbers are unlikely to differ much for a similar location.

Table 4-19, the costs and benefits of each alternative specified for each effect

Direct effects		Measurement unit	Zero alternative	Zero+ alternative	The Sustainable Highway	Sunken Highway	Tunnel
Construction costs		Mil. euros	-18,6	-29,3	-56,7	-84,6	-139,4
Implementation costs		Pro Memori	PM +	PM +	PM+/--	PM --	PM --
Maintenance costs construction		Mil. euros / Year	-0,2	-0,3	-0,4	-0,4	-0,8
Maintenance costs road surface		Mil. euros / 8 or 24 Years	-2,6	-2,6	-2,5	-2,6	-2,5
Traffic flow effects		Mil. euros / 8 or 24 Years	-0,3	-0,3	-0,3	-0,3	-0,3
Renewable energy benefits		Mil. euros / year	0,0	0,0	0,5	0,0	0,0
Building land benefits		Mil. euros	0,0	0,0	39,6	0,0	39,6
Urban quality effects		Mil. euros	0,0	0,0	0,0	0,0	16,9
External effects			**Zero+ alternative**	**Zero+ alternative**	**The Sustainable Highway**	**Sunken Highway**	**Tunnel**
Safety		Pro Memori	PM+/--	PM+/--	PM+/--	PM--	PM--
Noise		Mil. euros	10,1	12,2	20,3	16,2	20,3
Emissions	CO_2	Mil. euros / Year	0,0	0,0	0,03	0,0	0,0
	NO_x	Mil. euros / Year	0,0	0,0	0,1	0,0	0,0
	PM_{10}	Mil. euros / Year	0,0	0,0	0,4	0,0	0,0

The costs and benefits of Table 4-19 are displayed per time period (mostly per year or non-recurring) and have been converted to their Present Value in order to compare the magnitude of the effects. Several effects are unique to a certain alternative. This is caused by the fact that The Sustainable Highway offers an integral solution to several negative effects of road traffic. Other alternatives are mostly aimed at reducing the effects of a single nuisance factor. The effects that only occur for specific alternatives (such as building land benefits, urban quality effects and emission reduction) have a large influence on the final result and can in some cases compensate the higher construction costs of these alternatives. The NPV of all effects and alternatives is shown in Table 4-20. This table shows the final Benefit-Cost ratio for each alternative, or the measure in which an alternative contributes to socio-economic welfare.

Table 4-20, Net Present value over the entire lifespan of each alternative (Millions of euros)

Direct effects		Zero alternative	Zero+ alternative	The Sustainable Highway	Sunken Highway	Tunnel
Construction costs		-18,6	-29,3	-56,7	-82,4	-135,8
Implementation costs		PM +	PM +	PM+/--	PM --	PM --
Maintenance costs construction		-3,4	-5,3	-7,1	-7,7	-13,6
Maintenance costs road surface		0,0	0,0	4,1	0,0	4,3
Traffic flow effects		0,0	0,0	0,4	0,0	0,4
Renewable energy benefits		0,0	0,0	10,1	0,0	0,0
Building land benefits		0,0	0,0	39,6	0,0	39,6
Urban quality effects		0,0	0,0	0,0	0,0	16,9
Balance of direct effects		**-22,0**	**-34,6**	**-9,6**	**-90,0**	**-88,2**
External effects		**Zero+ alternative**	**Zero+ alternative**	**The Sustainable Highway**	**Sunken Highway**	**Tunnel**
Safety		PM+/--	PM+/--	PM+/--	PM+/--	PM--
Noise		10,1	12,2	20,3	16,2	20,3
Emissions	CO_2	0,0	0,0	0,4	0,0	0,0
	NO_x	0,0	0,0	1,7	0,0	0,0
	PM_{10}	0,0	0,0	6,6	0,0	0,0
Balance external effects		**10,1**	**12,2**	**29,0**	**16,2**	**20,3**
Total		**-11,8**	**-22,4**	**19,4**	**-73,8**	**-67,9**

This table summarises all socio-economic effects that the alternatives will have on the reference situation: a section of the A20 national highway in the north of Rotterdam. It is worth noting that the values in this table are in principle only valid for the reference situation. However, in similar situations, the same effects are likely to occur with comparable values.

The results of the analysis show a favourable outcome for The Sustainable Highway: it is the only alternative with a positive benefit-cost ratio and the ratio exceeds the other alternatives by far. The effects contributing most tot this ratio are the building land benefits and the benefits from the reduction in noise nuisance. Other contributing effects include financial benefits from marketing renewable energy (heat and solar energy) and a reduction in road surface maintenance. In addition there are socio-economic benefits such as emission reduction and (marginal) traffic flow effects. The second best alternative is the zero-alternative which only gains benefits from the reduction of noise nuisance. This was expected, since noise barriers are only solving a single issue (noise nuisance) while The Sustainable Highway attempts to solve multiple issues. These multiple issues result in multiple benefits which compensate the projects high investment costs. The other project alternatives all have much more negative benefit-cost ratios, due to their increased construction costs without any additional benefits to compensate these investments. An exception is the tunnel, which receives similar building land benefits to The Sustainable Highway and unique benefits for the increase of urban quality. This is caused by the elimination of the barrier effect. A tunnel provides a further exception in the way that it is possible to apply air filtering in tunnels. However, this has not been subject to analysis in this thesis since this is not common practice and little effect on the total benefit-cost ratio is to be expected.

Although this cost-benefit analysis shows a positive image of The Sustainable Highway's socio-economic feasibility, the concept's two most influential effects are influenced by uncertainty. Building land benefits can only be achieved if the land is currently in possession of the municipality, if users are willing to move, or if the land can be disowned. In the last two cases, substantial additional investments will need to be made in order to achieve the benefits. In addition, assumptions have been made on the number of apartments and the price that can be achieved for building land. The sensitivity of the model for changes in these parameters will need to be tested. Several assumptions also have a large influence on the value of the noise reduction. A sensitivity analysis will be performed in the next paragraph to determine the sensitivity of the model for changes in these two effects. The more sensitive the model is to changes in these factors, the more careful one has to be when drawing conclusions on the basis of this CBA.

The positive benefit-cost ratio of The Sustainable Highway shows that a socio-economically feasible location can be found for the concept. However, the location was chosen based on the fact that the concept was likely to achieve substantial benefits from building land in that location, contributing towards the concept's feasibility. In this case, socio-economic considerations were more important in the selection of a location than other criteria. When different criteria for the selection of a location play a bigger role, building land benefits might be substantially less. However, this analysis clearly shows that when it is possible to find relatively small plots of land to develop, the benefits can greatly contribute towards compensating the concept's investment costs. It seems that The Sustainable Highway is a socio-economically feasible solution in situations similar to the location that was analysed. Similar in this case means: a highway running through a densely populated urban area, where local residents experience severe hindrance from noise and air pollutants and where building land can be developed in the area.

4.2.5 Sensitivity analysis

In order to be able to asses the validity of the conclusions from the cost-benefit analysis, a sensitivity analysis was performed on the benefits from building land and the reduction of noise nuisance. The input parameters were changed and the effect on the outcome of the model was evaluated. This has resulted in some interesting conclusions.

The price per square metre of apartment space was set at €300.- after consultation with the appropriate agency in Rotterdam (OBR). This is one of the direct determinants of the total building land benefits. To analyse the influence that fluctuations in this price may have on the final result, the price is related to the total benefit-cost ratio in Figure 4-6.

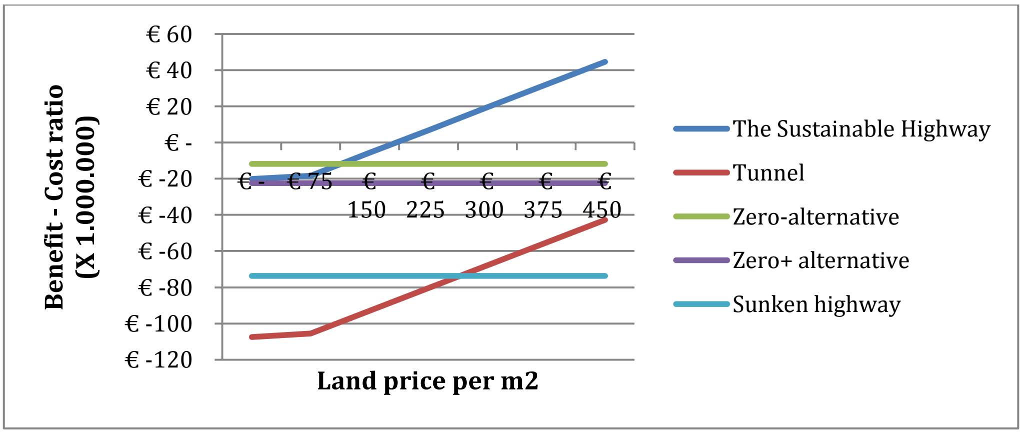

Figure 4-6, changes in BC-ratio as a result of changes in land price

This figure clearly shows that even at a much lower land price, The Sustainable Highway is still the alternative with the best BC-ratio. Furthermore, The Sustainable Highway already shows a positive BC-ratio at a land price of €184, while the tunnel alternative will reach its break-even point at a price of €705. The same analysis is done on the assumption that around 1400 apartments can be realised and has yielded similar results. Up to 45 percent less apartments still results in a positive BC-ratio.

The same variations have been applied to the assumptions in the noise reduction effect. Although the assumptions are based on rough estimates, these estimates apply equally to all alternatives. Should the assumptions change, this will affect each alternative equally, therefore not changing the ranking of the alternatives. Changes in the starting assumptions therefore do have an effect on the actual scores, but far less on the relative scores between the alternatives. This does not hold for the assumption that a maximum 10dB reduction will still have an effect on house prices. Should this threshold turn out to be 5dB, the alternatives which achieve a noise reduction greater than 5dB will have a bigger change in BC-ratio than the alternatives with a smaller reduction. Figure 4-7 shows the relation between NSDI threshold and BC-ratio.

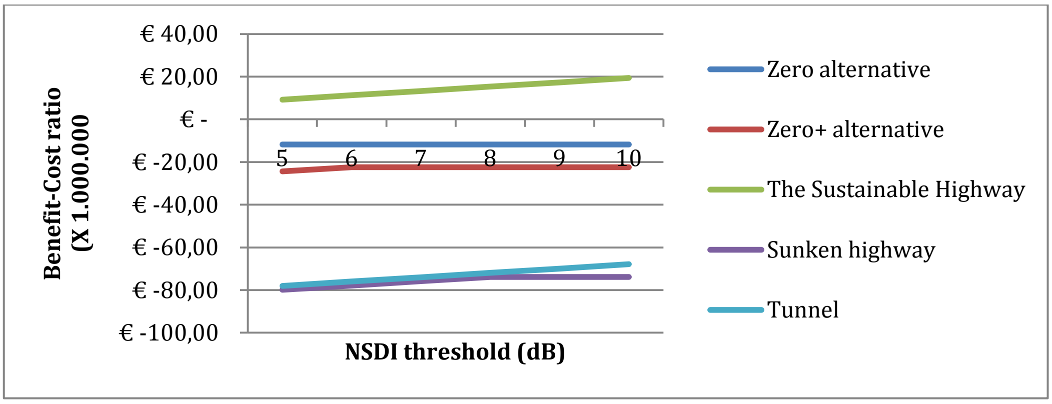

Figure 4-7, changes in BC-ratio as a result of changes in NSDI threshold

Although a lower threshold brings the BC-ratio of some alternatives closer together, the relative change is small. Although changes in the starting assumptions for these two effects have an effect on the total BC-ratio, the ranking of the alternatives never changes. It may therefore be concluded that the model is fairly robust for changes in its starting assumptions. So although these two effects contribute heavily in the total BC-ratio of The Sustainable Highway, in similar locations to the one analysed, these effects are likely to occur in a similar order of magnitude.

4.3 Conclusions on the socio-economic feasibility of The Sustainable Highway

In this chapter, the socio-economic feasibility of The Sustainable Highway has been analysed. A previously performed generic cost-benefit analysis has been analysed after which a new CBA has been carried out for a specific location. Although both analyses have departed from the same starting point they have yielded very different results. Similar effects have been analysed but different methods and the choice for a specific location, a section of the A20 in Rotterdam, have resulted in different conclusions.

The most important conclusion for this chapter is that, in the right location, The Sustainable Highway can provide a socio-economically feasible alternative solution to the negative effects of road traffic. When compared to other solutions, there are locations such as the A20 in Rotterdam, where the benefit-cost ratio of The Sustainable Highway will exceed the ratio of the other alternatives by far. Although the BC-ratio is greatly influenced by the benefits from building land and noise nuisance reduction, the model is robust for changes in their starting assumptions. Furthermore, because the difference between The Sustainable Highway and the other alternatives is so big, the concept can be the most socio-economically feasible solution, even in locations where substantially less benefits from building land can be achieved.

Although the model is robust for changes in its starting assumptions, the benefits from building land will in reality be difficult to achieve. The land will need to be available (which can be a problem in urban areas), or the present users will need to be relocated. This can be a difficult and time consuming process. How big these difficulties will be is very dependent on the location in which the concept is realised. On the one hand, investment cost to develop the land will rise substantially based on the land's current function, potentially greatly reducing the concept's benefits from building land. On the other hand, small plots of building land can already result in very large benefits. This means that in many locations at least some benefits from building land will be achievable. The challenges in realising maximum benefits from building land will have to be studied extensively when the plans to construct The Sustainable Highway are being tailored to a specific location. However, the objective of this chapter was to determine whether The Sustainable Highway could be a socio-economically feasible solution. Clearly, this is the case.

This analysis has resulted in the conclusion that, in the analysed location, The Sustainable Highway is a socio-economically feasible solution. However, this location might not be suitable from other perspectives. It could be argued that a location for a solution which mainly benefits the quality of life and health of local residents should only be implemented in the biggest problem locations from an environmental or public health perspective. In such a location, there may be hardly any building land available which causes The Sustainable Highway to be a far les attractive solution from a socio-economic perspective. This reduced socio-economic feasibility may result in the rejection of this solution altogether, while it might be feasible from other perspectives in this location. This causes a dilemma: is it wise to attempt realisation in a location where local residents suffer most from road traffic? Or should a location be chosen with a socio-economic perspective in mind? A possibility is, that for the first (pilot) location, socio-economic considerations should be used to show the feasibility of the concept in practice. When this is shown, the concept might be more easily accepted for different locations. For now, the observations that the concept *can* be feasible from a socio-economic perspective and that the choice of location has great implications suffices.

A final observation from the CBA is that all common infrastructural solutions have a negative BC-ratio here. This is remarkable since these alternatives are all common practice and a cost-benefit analysis is normally used to judge the socio-economical feasibility of these projects. None of these projects contributes towards socio-economic welfare in the Netherlands, which (based purely on this analysis) should lead to a rejection of these alternatives. Even in the Zuidas project in Amsterdam, which relies on far higher benefits from building land, the tunnel alternative has a negative BC-ratio (Eigenraam & Ossokina, 2006). Perhaps the reduction of the damage caused by external effects is undervalued in CBA's? Clearly, society sees it fit to implement these projects despite the negative BC-ratio. Perhaps society values the reduction of the damage caused by these effects higher than is common practice in social cost-benefit analyses.

Part II: the institutional context and implementation of The Sustainable Highway

In Part I of this research project, the feasibility of The Sustainable Highway has been analysed from a technological and socio-economical perspective. Most technologies that are applied in the concept are considered to be proven and a second opinion identifies the idea as 'promising to improve air- and sound-quality surrounding highways'. It is uncertain whether the current filtering technologies can provide the level of air quality that is needed to adhere to legal norms and regulations, but these technologies are currently being researched and improved. A pilot project will provide more clarity on this subject as it will to other potential doubts. Socio-economically, much depends on the location that is chosen. Benefits that can be obtained from the marketing of building land surrounding the infrastructure, form a large component in earning back some of the concept's substantial investment costs. Chapter 4 has shown that a location in which the concept is socio-economically feasible can easily be found, however this might not always be the location in which the concept will reach maximum efficiency in reducing the external effects of road traffic. After all, building land will have to be available in which case less residents currently occupy the land surrounding the infrastructure. In any case, the concept will provide an opportunity to increase urban quality and realise new inner-city residential property development in a more attractive living environment for local residents.

Following the considerations from the previous chapters, the concept on the whole seems technologically and socio-economically feasible. However, the concept will not be executed in a vacuum but in a highly complex institutional environment. Since a concept such as this has never been realised, there are some uncertainties of an institutional nature: What procedures need to be followed? Who will be responsible for construction, maintenance, or the distribution of energy and heat? Should this project be entirely in public hands, or be developed (in part) by private parties? In addition to these institutional issues there is the political feasibility of the concept: how will decision makers perceive the technological and socio-economical feasibility? The institutional context and perception of technological and socio-economical factors influence the political feasibility of the concept, which will ultimately determine whether or not the innovation will be adopted (Feitelson & Salomon, 2004).

In the first chapter of this second part of the research project, the general institutional context of The Sustainable Highway will be further explored. Theoretical concepts and insights regarding the definition and demarcation of the institutional context will first be discussed. Legal procedures surrounding the realisation of different infrastructural solutions will then need to be analysed and applied to The Sustainable Highway. The stakeholders which can be involved in the realisation of the concept will need to be mapped out just as their interdependencies and responsibilities. These contextual factors and actors together form the institutional environment surrounding The Sustainable Highway. Furthermore, the attitude of these stakeholders to The Sustainable highway will also be subject to analysis, since this influences the stakeholder's position towards the concept. Interviews will provide insight in these attitudes as well as to important perceived success-factors and barriers to realise the concept.

In the next chapter, an in depth analysis of the institutional context will be performed for a specific location. Local stakeholders will be identified as well as their views and which stakeholders are critical[6] to the success of The Sustainable Highway. The success-factors and barriers for implementation that were identified in the previous chapter will be applied to the local situation. The final chapter will use the leads which have been identified in Chapters 5 and 6 to make suggestions on ways to implement The Sustainable Highway in its institutional context.

[6] Whenever the term 'critical' actor is used in this thesis, critical is synonymous with 'crucial' and is no indication of the actor's attitude.

5. The institutional context of The Sustainable Highway

The realisation of infrastructure projects is embedded in a highly complex institutional context. These projects generally require the consent of many stakeholders and are governed by numerous laws and regulations in which all steps of the decision-making process are carefully outlined. The Sustainable Highway is a concept for which the institutional context is yet uncharted, given that nothing comparable has ever been realised in the Netherlands. In this chapter, the general institutional context of The Sustainable Highway will be analysed to gain insight into the environment in which the concept should be integrated. A better compatibility of the concept with its institutional context shall increase the political feasibility of the concept, which will ultimately influence the chance The Sustainable Highway will be adopted (Feitelson & Salomon, 2004).

To be able to analyse the institutional context, the question of what exactly this institutional context is made up of will need to be answered. Therefore, this chapter will start by exploring the theoretical aspects of an institutional context, after which the context itself will be analysed. The institutional context will be analysed by looking at three components. First, the legal procedures and decision making processes that apply to The Sustainable Highway will be described. This will be done by analysing the decision making procedures and regulations surrounding projects which share characteristics with The Sustainable Highway. In addition, the institutional consequences of some of the unique characteristics of the concept, such as energy generation, will be analysed. Second, the stakeholders (or actors) which will be involved in a possible realisation of the project need to be mapped out. Finally, when the procedures and stakeholders have been analysed, important stakeholders will be interviewed to learn their position towards The Sustainable Highway. This will allow conclusions to be drawn on the political feasibility of the project and on what stakeholders consider to be success factors and barriers of the concept.

5.1 Theoretical aspects of an institutional context

The success of a complex technological system is not just influenced by the quality of its technological design; its success is also influenced by the environment in which it is embedded. A technological system requires an institutional structure that coordinates the interaction of the project with its environment. However, in order to be able to design a suitable institutional structure, the institutional context of The Sustainable Highway should first be known.

5.1.1 Institutions: what they are and how they impact technology

The precise definition of institution, and therefore what can be considered to be part of the institutional context, is subject to discussion in scientific literature. Without diving too deep into the discussion on what one can consider to be an institution, a few definitions by different authors will lead to a conclusion on how to define an institution in this thesis. A very broad definition of what an institution is, is given by Goodin (1996): "In its most general characterization, a social institution is nothing more than a stable, valued and recurring pattern of behaviour". This definition is useful as a starting point, but also incredibly broad and therefore not very useful for practical application. An individual showing a stable, valued, recurring pattern of behaviour can also be considered to fall under this definition, while this is in general definitely not considered to be an institution. For something to be considered an institution, it would have to be generally accepted by certain (groups of) people over a certain period of time. Therefore Scharpf (1997) defines institutions as: "a system of rules that structure the course of actions that a set of actors may choose". This already comes a lot closer to what one intuitively would consider to be an institution, namely formalised institutions such as laws and regulations, which are by nature durable and accepted by large groups of people. Applied to technological systems, Koppenjan & Groenewegen (2005) consider institutions or institutional arrangements to be: "a set of rules that regulate the interaction between parties involved in the function of a (technological) system". These arrangements can be formulated in formal laws, but can also be of an informal nature like culture, norms or public values. This means that institutions are both explicit, overt structural agreements and implicit rules of which parties governed by them might not even be explicitly aware. In both of the last two definitions, actors (or stakeholders[7]) are mentioned as being governed or affected by institutions, however they can also be considered institutions themselves. Hodgson (2006) defines institutions as: "systems of established and prevalent social rules that structure social interactions. Language, money, law, systems of weights and measures, table manners and firms (and other organisations) are thus all institutions." Although not all authors would consider organisations to be part of the definition of an institution, they are in this thesis considered to be a vital part of the institutional context. They bring institutions to life and determine the value and relative importance of certain institutions. After all, the relative importance of an (informal or formalised) institution in the context of a technological system is determined by the network of actors surrounding the technological system. The institutional context is therefore made up of formal institutions (such as laws & regulations, contracts), informal institutions (such as norms, culture) and actors or stakeholders.

To analyse the institutional context, which has just been specified, a four-layer model has been developed by Koppenjan & Groenewegen (2005; 2008). This model shows the interactions between institutions and technology and the dynamics that are involved. This model distinguishes four layers of analysis with regard to the functioning of complex technological systems and is shown in Figure 5-1.

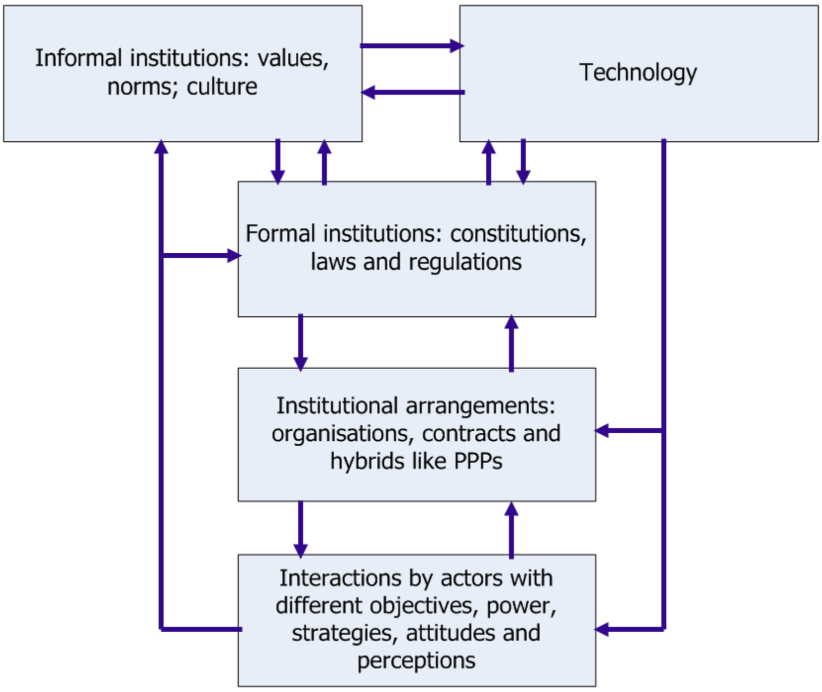

Figure 5-1, four-layer model (Groenewegen, 2008)

The institutional context is thus divided into four layers, where for each layer different types of institutions are relevant:

- Layer 1 contains the informal institutional environment of socio-technological systems or the informal rules of the game. This layer determines what behaviour is socially acceptable within the group of actors contained in layer 4. It contains the norms, values and culture by which the

[7] The terms 'actor' and 'stakeholder' are used interchangeably in this thesis. Various sciences provide various definitions of both terms, however both terms are used here to indicate (public or private) organisations, groups of people or individuals that have a certain interest in the system, and/or that have some ability to influence that system, either directly or indirectly (Enserink et al., 2009).

behaviour of actors is driven and constrained. It also contains technology and the interaction between informal institutions and technological systems.

- Layer 2: the layer of the formal institutional environment of socio-technological systems contains the formal rules of the game. This includes legal rules and procedures and determines the legal position of the actors in layer 4 and of the socio-technological system itself. Examples are: civil law, building decrees, formalized decision making procedures.
- Layer 3: the layer of formal and informal institutional arrangements of socio-technological systems contains arrangements which coordinate the functioning of the actors involved in the socio-technological system. This layer concerns arrangements which govern only specific actors and excludes more general institutions such as laws and regulations. These arrangements (or governance structures) contain among others: gentlemen's agreements, long-term contracts, joint ventures, strategic alliances, cartels and public private arrangements.
- Layer 4: the layer of actors and games in their socio-technical systems contains actors which are relevant in the context of the socio-technological system which is being analysed. Not only the actors themselves, but also the entire system of interdependencies and attitudes of the relevant actors can be analysed as part of this layer. All layers in the model are not only influenced and constrained by the higher levels, the lower layers also have an influence on the development of the higher layers, showing the dynamics of the system. Actors can therefore have great influence on the institutions governing the socio-technological project.

Taking the four-layer model as a starting point, the institutional context of The Sustainable Highway can be analysed. When analysing an existing system, institutions from all layers will generally be present. Since The Sustainable Highway is a completely new system, not all institutions are yet in place. Some institutions will still need to be designed and this offers possibilities to design some of the institutions which embed the system into its institutional context. The existing institutions making up the present institutional context of The Sustainable Highway, mainly stem from layers one, two and four. These will be the layers that will be subject of analysis in this chapter.

Layer 4 can be analysed by performing an actor analysis. In this analysis all stakeholders, their perceptions, objectives, interests and dependencies are mapped out. Why actors are so important and how an actor analysis can be carried out will be discussed in sub-section 5.1.2. Layer 2 contains the laws which govern the concept and the decision making procedures which need to be followed in order to realise such a concept. A comparative analysis in which procedural aspects of The Sustainable Highway will be compared to other infrastructural projects will be carried out in paragraph 5.2. Layer 1 contains the cultural aspects of the institutional context. This layer of the four-layer model will only be touched upon briefly. Some theoretical aspect of cultures in organisations will be discussed in paragraph 5.1.4 which can lead to conclusions on the implications of cultural aspects for this thesis.

As mentioned, institutions from layer 3 are not yet present since the system only exists on paper. This offers the possibility to design some of these institutions. The institutional arrangements from the third layer of the model can connect the technological design of the system to the institutional context. In order to be able to design some of these arrangements however, the institutional context must be analysed first in general, but also for a specific situation. Therefore, the subject of this chapter will be the analysis of the general institutional context of The Sustainable Highway, the following chapter will present an in depth analysis of a specific location, while the final chapter will provide ideas on suitable institutional arrangements to connect the technological system to the institutional context. First, the theory around actors and actor analysis will be further explored.

5.1.2 How actor involvement can impact technology

Often, when designing technology, the interests and perspective of a single user or problem owner is taken as a starting point. This is fine when the problem owner has enough means to realise the project without any help or influence of other parties. As the technological system and its institutional context become more complex, the single user perspective becomes less plausible. In practice, the problem owner or designer of the system is often increasingly dependent on other parties when attempting to realise a project. That is why the designer or problem owner will need to be aware of the positions and problem perceptions of other parties. Important parties are those which can be involved in realising the system, are affected by the problem, or have the means to help solve the problem (Enserink at al., 2004).

When determining the overall feasibility of the project, stakeholders are important, which has already been established in the Political Economy model by Feitelson in Paragraph 3.1. A project may be deemed to be technologically and economically feasible, but this does not mean that this feasibility is perceived as being valid by all stakeholders involved. In other words: technological and economical feasibility may affect the political feasibility of a project, but the *perception* of the technological and economical feasibility is at least as influential. According to Feitelson: “Policy entrepreneurs can affect these perceptions by publications and media appearances that support or criticize the proposed innovation. … By doing so they try, essentially, to affect the ‘sanctioned discourse’, i.e. the discourse sanctioned by decision makers as being politically feasible” (Feitelson & Salomon, 2004). Actors can influence other actors’ perceptions and thereby the political feasibility of the project. In this respect, technical rationality needs to be linked with political rationality in order to mobilise support for substance (Bryson, 2004). However, reasoning from a viewpoint of technical rationality becomes more and more difficult when sometimes, the outcome of the discussion is more and more determined by who is the strongest, as opposed to who is right. Stakeholder analysis can be used to identify the (strength of) the positions of key stakeholders and their criteria for satisfaction. Bryson states that: “If key stakeholders are not satisfied, at least minimally, according to their criteria for satisfaction, the normal expectation should be that something will change, new initiatives will be undermined, and so on.” It is therefore vital to pay attention to these key stakeholders to assess and enhance political feasibility.

Attention to stakeholders is also important to convince those involved that the technological design meets all demands that current institutions impose on them. Stakeholders need to be convinced that the design is in accordance with all laws, decision making procedures, norms and values. Should the design show discrepancies, stakeholders are unlikely to cooperate towards a solution. The perception of key stakeholders regarding this compliance will influence the political feasibility of the project. However, this does not imply that all stakeholders need to be satisfied, since this would be impossible. It is essential to identify which stakeholders are critical to the success of the project, since these are the stakeholders on which the project is most dependent. Because of the importance of these stakeholders, stakeholder analysis becomes increasingly significant. Should the analysis identify too many key stakeholders, the complexity of the problem would become almost incomprehensible. Should some critical stakeholders be left out of the analysis, this could seriously damage the feasibility of the project. Literature suggests different techniques and methodologies for stakeholder analysis of which the point of gravity varies per method. The method as proposed by Enserink et al. (2004) shall be used to perform a stakeholder analysis in this thesis, since this provides a broad view of actors and their perceptions, values and resources, which ultimately leads to the identification and categorisation of all actors critical to the project.

5.1.3 Actor- and network analysis by Enserink et al. (2004; 2009)

This paragraph will briefly elaborate on the method of actor analysis that will be used later in this thesis. Whereas the previous paragraph contemplated the *why* of actor analysis, this paragraph will explain the *how*. Enserink et al (2004; 2009) identifies a six-step approach which will be adapted in this thesis to a five-step approach. The original approach proposes to analyse the formal positions of all actors in depth.

Although this can be valuable in most cases, for the purpose of this analysis, no in depth analysis will be performed on this subject. The focus of the analysis will be on identifying the positions of actors which are not necessarily laid down into formal institutions. The following five steps will be performed:

1. Formulation of a problem as a point of departure.
2. Inventory of the actors involved.
3. Determining the interests, objectives and problem perceptions of actors.
4. Mapping out the interdependencies between actors by making inventory of resources and the subjective involvement of actors with the problem.
5. Determining the consequences of these findings with regard to the problem formulation.

In addition, it will be interesting to identify how dynamic the actor positions are. Are their positions difficult to change, or is their position yet uncertain? After running through these steps it will be possible to assess the political feasibility of The Sustainable Highway and provide insight into the threats and opportunities that different actors offer. Gathering information on actor positions is notoriously difficult due to the dynamics and implicitness of some of the actor positions and available information. Trustworthy information is not always easy to come by. Information for the actor analysis for this thesis will be obtained in two different ways:

1. **Text-analysis:** Perceptions, resources and objectives will be extracted from written documents. Websites, annual reports and official policy statements offer a relatively reliable, though static, form of information. However, when it comes to the informal relations and positions between actors in the network, text-analysis might not always provide sufficient information.
2. **Interviews:** Therefore, a text-analysis will - where possible - need to be complemented with interviews. These interviews can be conducted with the stakeholders themselves, although the possibilities to interview all stakeholders are limited. Interviews are likely to require a large amount of time and resources and often not all (key) stakeholders will be available.

These two sources will complement each other in supplying information on all stakeholders, although it is likely that even after this analysis knowledge gaps will still exist. In this case, some positions will need to be estimated by the analyst, using logical reasoning based on the information that is available (Enserink et al., 2009). Needless to say, the analysis will demand caution when estimating positions due to the impact which wrongful assumptions might have on the outcome of the stakeholder analysis. Therefore, sometimes when information is missing, this will need to be indicated rather than estimated.

The findings of the actor-analysis will result in a static snapshot of the situation surrounding The Sustainable Highway. Actor positions, perceptions and instruments constantly change which results in a dynamic actor network. A stakeholder analysis is only a static picture of a moment in time of this dynamic network. These continuing dynamics are a constant source of uncertainty which increase as time since the snapshot progresses. This will need to be taken into account when interpreting results from the actor analysis.

5.1.4 How culture can impact innovation

In paragraph 5.1.1, culture, values and norms were identified as the first layer of institutions of the four-layer model. Although an in depth analysis of how culture can impact technology is outside the scope of this thesis, briefly exploring the theory on this subject can lead to valuable conclusions on the impact certain cultural aspects can have on the political feasibility of The Sustainable Highway.

In a stakeholder analysis, one can establish that certain actors have certain interests and objectives. One can also speculate on how these actors may attempt to achieve these goals. Actor analysis makes a start in exploring *why* actors want certain things. Cultural theory however, might provide further insight in why actors want what they want. Why certain actors desire certain solutions is dependent on their preferences and frame of reference. This frame of reference can be greatly influenced by the prevalent culture that is present within the country, community, actor or organisation itself. An actor might reason to choose a preferred solution to a certain problem after careful deliberation, however, which solutions are eligible for choice is in the first place determined by cultural aspects. The first choice – the available combination of values and practices – is made *for* the actor (Wildavsky, 1987).

Wildavsky (1987) argues that: "by classifying people, their strategies, and their social contexts into cultural biases that form their preferences, cultural theory can attempt to explain and predict recurrent regularities and transitions in their behaviour." If cultural theory can be used to explain some of the forces that drive actors, these actors can be better understood. This will allow a problem owner to tailor solutions to have a better fit with the cultural biases of critical actors, increasing the feasibility of a project.

Wildavsky identifies four dimensions of cultural theory based on the questions: Who am I? and what shall I do? The first question can be answered by whether an individual belongs to a strong group or a group with weak ties, while the second question is answered by responding that the individual is subject to many or few prescriptions. The strength or weakness of group boundaries and the numerous or few, varied or similar, prescriptions binding or freeing individuals are the components of their culture (Figure 5-2).

Number and variety of prescriptions	**Strength of Group Boundaries**	
	Weak	Strong
Numerous and varied	Apathy (Fatalism)	Hierarchy (Collectivism)
Few and similar	Competition (Individualism)	Equality (Egalitarianism)

Figure 5-2, Models of Four Cultures (Wildavsky, 1987)

Strong institutionalised groups, such as governmental organisations are often characterised by hierarchical collectivism. Hierarchists strongly believe that life will be a chaos, unless it is socialised, regulated and organised in a proper way (Hendriks, 1999). Since hierarchists are preoccupied with stability, innovation - which is the embodiment of change - does not always thrive well in environments dominated by hierarchists. Innovation thrives in a free environment and stems from a different cultural paradigm than hierarchical collectivism. This might make innovative projects hard to integrate in an institutional context which is by nature littered with procedures and hierarchical relations like the construction of new infrastructure. Cultural aspects of an actor can have influence on whether something new is considered 'troublesome' or 'interesting'.

These cultural aspects, together with other dominant cultural aspects such as religion and history, are part of the first layer of the four-layer model which was discussed in paragraph 5.1.1. Whenever cultural aspects are relevant for further study, they will be mentioned as they come up. In addition, when interviews will be conducted with relevant stakeholders later in this chapter, special attention will be paid to cultural aspects.

The next paragraphs will deal with the findings on the content of the institutional context of The Sustainable Highway. First the second layer of the four-layer model will be analysed in more depth. The procedural aspects of realising The Sustainable Highway will be discussed after which the first two steps of the actor analysis will be conducted. The final part of this chapter will concern interviews conducted with stakeholders to finalise the institutional context surrounding The Sustainable Highway.

5.2 Procedural aspects of realising The Sustainable Highway

This paragraph will analyse the procedural aspects of attempting to realise The Sustainable Highway. The Sustainable Highway is still in a very early process of planning, which means it is not yet subject to formalised decision making procedures. In multiple locations in the Netherlands, local politicians have started a discussion with the national government in an attempt to realise The Sustainable Highway within their respective communities. This process is characterised by informal relations and lobbying. It is an unruly process without many procedural aspects to analyse. This phase is dominated by stakeholder relations and will therefore be further explored in the stakeholder analysis. However, when stakeholders do decide The Sustainable Highway should be realised in a certain location, it will be subject to numerous formalised decision making procedures. In addition, the concept will have to comply with several important pieces of legislation which may restrict the further design of the concept. Therefore, the procedural aspects surrounding relatively similar projects can provide important lessons for The Sustainable Highway, even though these projects are in a different phase of realisation.

Identifying projects with similar procedural aspects to The Sustainable Highway is not an easy task, since truly similar projects have not yet been realised. Therefore, when identifying which decision making procedures need to be followed to construct The Sustainable highway, comparison is limited to projects with a few similar characteristics. The concept shares characteristics with (overground) tunnels (the fact that the highway is physically enclosed, the reduction of external effects), but also with noise barriers (the entry of daylight, construction methods). Since the realisation of both of these types of projects is governed by different legislation, both types of projects need to be analysed to discover which procedures apply to the realisation of The Sustainable Highway.

5.2.1 Comparing procedural aspects of infrastructural projects

Different types of infrastructural projects are governed by different legislation. The decision making procedures surrounding two (types of) projects will be discussed: the realisation of an overground tunnel near the city of Utrecht and the realisation of noise barriers in an urban environment.

<u>Overground tunnel on the A2 near Utrecht</u>
The A2 near Utrecht is being widened to 2 x 5 traffic lanes which results in increased noise hindrance and a deterioration of local air quality. To shield the environment from these effects an overground tunnel will be constructed which covers the entire highway over a distance of 1650 metres. Since the construction of the overground tunnel is part of the plan to increase the capacity of the highway the Dutch "tracélaw" governs the decision making process. This law prescribes the following decision making procedure (Rijkswaterstaat, 2009):

- **Step 1 - Start memo:** The start memo defines all background material and starting assumptions of a project such as the expansion of a highway. It presents possible solutions to the current (traffic)problem. In the start memo, the environmental effects that shall be researched in the Environmental Impact Assessment (or MER in the Netherlands) are defined.
- **Step 2 - Involvement and advice:** The start memo is available for inspection for six weeks at libraries and city halls. During this period, Rijkswaterstaat holds information meetings for all those concerned to explain the start memo. Whoever wants to, can provide a response to the start memo. These responses are supplied to the MER commission, which consists of independent environmental advisors. Their advice and the provided responses form the basis of the traject-note / MER.
- **Step 3 – Traject-note / MER:** the ministers of Traffic, Public Works and Water management (V&W) and Housing, Spatial Planning and the environment (VROM) determine the demands

the which the traject-note / MER should satisfy. In the traject-note / MER an analysis of all current and future problems and their possible solutions is given. It also explores the possible consequences of a solution.

- **Step 4 – Involvement, advice and examination:** The traject-note is open for inspection and reaction for another six weeks. In this period, additional information meetings are held for parties involved. This round of involvement should clarify whether the environmental information in the traject-note is correct and complete enough to take a decision. The general public is allowed to submit their preference for a solution. Councils of (among others) towns and provinces are also invited to provide their opinions on the traject-note. After this round of consultation, the MER commission examines whether the information in the traject-note is correct and complete and advises the minister on this.
- **Step 5 – Position:** The minister of V&W chooses, together with the minister of VROM, what they deem is the best solution to the problem. They should take the information from the traject-note / MER, the opinions of parties involved and advices in to account.
- **Step 6 – Draft-tracédecision:** The position is further detailed in the draft-tracédecision. Involved parties can once again respond to this decision.
- **Step 7 – Tracédecision:** The minister of V&W, together with the minister of VROM makes the final tracédecision. They should take all reactions on the draft-tracédecision in to account. Civilians and companies can appeal to this decision at the ‘Raad van State’. When the decision has become final, towns and provinces involved should ensure the chosen solution is implemented by providing the permits needed.
- **Step 8 – Realisation:** The final decision has been taken, all decision making procedures have been followed and the financial means have been made available. The realisation of the project can start.

The procedure that is described in the tracélaw is clearly quite complex and demanding and ensures a careful decision making process. However, the tracélaw is only applicable in the following situations (Tracéwet, 1993):

1. The construction of a main road, national railroad or main waterway;
2. The change of a main road consisting of:
    a. The change of a road to a highway
    b. The expansion of a road with one or more traffic lanes if the to be expanded part connects two junctions or highway connections.

The overground tunnel near Utrecht is part of a larger plan to expand the highway and the entire project is thus governed by the tracélaw. Due to the complexity of constructing a (overground) tunnel, realising such a project will often be carried out at the same time as the expansion or change of a highway, causing it to be governed by the tracélaw. This situation can differ quite significantly from constructing The Sustainable Highway, since it can be constructed over an existing highway without physically changing its trajectory. However, the tracélaw will apply to The Sustainable Highway if it is constructed at the same time as a new highway or when an existing highway is being expanded or changed. In addition to this procedure, the overground tunnel near Utrecht also has to comply to several other laws and regulations. One that is particularly interesting in this case is the Dutch tunnel-law.

Currently, any tunnel of over 250 metres is governed by the tunnel-law (Wet aanvullende regels veiligheid wegtunnels, 2006). The tunnel-law imposes certain demands on tunnels to ensure the their safe operation. According to tunnel-law, it is not allowed to have any on- and off-ramps in a tunnel. For this reason, the on- and off-ramps under the overground tunnel on the A2 near Utrecht were moved to an area outside of the tunnel area. Having to comply with this demand can be a problem in urban areas, since it is here where most on- and off-ramps are generally present. In addition to this limitation, there are several additional rules related to the safe operation of a tunnel. The commission for tunnel safety assesses the safety in a tunnel in the early planning stages of each tunnel project. For each new tunnel, the commission is obliged to advise the initiator of the project on his compliance with tunnel-law. Currently, when The Sustainable Highway would be constructed (and would be longer than 250 metre) it is governed by tunnel-law and thus subject to assessment by the commission for tunnel safety.

In Chapter 2, the safety aspects of The Sustainable Highway were deemed to be fundamentally different from those of a tunnel. To recap it was concluded that:

"… in a normal situation, the safety aspects of The Sustainable Highway do not differ significantly from a 'normal' highway. In case of a calamity, the system will start to adopt more characteristics of a tunnel. However its safety characteristics are in most cases much better than a tunnel." (Paragraph 3.3.2)

Although the safety on The Sustainable Highway is much better than under a tunnel, under current legislation, there is no difference between transparent canopies and (under- or over-ground) tunnels. The commission on tunnel safety advises a redefinition of what exactly a tunnel is, since currently, due to elements of tunnel-law: "cities cannot construct these tunnels, while they would stimulate traffic flow and increase the quality of the air" (Commissie tunnelveiligheid, 2009). However, without redefining what a tunnel is, it will be much more difficult for initiatives such as The Sustainable Highway to be constructed.

There are two more pieces of legislation which are currently relevant for all infrastructural projects. The first one is the MIRT, or the multiple-year plan for infrastructure, spatial development and transport. The goal of the MIRT is to increase the coherence between investments in large spatial development projects, infrastructure and public transport (Ministry of Transport, Public Works and Water Management, 2009). The MIRT contains three instruments which together ensure that the goals of the MIRT are realised. These are the governmental deliberations between national and regional governmental authorities in the spring and autumn, the MIRT regulatory framework and the MIRT project book. The cabinet chooses to only incorporate projects into the MIRT that include a physical spatial intervention and in which the national government is financially involved (Ministry of Transport, Public Works and Water Management, 2009). It can therefore be regarded as the national government's investment plan in the physical spatial domain. This means that if government funding is required for an infrastructural project, it will need to be incorporated in the MIRT. In order to realise this, the project will need to be discussed in the governmental deliberations between national and regional governmental authorities. Twice a year, the ministers of Transport and Housing deliberate with regional authorities regarding the MIRT. When a decision is made on a local level that The Sustainable Highway is a preferable solution, it is in these deliberations that the project will have to be discussed. Although the project is still in the early planning stages, this would be the first formalised step in the decision making process towards realising The Sustainable Highway. The MIRT offers both chances and limitations to infrastructural projects. The MIRT offers a platform to discuss these projects, but since this occurs only twice a year, there is a limited window of opportunity to introduce new projects. When such a new project will need to be introduced, the biggest effort will have to be concentrated on the period preceding a MIRT deliberation, in order to get the project on the agenda.

The second piece of legislation which is of interest to new infrastructural projects is the recently adopted crisis and restoration law (crisis & herstelwet). This law facilitates a quicker implementation of certain spatial and infrastructural projects. Several projects have already been identified, and although the overground tunnel near Utrecht is not specifically mentioned, the procedures governing the realisation of this project are adapted by the law. Furthermore, the law is even more relevant for The Sustainable Highway since it leaves room for special projects such as: "the development and realisation of other spatial and infrastructural projects for the generation of renewable energy" (Eerste Kamer, 2009-2010).

The crisis and restoration law might open a window of opportunity for special projects such as The Sustainable Highway to be introduced.

The procedures that should be followed when realising The Sustainable Highway can be quite similar to the construction of an overground tunnel on the A2 near Utrecht. The construction of the overground tunnel is governed by the tracélaw, but only since it is part of a capacity increase of the A2. When The Sustainable Highway is constructed as a standalone project and no changes to the trajectory of the highway are made, it is not governed by the tracélaw. It will then share more similarities with the construction of a noise barrier along an existing highway. The procedures surrounding the construction of such a project will be discussed next. What does remain similar to an overground tunnel however, is the fact that under current legislation, The Sustainable Highway is a tunnel and will need to comply with several demanding safety rules and procedures. Furthermore, the project will need to be incorporated in the MIRT if government funding is required and can be governed by the crisis and restoration law.

<u>Noise barriers in an urban environment</u>
Local residents often experience noise hindrance in an urban environment. To reduce the noise load, noise barriers can be placed on each side of the highway. When no change in the trajectory of the highway is made, the tracélaw does not apply. However, there are certain other procedures a government body needs to follow to guarantee a careful decision making process.

For each type of building, including a noise barrier, a town or city has to issue a building permit. Local residents and other parties involved can object to the issue of such a permit. A building permit is issued by the town or city where the building is intended to be built. When judging whether a building permit should be issued, the building plan should comply with several demands, most notably, the ones set forward in the building decree. In addition to this, the building plan should comply with the zoning plan. Careful design of the structure should ensure compliance with the building decree, however, compliance to the zoning plan for a noise barrier, or other roadside structure is not always likely.

In the Netherlands, a zoning plan describes what functions the space in a town or city is allowed to fulfil. It designates whether a space is meant for infrastructure, residential property or commercial property and should be updated every ten years. A zoning plan is binding for civilians, businesses and for the municipality itself and does not only contain rules on what functions space can fulfil, but also on for example the dimensions a construction is allowed to take. If a building plan does not fit the zoning plan, the building plan will have to be changed. Alternatively, if a building plan does not fit the zoning plan, the municipality can, under certain circumstances attempt to make an alteration to the zoning plan.

When a noise barrier needs to be constructed in an urban environment, it is likely to be of substantial size and the zoning plan might need to be adapted. Since The Sustainable Highway has never been constructed, it is very unlikely that a zoning plan has already anticipated its construction. Therefore, when constructing either a tall noise barrier, or The Sustainable Highway, it is likely that the zoning plan will have to be adapted. To ensure a careful decision making process when adapting the zoning plan, the procedure of taking a project decision (or in Dutch: 'projectbesluit') will have to be followed. This is only possible when the project is deemed to be of municipal interest. To take a project decision the following procedure has to be followed (Ministry of VROM, 2009):

- **Step 1 – Notification of project decision**: The government body planning to make a project decision has to give notification that it is planning to issue a project decision. This will allow parties that might be affected to issue their views.
- **Step 2 – Drafting the project decision:** The government body now has to determine exactly what area will be affected by the decision and which parts of the zoning plan will have to be

reviewed and which parts can be left unchanged. Other government bodies that are legally involved will need to be consulted as well as potentially affected parties.

- **Step 3 – Project decision available for inspection:** The draft project decision will be made available for the general public for six weeks to allow them to express their views on the draft project decision.
- **Step 4 – Project decision:** the project decision now has to be taken within twelve weeks and parties that have expressed their views will need to be notified.
- **Step 5 Announcement following project decision:** An announcement will have to be made within two to seven weeks concerning the project decision.
- **Step 6 – inspection and appeal:** the project decision will be available for inspection for six weeks during which an appeal can be launched to the courts. When this is unsuccessful, a final appeal to the council of state (Raad van State) is possible.

To summarise: when the construction of either a noise barrier or The Sustainable Highway is not part of a capacity increase of a highway and does therefore not fall under the tracélaw, it will require a building permit which requires compliance to the zoning plan. The building permit will state exactly with which demands the structure should comply. In addition, should the structure not comply with the zoning plan, a project decision will have to be taken to change the zoning plan to incorporate the structure. This is a time consuming process which will delay construction, but is inevitable since The Sustainable Highway is unlikely to comply with the zoning plan in any city. When The Sustainable Highway is part of a capacity increase of a highway, the tracélaw procedure will have to be followed. When no capacity increase is being carried out, The Sustainable Highway will become a stand-alone project which requires a building permit and a change of the zoning plan due to its unique nature. Furthermore, the tunnel law, MIRT and crisis and restoration law still apply to the concept even though it might not be part of a highway capacity increase. In addition to general procedural aspects, The Sustainable Highway has several unique characteristics which have procedural or institutional consequences.

5.2.2 Unique institutional aspects of The Sustainable Highway

Looking at procedural aspects surrounding other infrastructural projects can provide insight in a part of the procedures that will need to be followed when realising the Sustainable Highway. However, The Sustainable Highway is not only a technological innovation, it will also require innovation in the institutional domain which means no previous projects are available for comparison. In Chapter 4, it was already established that the problems surrounding the external effects caused by road traffic are not only a problem related to mobility, but can also be framed as a spatial development problem. After all, urban density cannot be increased without dealing with the negative effects of road traffic. This causes an additional dimension to become important in the institutional domain: the area surrounding infrastructure. Another characteristic of the concept which has institutional consequences is the fact that it generates renewable energy and heat. Under normal institutional arrangements there is no room for the complex situation in which energy has to be distributed and sold over a very long period of time. It is likely that far more actors will need to be involved in the construction and exploitation of The Sustainable Highway than is the case in normal infrastructure. This requires complex institutional arrangements. The implications of these characteristics of The Sustainable Highway will be discussed next.

<u>Ownership and governance</u>
Generally, when constructing infrastructure projects relating to national highways, the ownership of the land and the governance of the area of the infrastructure project is a national affair. If the project concerns for instance the construction of noise barriers on an existing national highway, the land is generally already the property of the national government. The land surrounding the road may or may not be in state hands. However, this is of no great importance since no developments on- or changes to- this land are necessarily needed as part of the project. Should the new trajectory of the road require expansion of

the old trajectory, the required land will in general be bought or expropriated using the appropriate procedures and used for the development of the project. The land will then remain owned by the state since it now has the function of state infrastructure. A similar situation exists for the governance of an infrastructure project after it has been constructed. In general, the national government body in charge of road maintenance (Rijkswaterstaat) will maintain and govern the highway including any infrastructural additions such as noise barriers or tunnels. The area surrounding the road will still be owned by local public and/or private parties and will be governed by local authorities. The common situation around ownership and governance of infrastructure projects is shown in Figure 5-3.

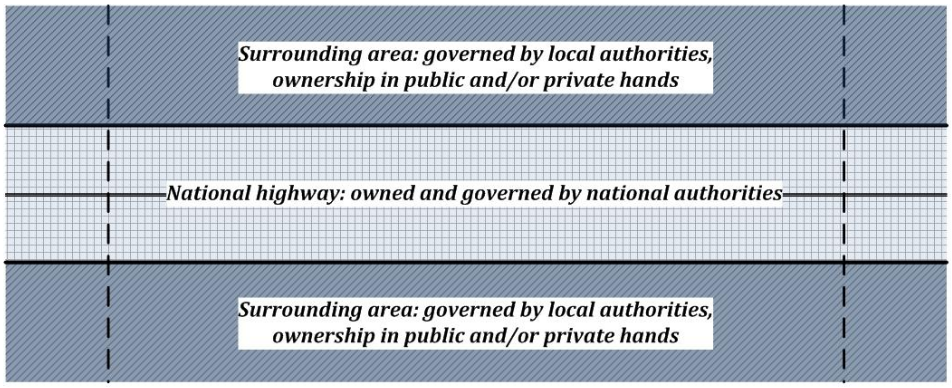

Figure 5-3, ownership and governance around national highways

The Sustainable Highway introduces the dimension of spatial development into this picture. The area of development is no longer limited by the boundaries of the highway trajectory, but surpasses them. To make The Sustainable Highway a success, the integral development of the entire area surrounding the highway is vital, since important economic benefits can be obtained. However, as stated earlier in this paragraph: the land surrounding the highway is not necessarily owned nor governed by the same authority that owns and governs the highway trajectory. Ownership is generally in the hands of a fragmented group. This group of land owners can consist of private home owners, housing corporations, entrepreneurs, municipal authorities, utility companies, etcetera. This severely complicates the development of the area, since parts of land that are planned to be redeveloped will, in some cases, first need to be obtained by the party realising The Sustainable Highway. How this situation complicates the development of the area surrounding The Sustainable Highway is dependent on the local situation. Should the local government already own (pieces of) the land then the institutional landscape will already become far more transparent. However, in any case, there will still need to be consensus between local and national authorities on how to tune the infrastructural developments to the spatial developments surrounding the highway. Especially, since the area surrounding the highway is governed by local authorities, while the highway trajectory is a national affair. A suitable institutional arrangement will need to chosen to allocate all tasks and responsibilities to the appropriate parties before The Sustainable Highway can be realised.

<u>Distribution and marketing</u>

The Sustainable Highway generates usable heat and renewable energy which can be marketed and results in financial benefits. These benefits can be used to compensate some of the concept's substantial investment costs. However, the party governing and maintaining national highways (Rijswaterstaat) has no experience in marketing and distributing energy and heat. Furthermore, it is unlikely they are willing to take responsibility for executing any of these tasks since this is outside of their normal responsibilities. In addition, the business model by which Rijkswaterstaat functions is not suitable to accommodate the yearly income from trading energy. These factors make it very unlikely that the party which has to come up with (at least some of) the investment costs of the concept will directly receive the benefits from energy and heat distribution. Since Rijkswaterstaat is an unlikely party for these unique tasks, some form of cooperation is needed between Rijkswaterstaat and other specialised parties. However, the question of who should be involved is not an easy one. Who to involve and how to allocate risks and responsibilities is a complex institutional design task. It is likely that a party with experience in energy marketing and distribution will have to take on the responsibility for the exploitation of this part of the concept. Since The Sustainable Highway and its sub-systems are anticipated to have a long lifespan, this party will have to engage into a long-term commitment for the distribution of the generated energy. This greatly increases the institutional complexity of the concept. A suitable institutional arrangement will have to be found to accommodate this part of the concept.

In normal infrastructure construction, the party that wants to realise the project will have to deal with a complex institutional context. However, The Sustainable Highway increases this institutional complexity in several ways. It expands the problem area to include spatial development. This enlarges the affected area of the project and therefore increases complexity. The period of institutional complexity is also lengthened, since an innovative institutional arrangement will have to be chosen to accommodate the involvement of other parties than is normally the case over a longer period of time. It is therefore very important to look at all parties that may be involved in the project over a longer period of time. The unique institutional aspects that surround The Sustainable Highway cause some unique institutional design challenges. It is likely that a consortium will need to be formed including actors with different expertises and responsibilities. The final chapter will begin to address these institutional design challenges. A first small step is already made in the next paragraph: all stakeholders that are part of the institutional context will be mapped out.

5.3 Stakeholders involved in realising The Sustainable Highway

This paragraph addresses which stakeholders (or actors) can be involved in the process of realising The Sustainable Highway. In the current (early) planning stages of realising The Sustainable Highway, actors dominate the decision making process, which is in this phase yet unstructured. Since this chapter aims to explore the general institutional context of The Sustainable Highway in The Netherlands, only the findings from the first two steps of the approach proposed by Enserink et al. (2004) will be described here. The final steps, in which the spectrum of actors is explored in more detail, will be dealt with in the next chapter. After all, that chapter will concern an in depth study of a specific location which will allow to identify the exact parties involved in far more detail than would be the case for a generic analysis aimed at identifying the general institutional context of The Sustainable Highway. This part of the actor analysis will be used to identify which actors are important, independent from which location will be chosen in the Netherlands. In addition, the list of actors can be used to determine whose opinion is of interest in determining the perceived feasibility of The Sustainable Highway under policy makers.

5.3.1 Step 1: Formulation of a problem as a point of departure

The problem which has been formulated in the first chapter and reframed as a spatial development problem later in this thesis is used as background for the problem formulation in the stakeholder analysis. However, the problem which is analysed in the actor analysis is much more specific in nature. The conclusion of Part I of this thesis will serve as a starting point for the problem formulation in the stakeholder analysis. The problem used in this analysis will be defined as follows: 'In certain locations, road traffic on national highways causes severe hindrance to local residents. The Sustainable Highway is a technologically and socio-economically feasible alternative to the solutions commonly used to solve problems with the negative external effects of road traffic; however, certain barriers prevent the realisation of this concept."

The actor analysis will be used to determine the position of stakeholders towards the formulated problem. Analysis in Part I of this thesis shows that The Sustainable Highway can be a feasible solution, but whether this is perceived to be true by all involved stakeholders remains to be seen. Their perception of different aspects of the problem and the proposed solution will be subject of analysis.

5.3.2 Step 2: Inventory of the actors involved

In step two of the actor analysis all actors are identified which are important from the perspective of the formulated problem. In this chapter, only actors at a very high aggregation level will be mentioned, since this analysis aims to identify the general institutional context of The Sustainable Highway, and not the institutional context at a detailed level for a specific location. This institutional context will then be applicable to general situations surrounding The Sustainable Highway regardless of the location. The next chapter will add depth to the actor analysis by focussing a study on one specific location. Here, an overview will be made of all aggregated actors that are or can be involved in the realisation of the project. Annex 7 shows the method of analysis which is used to identify possible actors. The actors which can be involved in the realisation of The Sustainable highway, resulting from this analysis are shown in Table 5-1.

Table 5-1, actors potentially involved in the realisation of The Sustainable Highway

Category	Actor
Governmental authorities	The cabinet
	The lower chamber
	Ministries of: Transport, Public Works and Water Management; Housing, Spatial Planning and the Environment; Agriculture, Nature and Food Quality, Economic affairs; Finance
	Rijkswaterstaat
	Provincial authorities
	Urban regions
	Municipal authorities
	Commission for tunnel safety
Private parties	Movares B.V.
	Building contractors (infrastructure)
	Property developers
	Energy companies
	Energy distributors
	Housing corporations
	Universities
	Suppliers of components
	Research institutes (TNO, CPB, RIVM, PBL)
Interest groups	Environmental groups
	Residents' organisations
	Road users' organisations (ANWB, TLN)
	Political parties
Non-organised actors	Road users
	Local residents
	Energy consumers (both public and private)

Universities and research institutes, although they can be considered (semi-)public institutes are listed here as private parties. The reason for this is that in their role as advisors they fulfil a private role which has nothing to do with whether or not they are in (semi-)public hands. This list includes several (groups of) actors which require further detailing. In realising The Sustainable Highway, especially local (municipal) authorities play an important part. In practice, the local authorities are composed of many different actors with each a different opinion and role within the community. In Chapter 6, these actors shall be elaborated on in more detail. However, for the purpose of mapping out the institutional context this higher level of aggregation is sufficient.

For the actor analysis to be most valuable, the next steps require a higher level of detail. They shall therefore be discussed in the next chapter, where a study shall be performed on a specific location. The actors that are mentioned here are part of the actor field that exists regardless of which location The Sustainable Highway is executed. Besides serving as input for further actor analysis, it serves a second purpose. In the next paragraph, the perceived feasibility of The Sustainable Highway shall be tested by interviewing several actors. The list of actors from Table 5-1 shall serve as a starting point for selecting which actors shall be asked to help determine the feasibility of The Sustainable Highway.

5.4 Perceptions of The Sustainable Highway and its institutional context

The final step in piecing together the general institutional context of The Sustainable Highway shall be taken by investigating how The Sustainable Highway is perceived by stakeholders. Although the conclusion of Part I of this thesis was that the concept is - conditionally – technologically and economically feasible, the perception of these two factors by stakeholders can greatly influence how feasible implementation of the concept actually is. By conducting interviews with different stakeholders, the knowledge gap regarding perceptions of actors can be filled. In addition to the question of feasibility, these interviews are used as tools to divulge a range of other information. First, who shall be interviewed needs to be determined. Second, what information is required from these stakeholders shall be discussed. Finally, the results of the interviews shall be presented.

5.4.1 Developing interviews

Interviewing all stakeholders from Table 5-1 would provide the most information on the feasibility of The Sustainable Highway. However, since interviewing is a time consuming process, a selection shall need to be made from this list. A possibility is to only interview respondents which are already familiar with the concept; their opinion on The Sustainable Highway will then not be dependent on information supplied by the interviewer. This shall provide a more truthful image of the stakeholder perception on the concept. The possibility that bias could be introduced by the interviewer in no longer present when only these stakeholders are included as respondents. It also opens up the possibility that the respondent shall provide insight into any bias he or she might already have towards the concept. Since uncovering the feasibility of the concept is one of the main goals of these interviews, any bias that respondents might have shall be interesting to uncover. The following actors have been found willing to share their thoughts on The Sustainable Highway:

- Ministry of Housing, Spatial Planning and the Environment
- The bureau of public works (GWR), part of the municipal authority of Rotterdam
- The bureau of urban development (OBR), part of the municipal authority of Rotterdam
- DCMR Environmental protection agency, part of the Rijnmond area regional authority
- Former city councillor for the city of Rotterdam, currently member of the lower chamber for the VVD fraction
- City councillor for the city of Venlo
- City councillor for the city of Dordrecht
- City councillor for the city of Diemen
- Policy officer attached to the GroenLinks fraction of the lower chamber

For the purpose of these interviews, all respondents' answers are regarded as equally important. No division is made here with regard to the role an actor can play in the process of realising The Sustainable Highway. In the next chapter, a division will be made on critical and less critical actors; however, this has no consequences on the importance of the respondents' answers in the interviews.

The respondents will be able to provide a diverse image of the feasibility of The Sustainable Highway. Some additional subjects need to be identified for which the views of the identified stakeholders can add value. First of all, technological and economical feasibility will need to be part of the questionnaire. In public discussions on the subject of The Sustainable Highway, doubts on these two factors come up regularly. To identify any other doubts the respondents might have they will be asked what they regard to be the largest barriers to realise the concept. Together with the ‘success factors’ of the concept, this information will provide insight in the biggest perceived pros and cons of the concept. In addition, some questions on where the concept will be most successful and who should be involved in the further development of the concept are included in the questionnaire. Finally, the respondents will be queried on innovative projects in general: are they more difficult to realise? The questionnaire resulting from these findings can be found in Annex 5.

These questions have been posed to all actors from paragraph 5.3.1 in personal oral interviews. The summaries of those interviews can also be found in Annex 6. All respondents have provided their permission for the publication of these interviews, which means that no aggregation of the interviews into anonymous data is needed. Knowing which actor has presented which answer adds value to further analysis, since this provides some clarification on the position of that actor in the network.

5.4.2 Findings on perceived feasibility

A total of eleven respondents were interviewed, divided among 9 actors. For background information, one can refer to Annex 5 which contains the complete interview results. Now, the aggregated results of the interviews will be presented per subject. The findings will be elaborated on in detail due to the added value for further analysis. The full version of all aggregated information can be found in Annex 6.

Technological feasibility

All respondents have indicated that they feel the concept is technologically feasible. However, this does not mean that they assume an unconditional failure free operation and implementation of the concept. Several respondents have indicated conditions under which they believe the concept is feasible, or have expressed that they believe in the feasibility of the concept should certain items turn out to work the way they have been designed to. The following factors were mentioned more than twice as a technologically uncertain factor:

Table 5-2, perceived technological uncertainties

Technological uncertainties	No. of times mentioned
Temperature under canopy	3
Filter technology	3

A few things stand out when looking at the identified uncertainties. First, the broad interpretation of ‘technological’ uncertainty. When looking at the full table in Annex 6, it seems respondents have interpreted ‘technological’ as: any uncertainty following from the specific design of the concept. Second: no uncertainty has been identified by more than three out of ten respondents. The common idea among most respondents on the technological concept is that all uncertainties can be dealt with within the design of The Sustainable Highway and that the concept is, in general, technologically feasible.

Economic feasibility

Most respondents (eight out of eleven) indicate that The Sustainable Highway can be economically feasible in certain situations. Although it might seem that The Sustainable Highway is perceived to be economically feasible, most respondents indicate that it will only be feasible under certain conditions. Two respondents indicate that it is very doubtful that there will ever be a situation in which the concept is economically feasible. The following factors were named more than twice as conditions to increase the economic feasibility of The Sustainable Highway to acceptable levels:

Table 5-3, perceived conditions for economic feasibility

Conditions for economic feasibility	No. of times mentioned
Benefits from private sources	6
A tunnel is not possible	5

It seems that the perception is that the concept will only be economically feasible if benefits from private sources can be realised. On the other hand, only one respondent mentioned that the state will need to contribute financially to the project. Although this condition was not mentioned explicitly by other respondents, the impression gained from the interviews is that some public financing is implicitly assumed by all respondents. Almost half of the respondents indicates that the preferred solution for infrastructural problems is in most cases a tunnel. The Sustainable Highway will only become (economically) attractive if a tunnel is too expensive, or impossible for other practical reasons. This is remarkable since the Benefit-Cost ratio of a tunnel is far less positive than that of The Sustainable Highway. However, this can be explained by the fact that most respondents would experience more benefits than costs in case a tunnel would be constructed. A final interesting note from one of the respondents is that sometimes costs are not important at all, when a solution needs to be found for an infrastructural dilemma. This rhymes well with the perception of all respondents that a tunnel is the alternative of choice, despite its higher costs. When dealing with certain infrastructural dilemmas, the alternative that is left standing after the political battle is not necessarily the most cost-effective one.

Success factors

When the respondents were asked to identify the most promising aspects of the concept: the so-called success-factors; a great range of different aspects was mentioned. However, almost all respondents (nine out of eleven) mentioned the fact the concept offers an integral solution for many different problems, most notably noise nuisance and local air quality. It offers a possibility to greatly increase local living conditions which is unique for an infrastructural solution. Mentioned success factors furthermore include:

Table 5-4, perceived success-factors of The Sustainable Highway

Success-factors	No. of times mentioned
Integral solution for noise and emissions	9
Investment costs compared to tunnel	3
Ability to increase urban density / quality	3

Although many factors are mentioned (Annex 6) it is striking that some factors are absent. The generation of renewable energy is not mentioned by any of the respondents, nor are the benefits that can be obtained from building land. Although the possible increase of urban density and quality are mentioned the financial, the ability to win back some of the concepts investment costs is never explicitly mentioned. This final point is even more striking, considering some respondents name it as a condition for economic feasibility of the concept. The problematic nature of actually obtaining benefits from developing the area around The Sustainable Highway might cause respondents to associate it with problems, rather than success.

Possible barriers

The respondents were asked what barriers they foresaw, or have experienced when attempting to realise The Sustainable Highway in their respective communities. This has resulted in a diverse list of barriers that are perceived to be present by the different respondents. An important observation is that the list includes roughly two different types of barriers. First, barriers that the respondents feel need to be resolved before they themselves can support the concept. Second, barriers that respondents perceive to be present in other stakeholders. Other stakeholders mainly include (governmental)organisations of who's cooperation the respondent is dependent when attempting to realise or support the concept. The most frequently mentioned barrier (five out of eleven respondents) is one of the second kind, namely a perceived scepticism towards innovation which is experienced as being present among a broad range of government organisations and representatives.

Table 5-5, perceived barriers for realising The Sustainable Highway mentioned more than twice

Barriers	No. of times mentioned
Scepticism towards innovation / new things	5
Investment costs	5
Fear of delays	3
Spatial implementation	3
Costs from a different source than benefits	3
Benefits from building land are difficult to realise	3

A feeling, experienced by most of the respondents is the general scepticism towards a concept which is innovative and thus by nature: not proven in practice. One of the respondents of the bureau of urban development in Rotterdam explains this quite eloquently (Annex 5):

“Many people are very sceptical towards new things. There is always immediately a ‘but’, without an open attitude towards a concept. This culture is very dominantly present in people that make the decisions on these types of (infrastructural) projects. Something new is perceived to be potentially troublesome and immediately encounters resistance.“

This cultural aspect is, according to respondents, very common in especially the ministry of Transport, Public, Works and Water Management and Rijkswaterstaat, both important stakeholders in the process of realising The Sustainable Highway. When the respondents were in a later question asked whether realising an innovative infrastructural project was more difficult than realising a normal infrastructure project, eight out of eleven replied that this is the case. Respondents indicated that at least part of this is caused by the cultural resistance towards innovation. Interestingly, this corresponds well to the cultural archetypes that were introduced by Wildavsky (1987). Both Rijkswaterstaat and the Ministry of Transport appear to be hierarchical collectivists, with a strong inclination to control each aspect of a project. Although understandable, this will form a barrier for any innovative infrastructural project. Perhaps actors belonging to different cultural archetypes will provide a better environment for innovative infrastructure projects to be implemented.

Not only cultural aspects form a barrier for The Sustainable Highway to be realised. The are other significant barriers based on content which are mentioned by several of the respondents. Important financial barriers include the high investment costs of the concept, but also the fact that whoever invests in the concept will not necessarily be the one reaping any of the benefits. This is a structural problem for which a solution will need to be found in the institutional domain. Other financial barriers include the fact that the benefits from marketing building land might be quite difficult to achieve, based on the local situation. Taking into account that these benefits form a large part of the concept’s potential benefits, this is arguably, one of the biggest financial problems that has to be dealt with. Once again, it appears that choosing a suitable location for the concept will have a very significant impact on the feasibility of the concept. Besides choosing a suitable location, choosing a suitable moment to introduce the concept into the decision making process is also considered a dilemma.

A final barrier which is quite interesting to note is the matter of ‘taste’. While some respondents indicate the concept to be ‘difficult to spatially implement’, which can also be defined as aesthetically unattractive or ‘ugly’, others state the concept to be ‘a huge visual improvement’. It appears that this barrier comes down to the difficult matter of taste. Although this final barrier might be hard to deal with, the other identified barrier do require a solution. Chapter 7will deal with potential solutions to these barriers.

<u>Perceived solutions</u>
To overcome the perceived barriers, the respondents were asked to propose solutions. Many potential solutions were mentioned, the ones that were mentioned most are displayed in Table 5-6.

Table 5-6, perceived solutions to the identified barriers

Solutions	No. of times mentioned
Build a pilot project	5
Financial contribution by local parties	3
Local champion	3
Window of opportunity	3
Attention for the political process	3

Again, there is clearly some coherence in the suggestions done by several respondents. Almost half of the respondents agrees on the solution that a pilot project should be built. In their perception, this will decrease the possibilities for others parties to attack the concept's technological and economical credibility. Should the pilot project be successful, it will serve as a precedent and eliminate many of the barriers that were identified in Table 5-5. Other important solutions include the availability of local financial support and the support of a 'local champion'. A local champion, according to the respondents, is a local (public or private) party, which has considerable influence both locally and nationally which takes an active role in attempting to realise the project. With such an important, influential local person involved the project's chances would be greatly increased. In addition, a window of opportunity will be needed in order to realise the solution. The recent adoption of the crisis and restoration law (crisis- en herstelwet), might provide such a window of opportunity. Chapter 7 will provide a further elaboration on these potential solutions.

<u>Suitable locations</u>
To identify suitable locations on which to realise The Sustainable Highway from a political perspective, respondents were asked to indicate which characteristics a location should have for it to be suited for a Sustainable Highway. Respondents were quite divided which caused contradicting suggestions. For instance, while some believed that first a small scale project should be executed, others believed that a location with high political exposure should be chosen. Most respondents agreed that it should in any case be a location in which local residents experience severe hindrance from a national highway and that the availability of land to develop would greatly increase the feasibility of the concept.

<u>Stakeholder involvement</u>
Most respondents agree that the ministry of Transport, Public Works and Water Management, together with the department which is responsible for road construction and maintenance: Rijkswaterstaat are the most critical actors in realising The Sustainable Highway. Most respondents furthermore establish that the resistance to look into the possibility to realise the concept is the highest with these specific actors. This is a significant problem for which a solution needs to be found. Both actors appear critical to the realisation of The Sustainable Highway.

Although The ministry of Transport and Rijkswaterstaat are perceived to be the most important actors, some respondents indicate other actors which may provide a positive contribution. Actors that are mentioned most are the ministry of Housing, Spatial Planning and the environment and influential local politicians. When attempting to realise the highway actors from these two categories will be needed as vital allies.

5.4.3 Summarising stakeholder perception

All eleven stakeholders perceive the concept to be technologically feasible, albeit under certain conditions. Most stakeholders perceive the concept to be economically feasible if local financial support can be obtained. The biggest problem in feasibility can be found in the political domain. Respondents report a culture of resistance towards innovation in two of the most critical actors. This cultural resistance is one of the most important factors that will need to be dealt with, besides factors that can be solved by carefully choosing a location and a moment in time to introduce the concept.

Not that this, almost natural, resistance against new and innovative ideas cannot be justified. Infrastructural construction is surrounded by an extremely complex institutional context, which has been clearly established in this chapter. The dynamics of this context, which follow from the four-layer model of Figure 5-1, cause a change in one layer to immediately influence the other layers. It is up to the ministry of Transport and Rijkswaterstaat to constantly find a balance in this context when they attempt to realise an infrastructural project. Only the slightest touch can tip a carefully balanced compromise, which will have large consequences for any meticulously drafted plans. Any interruption can mean a change of plans and thus a delay in an already time consuming process. Knowing this, it shouldn't come as a surprise that the unknown will be approached quite wearily by any sensible actor in this institutional network. Another justification is the (political) responsibility for infrastructural projects. The chance that something will go wrong in an innovative project (however small) is always larger than with the construction of a conventional project. Since the parties responsible (in this case the Ministry of Transport and Rijkswaterstaat) will face heavy criticism from the lower chamber and general public should something go wrong, this enhances their apprehensiveness towards trying new things. However, these factors should not be an excuse to dismiss potentially promising innovations.

5.5 Conclusions on the institutional context

The institutional context surrounding The Sustainable Highway is a complex subject of analysis. There are many definitions of what an institution is; in this thesis the four-layer model is used to analyse the institutional context of The Sustainable Highway. The institutional context exists of informal institutions such as norms, values and cultural aspects, formal institutions such as laws and decision making procedures together with the actors involved and their perception of The Sustainable Highway.

Although The Sustainable Highway is still in the early planning stages of project realisation, procedural aspects of later phases have consequences for the phase the project is in know. Important procedural aspects belonging to the second layer of the four-layer model include the decision making procedures which will need to be followed when realising The Sustainable Highway. If The Sustainable Highway is part of a capacity increase of a highway or the construction of a new highway the decision making procedure is described in the tracélaw. Should the concept be built over an existing highway the procedure is more likely to show similarities to that of constructing noise barriers. A building permit will have to be issued by local authorities and the structure will have to comply with the zoning plan. Currently, a tunnel longer than 250 metres is governed by tunnel law. Although this might change in the near future, this imposes serious restrictions on the design of The Sustainable Highway. In addition, The Sustainable Highway will need to be incorporated in the MIRT and the crisis and restoration law might open a window of opportunity. Final points of attention when looking at procedural aspects include the ownership and governance of land and infrastructure and the distribution and marketing of usable heat and energy.

Actors (or stakeholders) form a second important part of the institutional context. An inventory of all potential actors involved on a national level has been made and eight of these actors have been found willing to share their views on the feasibility of The Sustainable Highway. Although all actors regard the concept technologically feasible en most regard it economically feasible, respondents indicate that they experience much resistance from certain actors when attempting to include The Sustainable Highway in the decision making process. It is their opinion, that much of this resistance originates in a reluctance to innovate and a culture of always doing the same things in several important actors. All findings from this chapter will now be applied in an in depth study on a specific situation in the next chapter.

6. Applying the institutional context

In this chapter, the findings from Chapter 5 on the institutional context of The Sustainable Highway will be applied to a specific location. Applying the institutional context to a case will enable a more in depth analysis than would be possible when merely looking at the general concept. This chapter will start by analysing the contextual factors of a specific location, after which a detailed analysis on actors and their positions will follow. This will provide information on what the decision making process on The Sustainable Highway will look like in a certain location. Figure 6-1 clarifies this relation.

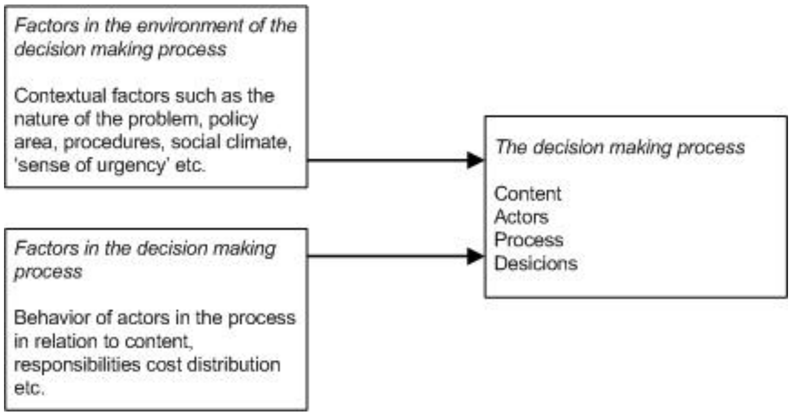

Figure 6-1, input for the decision making process (based on: Koppenjan J. , 1993)

The exploration of the institutional context will provide leads which can later on be used in the design of institutional arrangements, and a process to commit parties to the concept of The Sustainable Highway. Therefore, the contextual factors and behaviour of actors will provide input for the institutional and process designs of Chapter 7

This chapter will consist of three main parts. In the first part a location will be chosen of which the contextual factors will be analysed. Second, the next steps of the actor analysis will be performed resulting in a detailed image of the actor network for the chosen situation. Finally, all other parts of the general institutional context will be compared to the chosen situation to see if the context applies in its entirety. This will lead to conclusions on the compatibility of The Sustainable Highway with its institutional context for this specific situation. This will provide leads which can be used to find solutions on improving this compatibility for the implementation of The Sustainable Highway.

6.1 Contextual factors of a specific location

A suitable location will need to be selected to analyse the contextual factors of The Sustainable Highway in more detail. This will lead to conclusions on the compatibility of The Sustainable Highway with this environment. When selecting a location to apply the institutional context to, it is important that even before analysis the area already seems promising for The Sustainable Highway. There are several reasons for this. First, finding a location where the institutional context has a high compatibility with The Sustainable Highway is far more challenging than finding a location with a poor fit. For instance, any location where few local inhabitants experience hindrance from road traffic is unlikely to justify an investment in The Sustainable Highway. The likelihood of the concept being realised in such a location appears to be low even before analysis has started, and is therefore not very interesting to analyse. Second, analysing a location which appears promising at first sight might uncover barriers which are the most difficult to overcome, even in a promising location. Third, choosing a location which at first glance appears to be promising will lead to far more interesting and less obvious conclusions on the compatibility of the concept with its institutional environment.

A definition of locations, which are suitable from a technological and socio-economic perspective has already been given in Part I. Suitable locations, are those in which: a highway is running through a densely populated urban area, where local residents experience severe hindrance from noise and air pollutants and where building land can be developed in the area. In order for a location to be promising from an institutional perspective, it needs to satisfy additional institutional criteria. In light of the cultural problems which have been identified in Chapter 5, it seems first and foremost important to select a location in which local parties are open and susceptible to the solution.

The city of Rotterdam seems like a suitable location for an in depth analysis of the institutional context because of their previous interest in The Sustainable Highway. It is a concept which has already been deemed promising in this city (Gemeente Rotterdam Gemeentewerken, 2009), which means the community is susceptible to innovative solutions. Furthermore, the city's ring road contains many environmental bottlenecks and the city is progressive in environmental politics. The Rotterdam Climate Initiative for instance, is an ambitious programme to reduce the emissions of CO_2 in the Rijnmond area by 50% compared to their 1990 levels (Rotterdam Climate Initiative, 2009). Although CO_2 reduction is only part of the concept and the concept's main goals are to reduce noise and local air pollutants, this progressive environment seems like a promising institutional context to analyse in more detail. Furthermore, since Rotterdam is a big city, local politicians have a larger influence in national politics than politicians from smaller communities. This is especially important since the concept still needs to gather support in national politics. Support from the region is invaluable in the early planning stages of project realisation.

As mentioned, the city does contain many environmental bottle necks such as the A4 near Pernis, and the A20 in Rotterdam north which were discussed in the second opinion on the concept. In addition, the A13 near Overschie has been a problem location for a long time, while the new to construct A13/A16 traverse is also at the centre of attention. However, there are several reasons to once again analyse the A20, in favour of the other problem locations. As earlier established, there might be locations where the impact of the highway on the surrounding area is bigger. However, the A20 in Rotterdam is a location where local residents do experience severe hindrance from the highway and the construction of The Sustainable Highway seems socio-economically feasible on that location based on Chapter 4. Furthermore, the availability of building land has been mentioned by several respondents as a condition for economic feasibility. The other locations all have a far more limited availability of building land. Finally, since the location has already been analysed from a socio-economic perspective in depth, much more information is available on this location, than on the other locations.

When looking for a location which is promising from an institutional perspective, stakeholder perception is important. Because of this, respondents were asked to identify criteria for a suitable location in the interviews of Annex 5. These criteria are displayed in Table 6-1.

Table 6-1, suitability of the A20 in Rotterdam from a stakeholder perspective

Characteristics of a suitable location are:	No. of times mentioned	Applicable to the A20 in Rotterdam?
Highway is a high environmental burden locally	7	Yes
Land development is possible	3	Yes
Small scale	3	Yes
In the picture / a known problem location	2	Yes - No
Highway forms a barrier	2	Yes
A new highway	2	No
Local politicians have national influence	2	Yes
No big political / economical interests	2	No
National highway	2	Yes

Although some of these criteria might not be self-evident or sometimes even contradictory, they provide an interesting indication of additional criteria. It appears, the previous definition of suitable locations, which was drafted from a socio-economic perspective still holds. The reason being that the two most often mentioned criteria of this table, are already part of this definition. Therefore, it is interesting to review whether the A20 in Rotterdam north satisfies these criteria.

The analysed location was the section of the A20 highway in Rotterdam, between the Rozenlaan-viaduct and the highway exit Crooswijk, which is about 715 metres long (Paragraph 4.2). The A20 runs though a densely populated area in Rotterdam and processes over 160 thousand vehicles every day (Traffic & Shipping Division (RWS), 2007). It causes a high environmental burden on local residents and the environment. Land development is possible, under certain conditions that have been discussed in Chapter 4. The location is relatively small scale (less than a kilometre long and only 2x3 lanes wide), especially when compared to the A4 near Pernis which is in some points nine lanes wide. The scale of the project would correspond to the reference design of The Sustainable Highway and would therefore be a suitable size for a first project from a technological perspective.

There might be other bottlenecks in Rotterdam which currently receive more attention. However, due to the possibility to develop land in the vicinity of the A20 and the socio-economic analysis which has already been performed, this will be the location for further analysis. Much of the institutional context will be similar for the entire Rotterdam area. Therefore this analysis will also be (partly) valid for these other bottlenecks in the area. Now, first the actors involved in this area will be analysed in depth after which the remainder of the institutional area will be analysed for this area.

6.2 Detailed stakeholder analysis

In Chapter 5, the first two steps of the method by Enserink et al. (2004; 2009) were already executed. This has resulted in a list of actors which are part of the general institutional context. This list of actors requires further detailing and specification for the chosen location. Especially the municipal authorities will require further detailing since Rotterdam contains many departments which will all be concerned with a different aspect of The Sustainable Highway. Annex 7 contains the fully specified list of actors. The stakeholder analysis can now continue with the identification of actor positions.

6.2.1 Actor analysis step 3: determining the interests, objectives and problem perceptions of actors

The problem formulation of step 1 is still only one side of the problem. Each actor will experience the problem differently and step 3 will provide a detailed analysis of the gap between the original problem perception and that of the actor. The reason for this different problem perception can often be found in the interests and objectives an actor has. Interests are the issues that matter most to an actor and are not directly linked to a problem situation, while objectives indicate what actors wish to achieve in a certain situation. A table has been compiled which summarises each actor's interests, objectives and problem perception. This table can be used to identify where perceptions of actors differ and where they are similar. It may also be used to identify possible proponents of the same solution as the problem owner (who is in this case the 'solution holder') and similarly to identify opponents. The complete actor analysis results can be found in Annex 7.

Normally, analysis shows actors having different problem perceptions resulting from their various interests and objectives. In this case, although interests and objectives differ significantly between actors, much of the perceived problems are the same. For instance, most actors agree that mobility or accessibility is important for their respective communities and organisations. They furthermore agree, that increased mobility causes environmental problems and problems with noise, air quality and public health in general. These problems are perceived similarly by most actors. The difference lies in what an actor believes is the core of the problem. If an actor believes accessibility is the most important aspect of the problem, The Sustainable Highway is not likely to be best the solution to his problem. Expanding roads, or stimulating road users to use public transport might be much more effective ways to achieve a solution to his problem. When an actor is most concerned with the wellbeing of local residents or with spatial development around infrastructure, The Sustainable Highway might appeal much more to his frame of reference. Finally, there are actors that do not experience any of these problems to be in their core interest, however they can be involved in the solution of the problem. They are important stakeholders in the process of realising The Sustainable Highway. However, the problems associated with road traffic are not problems they perceive to be the most important from the perspective of their interests and objectives. These considerations result in the following categorisation of actors:

- **Similar perceptions:** One of the problems solved by The Sustainable Highway touches the core interests or objectives of this actor. Furthermore, they accede that The Sustainable Highway might be a suitable solution, when certain conditions are satisfied;
- **Conflicting perceptions:** Although these actors may have mutual interests or objectives, they do not see The Sustainable Highway as their preferred solution to the problem;
- **Neutral / no position:** These actors do not oppose nor support the construction of The Sustainable Highway. Either they are not touched in their core interests or objectives by the problem, but can be involved in the solution. Or they are touched in their core interests or objectives, however, they have not yet expressed an opinion on preferred solutions to the problem and their perception could go either way.

Based on this categorisation, actors with conflicting or neutral perceptions, are not necessarily opposing – or neutral to- the problem. They are neutral to – or opposing – the solution. This is slightly different from normal actor analysis where often completely different problem perceptions are present. In addition, actors with similar perceptions do not necessarily believe The Sustainable Highway is the best possible (or only) solution to their problem, however they do believe that under certain conditions it can be a feasible solution. They might feel equally positive about other solutions though. This categorisation of stakeholder perception results in the following division of actors among these three categories:

Table 6-2, overview of stakeholder perceptions

Similar perceptions	Conflicting perceptions	Neutral / no position
Ministry of Housing	Ministry of Transport	The lower chamber
Municipal divisions (GWR, OBR, dS+V)	Rijkswaterstaat	Ministry of Economic Affairs
ROM-Rijnmond		Province of South Holland
DCMR		Urban Region Rotterdam
Borough councils		College of Mayor and Councillors
Rotterdam Climate Initiative		City council
Housing corporations		Commission for tunnel safety
Residents’ organisations / residents		Building contractors
Political parties		Property developers
		Energy companies / Stedin
		Suppliers of components
		Universities / Research institutes
		Environmental groups
		Road users’ organisations / road users
		Political parties
		Energy consumers

The municipal divisions GWR, OBR and dS+V of the city of Rotterdam have all been involved in the counter-expertise which has been performed by the engineering office of GWR (Gemeente Rotterdam Gemeentewerken, 2009). The conclusion from this second opinion was that The Sustainable Highway can be a feasible alternative to noise barriers and tunnels. In addition, based on the interviews, they appear to be supportive of the concept, should certain conditions (such as working filter technology or available building land) be satisfied. However, although these divisions have an important say in the matter, they are always dependent on political decisions made by the College of Mayor and Councillors and the city council. These are listed as actors which currently have no position, since they have not yet stated their support or rejection of the solution. In other towns the college and city council have often been very supportive of the project. However, it is uncertain whether this will be similar in Rotterdam. Therefore, it is too soon to classify them as having 'similar perceptions'.

Local residents and their representatives are also likely to see The Sustainable Highway as a solution which is advantageous to them. This is of course in a situation where the highway is already a barrier through their community (such as is the case with the A20). In case of a new highway local residents might perceive the barrier the concept poses to be a problem, regardless of the advantages it offers. In addition, for housing corporations concept will offer significant benefits in the form of rising prices of existing real estate, whilst the Rotterdam Climate Initiative, will experience a contribution to the reduction in CO_2 emission. For the ministry of Housing the integral concept The Sustainable highway offers is perceived as a very positive factor. It provides advantages in several of the domains (Housing, Spatial Planning and the Environment) for which the ministry is responsible. Finally, political parties are not specified in this table, but are present as having both neutral, and similar perceptions. The reason for this is the dynamics of the political landscape. On the 26th of November (2009) four national political parties (GroenLinks, the SP, the PvdA and D66) expressed their support for a motion in the lower chamber to start an experiment with The Sustainable Highway (Tweede Kamer, 2009-2010). However, the position of the other national political parties is still unknown as is the support of the regional chapters of these parties. However, political support in local communities has on several occasions proven not to be a problem, since the benefits of the concept for local parties, generally exceed the costs.

Parties which currently have a neutral position (or no position) can eventually shift to become either supporters or opponents of the project, however they cannot be classified as belonging to any of these categories yet. Parties that could easily become supporters are the parties that have no specific interest in the problem, but do have an interest in the solution. These are potential partners in the realisation of the project such as building contractors, property developers, energy companies, suppliers of components and large energy consumers. Although they currently might not even be aware of the project, as soon as they can participate they are likely to become supporters. Other actors which are currently neutral but can easily become either proponents or opponents of the project are the governmental bodies in this category. Although several members of the lower chamber have expressed themselves in favour of The Sustainable Highway, as a whole, the lower chamber is currently neutral; so are the province of South Holland and the Urban Region Rotterdam. For road users and their organisations the most important aspect of the situation is the way in which they will experience The Sustainable Highway from a user perspective. This is currently named as one of the uncertain factors of the concept, although, it is likely to be perceived in a more positive way than a tunnel. However, this an uncertain factor and road users are therefore among the neutral parties. Environmental groups are likely to welcome the effects of the project, however there is no certainty on whether they would prefer other solutions over The Sustainable Highway. Finally, the commission for tunnel safety is not really a party in this discussion, however, their opinion on the matter of whether the concept is governed by tunnel law will be an important factor in the realisation of the project.

The final category is that of parties that currently prefer another solution to The Sustainable Highway. These parties accede to the problems that are caused by road traffic and currently take measures to reduce the hindrance for local residents. However, these measures are normally in the form of single-issue solutions such as noise barriers. Furthermore, although technological advances in the area of noise barriers with increased effectiveness and more silent asphalt are used, true innovative solutions are very uncommon. In 2008 for instance, Rijkswaterstaat has published a map showing all noise reducing measures for the 2008-2013 period. Although this map shows over a hundred measures, only one of them is marked as being an innovation (Rijkswaterstaat, 2008). This clearly shows the preference of Rijkswaterstaat for proven solutions. Furthermore, the minister of Transport, Public Works and Water Management has stated on numerous occasions that he currently doubts the technological feasibility of the system. This is in sharp contrast with the conclusions in Chapter 2 and the information from the interviews and that were conducted in which all respondents indicated, that they perceived the concept to be technologically feasible. In addition, the independent counter expertise came to a similar conclusion on technological feasibility. However, the minister has not categorically denied the possibility of The Sustainable Highway ever coming into being. There is still a possibility that actors from this category will shift towards becoming neutral, or supporters of the solution.

An interesting conclusion that can be drawn from Table 6-2 is that, the further one gets from local authorities and the closer to national governmental authorities, the more resistance one appears to encounter. This is not surprising since this project is a classic example of a project where the benefits occur mainly on a local level, whilst (at least some of) the costs will occur on a national level. It appears that the more costs can be borne locally, the more feasible the project will get. This connects well with the notion of a 'local champion' which was introduced in Chapter 5. Local parties experience more advantages of the project, and will therefore more easily be inclined to participate in persuading the more sceptical actors in the institutional context. When such a local party has considerable influence both locally and nationally, and is willing to take an active role in the project, it can be considered a local champion (sometimes also referred to as project champion) and play an important role in the realisation of the project. A local champion might persuade the opposing actors to shift towards becoming proponents of the project, although an apparent cultural resistance is difficult to overcome. There may be a chance with regional governmental authorities, since it appears provinces and urban regions have not yet taken up a position.

Table 6-2 is only a static snapshot of the current situation, while in practice, the interaction between stakeholders occurs in a dynamic context. Therefore, positions of actors can change, influencing the sanctioned discourse, which in turn influences the political feasibility of The Sustainable Highway (Feitelson & Salomon, 2004). It was established in Chapter 3 that the political feasibility is one of the most significant influences on the adoption of an innovation. An interesting example of the dynamics of actor positions and its influence on political feasibility, is the discontinuation of the activities of ROM-Rijnmond. This actor has for over a year been the most active party in facilitating a platform to analyse the feasibility of The Sustainable Highway in the Rotterdam Region. ROM-Rijnmond is an agency with significant influence in the region, which has taken an active role in bringing the concept of The Sustainable Highway a step further. In this period, a second opinion has been carried out on the concept, a social cost-benefit analysis has been performed and the concept has been presented to councillors of the city of Rotterdam; which have responded in a positive manner. Thereby, ROM-Rijnmond can be considered to be a local champion. However, from the 1st of January 2010, the organisation is being discontinued. The disappearance by this actor from the institutional context has already had serious consequences for the political feasibility of The Sustainable Highway. ROM-Rijnmond's tasks are taken over by different municipal divisions and the responsibility of the concept of The Sustainable Highway now lies with the dS+V. The further research projects regarding the feasibility of The Sustainable Highway are now under their responsibility. However, there have been no clear further developments since responsibility has been carried over by ROM-Rijnmond in the summer of 2009. This shows the dynamics of the actor context and the way in which public discontinuity can have a large influence on the adoption of an innovation. It also shows the impact a local champion can have. The project will develop rapidly under the guidance of such a local champion, however, the vacuum that such a party leaves when it is discontinued is hard to fill. A local champion can in this case be an organisation or a person.

Besides public discontinuity, there is uncertainty regarding policy which also influences the feasibility of the project. This uncertainty regarding policy is reinforced by political discontinuity: the electoral cycle.

Parties may come to power which do not agree with the agreements made between private parties and public authorities (van Ham & Koppenjan, 2002). In the Netherlands, most political bodies are re-elected every four years. After these four years, a regime change might take place, changing the institutional context for a specific location entirely. Since infrastructural projects typically take more than four years to complete, a party attempting to realise such a project will in general have to deal with more than one regime. This is time consuming and typically, political discontinuity introduces an additional source of uncertainty for private parties operating in the public domain. In some cases, political discontinuity occurs much sooner then after four years, since the positions of politicians are precarious and constantly under pressure. Another example of this type of political discontinuity occurred shortly after the concept was presented to three councillors of the city of Rotterdam. The concept was presented in April 2009 to these councillors, who according to a respondent from the interviews being present, were supportive of the concept. The next day, two of the councillors resigned due to a separate political issue. It takes time to appoint new councillors, which are likely to suffer from a very high workload in their first months in office. The support of the new councillors is therefore difficult to gain. This shows that gathered support can easily be reduced by the dynamics of the actor context and that local support (or local champions) are difficult to win, but easy to lose. Having broad support for the concept from a range of different actors is therefore vital to the feasibility of the concept. Next, it is important to determine of which actors the project is truly dependent and who are critical to the success of the concept. This will be discussed in step 4 of the actor analysis.

6.2.2 Step 4: Mapping out the interdependencies between actors by making inventory of resources and the subjective involvement of actors with the problem

In the previous step, the interests, objectives and perceptions of actors were analysed. However, this unveils little information on the dependency of the problem owner on each actor. This dependency is for the largest part determined by the resources (or instruments) an actor has access to, the extent in which these resources are replaceable and the manner in which the actor has conflicting or similar interests to the problem owner. When these factors are analysed, the so called 'critical actors' can be identified. Without the support of these critical actors, the solution to the problem will be extremely difficult to attain.

To determine whether an actor's cooperation is critical, its instruments to influence either the problem or the solution will need to be mapped out. Instruments can for instance be financial, legal or informal in nature. Governmental actors have formal decision making power or other legal instruments at their disposal to influence the situation. Furthermore, governmental actors are unique in having the authority to authorize or block a project. Their decision making power has a very low degree of replaceability. For realising the project, the problem owner is often highly dependent on such formal instruments. The importance of resources combined with a limited replaceability of these resources makes an actor's instruments critical to realise a project. As a contrast, an instrument which has a high degree of replaceability is for instance money. Although essential for realising the project, financial means are often available in more than one place. An actor's financial influence alone therefore rarely makes it critical to the realisation of the project, however important it may be. However, should this actor have additional resources, such as the ability to influence decision makers or have unique links to other actors, the combination of resources will make an actor critical to the realisation of the project. Table 6-3 contains a list of all critical actors based on their instruments, the degree of replaceability and the problem owner's dependency on this actors resources. This table is only a summary of the full analysis. The complete list including non-critical actors with their respective instruments can be found in Annex 7.

Table 6-3, instruments of actors and their importance

Actor	Instruments	Degree of replaceability	Dependency	Critical actor?
The lower chamber	Authority to make decisions / access to other actors	Limited	High	Yes
Ministry of Transport	Authority to make decisions / knowledge / money	Limited	High	Yes
Ministry of Housing	Authority to make decisions / knowledge / money	Limited	High	Yes
Rijkswaterstaat South Holland	Knowledge / access to other actors	Limited	High	Yes
College of Mayor and Councillors / city council	Authority to make decisions / money / access to other actors	Limited	High	Yes
Municipal divisions (GWR / OBR / dS+V)	Knowledge / man power / access to other actors	Limited	High	Yes
Commission for tunnel safety	Authority to make decisions	Limited	High	Yes
Property developers	Ability to bear risks in the project / money / knowledge	Medium	Medium	Yes
Political parties	Access to other actors / organisation power	Large	High	Yes

Critical actors are either needed for a successful realisation of the project or can block the realisation by utilising their instruments. For instance, the lower chamber’s permission is not explicitly needed for realising the project. However, should the Ministry of Transport or Housing participate in the project, the lower chamber has the power to block these ministries from providing (financial) support, effectively stopping the project. On the other hand, the lower chamber also has the power to force the ministries to participate in realising the project, making it a very powerful, critical actor. The ministry of Transport is the most critical actor in the network. They have the power to make decisions on projects concerning national highways, can financially support the project and have access to a tremendous amount of knowledge through their Rijkswaterstaat division. Rijkswaterstaat is also mentioned as a separate actor. The reason for this is that Rijkswaterstaat also advises the Ministry of Transport on projects regarding infrastructure. Furthermore, Rijkswaterstaat will ultimately be responsible for the part of the project which concerns the national highway. However, there is a hierarchical relationship between the two. The ministry of Transport can decide that Rijkswaterstaat should participate while Rijkswaterstaat can advise the ministry to participate. This is a very dynamical relationship and influencing the one might very likely influence the other. Through the media and through their network they can also influence the participation of other actors.

Since the chosen location is within the borders of Rotterdam, the College of Mayor and Councillors and the city council will have significant influence on several aspects of the project. Although, the highway area is strictly the responsibility of Rijkswaterstaat, the area around the highway is governed by the local authorities. Since The Sustainable Highway can result in spatial development almost as much as it is an infrastructural project, the municipal authorities have significant blocking power. More importantly, they can also play an important part in realising the project since they can contribute financially and exercise great influence on other parties to participate. Furthermore, they can decide to invest manpower and knowledge through one or more of their municipal divisions (GWR, OBR or dS+V). The support of local governmental authorities is critical to the success of the concept. The relationship between the College of Mayor and Councillors and the municipal divisions is similar to that of Rijkswaterstaat and the Ministry of Transport. The divisions can advise the mayor and councillors while the councillors can decide to let the municipal divisions cooperate. Furthermore, these divisions can take charge of the process of realising The Sustainable Highway since they have significant influence in both local governmental and private parties.

Several private parties are also considered critical to the success of The Sustainable Highway. There are many different building contractors, property developers and energy companies, which means that each individual building contractor’s instruments have a high degree of replaceability. Normally, these actors would, on the basis of this criterion, be classified as a non-critical actor. However, when realising The Sustainable Highway, private sector participation seems critical. Partial private financing has been named as a condition by several actors, while other have indicated that the concepts feasibility would be greatly increased if private parties would be willing to bear risk. Furthermore, since the local situation on the A20 in Rotterdam is being analysed, there might be a limited number of parties with enough local commitment to participate in the project. Therefore, these private parties *as a group* are considered to be a critical actor. For the success of The Sustainable Highway it is critical that at least one party from each group participates; therefore, these groups of actors are considered critical actors. Political support is also considered critical, since without a political statement from a majority of the political parties, both the lower chamber and city councils will not support the project. Finally, the commission for tunnel safety is critical due to their ability to impose restrictive safety demands on the concept, making it more difficult and costly to implement.

Of the governmental authorities, the local and national bodies are considered as critical actors. However, both provincial and regional governmental authorities are not considered to be critical actors. The reason for this is that the location concerns a national highway through a municipal area. Since the province and Urban Region Rotterdam are mostly involved in trans-municipal projects they are not critical actors for this specific location. However, this does not mean that they cannot be critical for other locations, or have considerable influence in this location. Subsequently, although they are not critical actors, they should not be neglected and can become powerful allies in the realisation of The Sustainable Highway. In addition, there are several actors which, although not critical, can be important to the success of The Sustainable Highway. The full list of actors and their instruments is available in Annex 7

Besides perception and dependency, there is one more factor of importance when determining actor's positions. This is the dedication of an actor to the problem or to a solution. This dedication will determine the likelihood that an actor will actively participate in realising or blocking the proposed solution. An actor is likely to be dedicated when it experiences clear costs or benefits by the problem or proposed solution. When an actor does not experience clear costs and benefits, it is less likely to try and influence the situation. Whether an actor is dedicated does not necessarily relate to the proposed solution. An actor might just as well be dedicated to the problem or a different solution. Annex 7 contains a list of all dedicated and non-dedicated actors.

To summarise actor dependencies, an overview is made of all actors on which the problem can be dependent in some way. Actors with neutral perceptions are now split over two (similar and opposing) categories, which lead to the overview of Table 6-1.

Table 6-4, actor dependencies for The Sustainable Highway in Rotterdam

	Dedicated actors		Non-dedicated actors	
	Critical actors	**Non-critical actors**	**Critical actors**	**Non-critical actors**
Similar / supportive perceptions, interests and objectives	The Lower chamber Ministry of Housing Municipal authorities Municipal divisions Political parties	Province of South-Holland Urban Region Rotterdam Borough councils Rotterdam Climate Initiative Environmental groups Residents' organisations Local residents ROM-Rijnmond	Property developers Building contractors Energy companies	Housing corporations Stedin Suppliers of components Universities Research institutes Road users' organisations Road users Energy consumers Ministry of Economic Affairs
Conflicting perceptions, interests and objectives	Ministry of Transport Rijkswaterstaat Commission tunnel safety Political parties			

The top left section of the table contains critical, dedicated actors with similar perceptions that are likely to participate towards the realisation of the project. These actors can be potentially strong allies, while dedicated non-critical actors with similar perceptions can be weak allies. The actors from these two sections are the easiest to involve in the process and likely to take the side of the problem owner. However, since both some municipal authorities and the lower chamber were originally qualified as have in neutral perceptions, it is uncertain whether they will indeed side with the problem owner this easily. Involving these actors in the process to realise The Sustainable Highway as soon as possible will increase the feasibility of the project since they can be critical for its success. The volatility of these actor's positions immediately shows the dynamics of the actor network again: a favourable position today may change into an opposing position tomorrow. Chapter 7 will deal with ways to keep these actors in the top left quadrant of the table to ensure their continuing support.

Actors in the lower left quadrant are the most significant opponents of the project and are sometimes referred to as 'biting dogs' as opposed to 'barking dogs' (dedicated, non-critical) and 'sleeping dogs' (non-dedicated critical)(Enserink et al., 2009), because of their tendency to actively oppose the project. However, in this specific situation, even these actors do not categorically oppose the possibility of the realisation of The Sustainable Highway. For instance, although up until now the Ministry of Transport and Rijkswaterstaat have often opposed the constuction of a highway canopy due to financial and procedural reasons, they do not reject the possibility of it ever being constructed. It is therefore possible to change their position under the influence of other actors such as local governmental authorities or the lower chamber.

Infrastructural building contractors, property developers and energy companies can fulfil a critical role in realising The Sustainable Highway. They can provide (both financial and other) support in areas where Rijkswaterstaat is less comfortable in participating. However, they are currently neither involved in the problem nor the solution, which means they still have to be actively involved in the process of realising The Sustainable Highway. The upper right part of Table 6-4 contains actors which are neither dedicated to the problem nor the solution, but can, due to their similar perceptions, become allies of the problem owner. However, these actors do not need to be involved initially.

Table 6-4 shows a static overview of current actor positions and dependencies, which means the positions of actors are subject to change. By far the most actors are in the top half of the table, leading to conclusions that more proponents than opponents are present in the network. However, two of the most important actors, the Ministry of Transport and Rijkswaterstaat are the opposing actors. Since this is a static snapshot, this position can change. Actors can change their positions and it is the task of the problem owner to persuade the actors to change their positions in favour of the proposed solution. Chapter 7 will deal with ways to influence the dynamics of the institutional context to change actors positions gain and keep their support.

6.3 Compatibility of the institutional context

The process of the realisation of The Sustainable Highway is dependent on the compatibility of the concept with its institutional context. In Chapter 5, the general institutional context was mapped out, while in this chapter a more detailed analysis of the actor context has provided some additional depth to the analysis for the A20 in Rotterdam. In the final paragraph of this chapter, a closer look will be taken at other parts of the institutional context and their compatibility with The Sustainable Highway in this location.

6.3.1 Compatibility of procedural aspects

Currently, The Sustainable Highway is not yet part of formalised decision making procedures in Rotterdam, since first political support will need to be mobilised. However, when looking ahead to when this would be the case, certain procedural aspects start to matter. On the A20 in Rotterdam, no expansion of the highway is planned. Therefore, should The Sustainable Highway be constructed in this location, it will not be part of a tracédecision as laid down in the tracélaw. Should another location in the Rotterdam area be selected, such as the new A13 / A16 traverse, the tracélaw will be applicable. This location however, is subject to a zoning plan, which will need to be changed if The Sustainable Highway is to be realised in this location. Furthermore, the concept will required a building permit as will all related construction projects. Related construction projects will for instance be the land development projects around the highway and the construction of the infrastructure that is needed to distribute renewable energy and usable heat.

Near the A20 in Rotterdam, land development is likely to be possible, which increases the complexity of the procedures that will need to be followed. Some of the concept's investment costs are likely to be funded by the revenues that result from the marketing of this building land. Since the price that can be achieved is related to the function of the land, (due to Rotterdam's building land pricing policy) the plans for land development and construction of The Sustainable Highway will need to be coupled in some way. This has consequences for the procedures which will need to be followed, since the possibility to construct the concept is now dependent on the possibility to obtain permits for developing building land and infrastructure to distribute energy and heat. Chapter 7 will go into suitable institutional arrangements which can govern this institutionally complex situation.

6.3.2 Compatibility of actor network

The actor context in Rotterdam seems favourable to The Sustainable Highway. Local actor support is needed to get the concept on the political agenda, which seems possible in Rotterdam. Hardly any opponents exist and these opponents are complemented by a large range of actors which have similar perceptions, interests or objectives as the problem owner. Furthermore, the size and strategic position of the city increase the political feasibility of the concept, since local politicians have considerable influence in national politics. Rotterdam is also a city which is very much 'in the picture' in national politics due to its problems with the negative side effects of mobility and industry and due to the city's economic importance. The local actor context offers possibilities to find a local champion which can take an active role in the process of realising The Sustainable Highway. Although recently the concept has lost its local champion in the form of ROM-Rijnmond, the actor context offers opportunities for this role to be taken over.

Another characteristic of the city of Rotterdam is its current focus on combating climate change by the means of the Rotterdam Climate Initiative, which shows the city is attempting to create a positive attitude towards environmentally friendliness. Rotterdam was also the initiator of the second opinion on The Sustainable Highway, which shows its willingness to look at innovative solutions to deal with its environmental problems. It seems, the culture in Rotterdam is not one of scepticism to innovation and change, but one of openness and progression. In Rotterdam, the tendency is not to wait for the national government to act, but to do things their own way. This seems like a culture in which innovation would thrive and an actor context with such cultural aspects might be a context with a high compatibility to The Sustainable Highway. Another characteristic of the actor context in Rotterdam is the large quantity of private parties that might be interested in investing in spatial development. Due to the dense urban environment in Rotterdam, good quality development locations are scarce. Property developers might be more numerous in a city such as Rotterdam than in smaller communities. This creates an interesting climate for investment.

A disadvantage is the current market circumstance for real estate in Rotterdam. Additional research will have to show whether profitable property development is possible in the current market circumstances. Furthermore, due to the size of the city and its problems with infrastructure, the municipal authorities' priorities might not be in realising The Sustainable Highway, but in realising different infrastructural projects. Other communities such as Venlo. De Bilt and Diemen have already showed explicit support for the concept, however the political influence of a larger city in national politics seems significantly higher. Overall, the part of the institutional context containing actors seems favourable for The Sustainable Highway due to many proponents, a positive culture, and a good investment climate. Possible disadvantages are different priorities of local politicians and the crisis on the housing market.

6.3.3 Applicability of success factors, barriers and solutions

The final part of the institutional context of The Sustainable Highway which will need to be applied to the A20 in Rotterdam is the perception of stakeholders regarding success factors, barriers and solutions from paragraph 5.4. It will need to be determined to what extent the success factors and barriers apply to this location. Furthermore, the applicability of the solutions to the local institutional context will need to be analysed.

Three success factors were mentioned most by the different stakeholders. All three apply equally to this situation. The most important success factor is that The Sustainable Highway is an integral solution to noise nuisance and poor air quality in urban environments. Since this is a location running through a densely populated area, where local inhabitants experience severe hindrance by these problems, this success factor applies. Furthermore, the ability to increase urban density is mentioned as a second success factor. Since land can be developed in this location, this factor also applies. Finally, the concept's investment costs compared to a tunnel are mentioned. The A20 runs through a densely populated area. This will make it very difficult to construct a tunnel in this location, resulting in an even bigger difference in investment costs.

The barrier mentioned most was the culture of resistance to new things, or scepticism towards innovation by important decision making actors. In this location, this applies to Rijkswaterstaat and the Ministry of Transport, however, these actors cannot be avoided in the Netherlands when realising an infrastructural project. In order to change their perception, it is possible to find actors with a high degree of influence in national politics which operate from a culture of openness and innovation. It has been shown that this culture is present in Rotterdam, possibly contributing towards a suitable climate for the realisation of The Sustainable Highway. Another barrier, the fear of delays in infrastructural construction is not present here, since no decision making procedure is yet underway on the A20. Furthermore, the concept is easy to implement spatially due to the fact that the highway already forms a barrier. The concept's high investment costs will continue to be a barrier in any location, however in this location large benefits from building land can compensate (some of) these investment costs. Although these benefits will be difficult to realise in any location, a positive point here is that parts of the area will be relatively easy to develop since no users will have to be relocated. The final barrier, that costs come from a different source than benefits, will be dealt with in Chapter 7 when suitable institutional arrangements will be discussed.

Most of the proposed solutions are applicable to this location. A pilot project can be built in this location, and a financial contribution by private parties can be obtained by marketing building land. A 'local champion' was frequently mentioned as being needed to take charge of the process to implement The Sustainable Highway. Finding such a local champion is of vital importance to the success of the concept.

All of the above seems to be in favour of the A20 in Rotterdam as the ideal location for The Sustainable Highway. Unfortunately, an important part of the solution is missing in this location. One thing which is mentioned by respondents as a solution, but can also be seen as a barrier, is a 'window of opportunity' or 'sense of urgency'. The concept can only be introduced at the right moment in time, when such a window of opportunity opens. This only happens when a sense of urgency to solve problems now, rather than later, is present. The political economy model of innovation by Feitelson clarifies this relationship (2004). Problem perceptions influence the social feasibility of an innovation. When there is no sense of urgency, the social feasibility of a project is reduced, and consequentially, so is the political feasibility. Sadly, in this location, there is no sense of urgency and thereby no window of opportunity. Other locations in Rotterdam (such as the A4 near Pernis and the A13 near Overschie) receive more attention than the A20, which severely hurts its chances as a politically feasible location for The Sustainable Highway. Perhaps, this window of opportunity is less important when it only concerns a pilot project. However, other locations in Rotterdam currently have a higher political feasibility than the A20, although they might be less feasible from a different perspective.

6.4 Conclusions on applying the institutional context to the A20

The institutional context from Chapter 5 was applied to the location of the A20 in Rotterdam between the Rozenlaan viaduct and the highway exit Crooswijk. This location was deemed to be a suitable location due to the compatibility of it with the characteristics a location should have, according to the stakeholder perception and socio-economic feasibility. The actor context in the Rotterdam region was analysed in detail and shows significant support for The Sustainable Highway. Only Rijkswaterstaat and the Ministry of Transport oppose the concept, which is problematic since they are the two most critical actors. Fortunately, the network contains many other actors which have considerable influence on the process of realising The Sustainable Highway. A large part of the lower chamber has already supported a motion to start an experiment with The Sustainable Highway and reaching a majority vote seems feasible. Other important actors include municipal authorities which can influence the Ministry of Transport and Rijkswaterstaat from a regional perspective. Due to the size, strategic and economic position of Rotterdam, local politicians will have considerable influence in national politics, making local cooperation even more important. Rotterdam has a culture for change and innovation, which is shown by the start of the Rotterdam Climate Initiative and the initiative for the counter expertise on The Sustainable Highway. This culture might provide an opposing force to the culture of scepticism to change and innovation which still appears to be present in Rijkswaterstaat and the Ministry of Transport. Furthermore, in a city such as Rotterdam, it is always possible to attract investors more easily than in a smaller community. This will increase the possibility to use the actor context to obtain private financing, which is recommended to increase the economic feasibility of the concept..

Rotterdam seems to have a favourable institutional context in which to realise The Sustainable Highway. The location of the A20 seems to offer great possibilities due to the ability to develop land, the severe hindrance by noise and air quality of local residents and the way in which the concept can be spatially implemented. However, although Rotterdam might be a suitable city, the A20 is currently not the most suitable location. The single most important reason for this is that currently, there is no sense of urgency to do something about the problems in this location. The A4 near Pernis, the A13 near Overschie and the new A13 / A16 traverse are all examples of locations which currently receive more attention, although they might be less suitable on different criteria such as socio-economic feasibility. Currently, there is no window of opportunity to implement The Sustainable Highway on the A20 in Rotterdam. However, as said before, the network is highly dynamic and a window of opportunity might suddenly be opened. When this happens, the A20 is a great example of a very suitable location for The Sustainable Highway. This conclusion can be extended to included that *any similar location* to that of the A20 in Rotterdam, would be highly suitable for The Sustainable Highway. Similar in this case means: a location, where a national highway causes severe hindrance to local residents. In addition, spatial development around the highway should currently be impossible due to environmental regulations, but would be possible if air quality is increased and noise levels reduced. Furthermore, where there is a culture which supports innovation and an actor network which provides local support for the concept and considerable influence of the actors in national politics. Finally, there should be a window of opportunity to introduce the concept.

Although this seems like quite a list of demands for a location to fulfil, such locations are present in many cities in the densely populated Netherlands. In these similar locations, The Sustainable Highway would be a technologically, socio-economically and politically feasible solution. Realising The Sustainable Highway, even in a suitable location, is an institutionally highly complex task. The next chapter will introduce suitable institutional arrangements and a strategy to let actors participate towards realising The Sustainable Highway.

7. Implementing The Sustainable Highway in its institutional context

In the previous chapter, the detailed institutional context of The Sustainable Highway was mapped out for a specific location in Rotterdam. This chapter will take the lessons learned from the analysis of contextual factors and actors (Figure 6-1) and use them to determine ways to influence the decision making process with regard to The Sustainable Highway. To convince stakeholders of the feasibility of The Sustainable Highway, an institutional and process design are needed which describe how the concept can be implemented into its institutional context. By doing so, the concept's feasibility in later stages is shown and barriers for the implementation of the concept are reduced.

It was established that there are many different actors which have an interest in either the problem or a potential solution. When attempting to realise a project in a complex multi-actor environment such as this, the interactions between parties need to be coordinated and controlled. Institutional arrangements can be used as tools to institutionalise the coordination between parties in the network. To gain parties' cooperation, the process of achieving the project will need to be designed. This chapter will start by analysing ways to overcome the barriers that have been established in previous chapters. Next, possible institutional arrangements will be discussed that coordinate cooperation between parties in the network. Finally, ways in which to achieve cooperation from other actors will be elaborated on. This chapter will take the perspective of the developer of The Sustainable Highway: Movares and its interests as a starting point.

7.1 The contribution of an institutional- and process-design

The Sustainable Highway is a concept in which previously, the development was mainly focussed on optimising the technological design. However, besides a technological design, an institutional design is also needed to implement a complex technological system into its environment (Koppenjan & Groenewegen, 2005). This institutional design should coordinate the positions, relations and behaviour of the parties designing, constructing, owning and operating the system. An institutional design does not follow directly from the technological design. However the technological design determines for a large part what issues should be settled in the institutional design. Examples of these issues can be found in the barriers that were identified in Chapter 6. An institutional design will need to be able to deal with these barriers. By doing so, these barriers for the implementation of The Sustainable Highway can be reduced.

Since The Sustainable Highway is a new concept without any precedents, the institutional design is not yet constrained as much as would be the case in realising a conventional infrastructure project. When looking at the four-layer model by Koppenjan & Groenewegen (2008), it becomes clearer what parts of the institutional context are still open for design. Layer one, two and four contain the technology, cultural aspects, formal institutions and actors, which have been analysed in chapters five and six. The institutions from these levels constrain the institutional design space. However, on the level of layer three (containing the institutional arrangements), the institutions still have to be designed. The execution of these institutional arrangements only becomes relevant when The Sustainable Highway moves past the earlier stage of planning. First, stakeholders in the public domain will need to be convinced to support the project. However, having an idea on what these arrangement could and should look like will help in convincing these stakeholders to support the concept. In this chapter, some possible institutional arrangements which can be used to coordinate relations and responsibilities between actors in the realisation of The Sustainable Highway will be discussed. Furthermore, a process design will be needed in addition to an institutional and technological design to ensure stakeholder participation.

Generally, when designing a technological system to fit in a multi-actor context, the technological design cannot be a blueprint created by a designer behind a desk (Koppenjan & Groenewegen, 2005). Instead, a design process involving multiple actors should be used, shaping the design to ensure optimum compatibility with its multi-actor context. However in practice, when designing an innovative idea, the most likely way in which the technological design will come into being is behind a desk without significant stakeholder interaction. According to the theory of process design, both the institutional and technological design should come in to being by interactions between the stakeholders that are needed to realise the system. In the case of The Sustainable Highway, most of the technological design is fixed. From Movares’ point of view, the outcome of the process is only satisfactory when its concept is part of the technological design. However, there is still significant room to design the spatial development and implementation into its environment. In addition, the concept’s design is still flexible enough for smaller adjustments to overcome difficulties or objections by other stakeholders. However, the ‘design-process’ has to take the technological concept described in Chapter 2 as a starting point. This constrains the freedom of movement in constructing the institutional and process designs.

Normally, process design is concerned with designing the design process. In the process design, factors such as: who should be involved, how should this involvement take place, what rules are relevant, and what conditions should be met are specified. In this case, the process design can be used to shape the institutional design, while small changes to the technological design are possible for the concept to stay intact. In addition, the function of a process design can be to encourage actors to cooperate towards a common goal such as ‘realising The Sustainable Highway’. Since this chapter takes Movares’ position as a starting point, the process design will be constructed with this goal in mind. The relationship between the barriers of Chapter 6 and designs will now be briefly discussed.

7.1.1 Using institutional- and process-designs to overcome barriers

In order to realise The Sustainable Highway, the barriers that were identified earlier will need to be overcome. The designs provide an example of how to overcome some of these barriers. An institutional design for instance, can arrange the way in which costs and benefits are allocated. In classic contracting, without private cooperation, the state would generally be responsible for all costs of an infrastructure project, whilst local parties might receive some of the benefits. In an institutional design it is possible to arrange that parties which receive benefits will also reimburse some of the costs. An institutional design can also arrange that the risks for realising benefits from building land are allocated to parties that are willing to bear these risks. These parties can for instance be local governmental bodies, but also private parties such as property developers. The same holds for the concept’s high investment costs: some of these can be recuperated by realising certain benefits. The way in which risks and the distribution of costs and benefits are distributed is part of an institutional design.

The process design describes a process which can bring parties together to reach an agreement on the realisation of a common objective or set of objectives. The way in which to realise these objectives can be formalised into institutional arrangements. The objective of Movares in this process is to bring the realisation of The Sustainable Highway a step closer. However, a design process is open ended in nature, which means that no guarantees can be given on the final outcome. Other parties are likely to have a different set of objectives and will attempt to influence the process to their own advantage. Process management can be used to control the process and direct it as closely to the identified objective as possible. Barriers that can be overcome by a well developed process are for instance the scepticism towards innovation or new things. When potential critics are included in the design process, they can introduce their own issues on controlling risks. A part of the outcome of the process might be an institutional arrangement which diverts risk from the more sceptical parties. This can reduce their scepticism. Another solution that can result from a design process is a the commitment of a ‘local champion’. An actor which is included in the design process might become committed to the proposed solution, resulting in him supporting the concept with his available instruments. This actor can grow into a local champion which can take an active role in the process to realise The Sustainable Highway.

By involving actors in the design process, they can feel committed to the solution and use their instruments to create a sense of urgency. This might open a window of opportunity which will allow the realisation of The Sustainable Highway to become reality. By designing institutional arrangements and a process to commit parties to The Sustainable Highway, the barriers that block the realisation of the concept can be overcome. Next, suitable institutional arrangements to coordinate the relations and responsibilities between actors will be discussed.

7.2 Designing institutional arrangements

Institutional arrangements are part of the third layer of the institutional context and coordinate the functioning of the actors involved in the socio-technological system. This layer concerns arrangements which govern only specific actors and excludes more general institutions such as laws, regulations and formalised decision making procedures. In order to design institutional arrangements which are suitable for The Sustainable Highway, first an analysis is needed of common institutional arrangements in infrastructural projects. Arrangements which are unrealistic or unsuited as coordination mechanisms will need to be excluded from further design activities. The most suitable arrangements will need to be further specified to include details on how relations and responsibilities will be coordinated between the different actors in the network.

7.2.1 Analysing institutional arrangements

In the previous paragraph the need for coordination by means of an institutional design was discussed. Coordination can be arranged in a number of different forms. Evasion, integration, contracting, management by self-interest, the network structure (Nooteboom, 2000) and Public Private Partnerships are often mentioned as means to coordinate relational risks between actors. In infrastructure projects, traditionally contracting was the most common form to coordinate relationships between public and private parties. However, the past fifteen years the role of market parties in executing tasks relating to the construction, operation and maintenance of infrastructure have increased. This development already started in the early eighties of the previous century. Rijkswaterstaat was obliged to outsource practical tasks with calculable costs and risks to market parties. In the nineties, market parties gradually gained more freedom in deciding which way they would deliver the requested product or service (Kennisinstituut voor Mobiliteitsbeleid (KiM), 2007). This development has resulted in Public Private Partnerships (PPP) in their current form.

According to Grimsey and Lewis (2002): “PPPs can be defined as agreements where public sector bodies enter into long-term contractual agreements with private sector entities for the construction or management of public sector infrastructure facilities by the private sector entity”. The main reason why governments undertake PPPs is the objective of achieving improved value for money, or improved services for the same amount of money, as the public sector would spend to deliver a similar project (Grimsey & Lewis, 2005). In the classic form of procurement of contracts for public works, many budget and time overruns have occurred. PPPs provide a way of transferring these risks to private parties; having them bear the risks of budget and time overruns is a way in which PPPs can add value for governments. The Dutch commission for the private financing of infrastructure states that the added value of PPPs can be applied in three directions (Commissie Private Financiering van Infrastructuur, 2008):

1. The possibility to realise better value for money of the infrastructure during the entire lifespan of the project;
2. The possibility to speed up the realisation of infrastructure;

3. The possibility to increase the volume of infrastructure.

This commission attributes this added value to the contribution the private sector can deliver in the form of private financing, combined with a high grade of efficiency, expertise, specialisation, continuity, discipline, decisiveness that the private sector has to offer. Often, the combination of public and private financing offers the highest added value. A distinction should be made here between private *financing* and private *funding.* By financing, the source of the financial means which are used to pay for the investment is meant. In public financing, these means are made available by the public sector. In private financing, these means are temporarily made available by one or more private party(s) such as contractors, banks or property developers. A case of private financing is when a private party invests in the infrastructure project, which is eventually carried over to public parties who in turn pay the private party for the project. By funding (as opposed to financing), the means that are eventually used to carry the costs of the investment are meant. The conventional way is public funding in which the national or local governments carry the eventual costs of the investment. In private funding, the costs are directly charged to the users of the infrastructure project, for instance in the form of toll roads. However, another way of private funding, is using some of the revenues from spatial development made possible by the infrastructure project, to fund (some of) the project's investment costs. The Sustainable Highway makes this final form of private funding possible. Therefore, a PPP would be a very interesting way of funding the project. Furthermore, The Sustainable Highway is typically a project which adds value to normal infrastructure projects. It improves the interaction between the road and its environment and adds the dimension of spatial development which increases urban quality. In addition, as stated in Chapter 6, Rijkswaterstaat is unlikely to perform all the functions that will need to be performed when implementing The Sustainable Highway themselves, making cooperation with a private party likely. Rijkswaterstaat will not manage the marketing of heat and energy and is not the appropriate party to take a leading role in spatial development; local parties are far more suitable for this task. Finally, due to the fact that both private financing and private funding is among the possibilities for the concept, The Sustainable Highway is an ideal candidate for a Public Private Partnership. From the perspective of Movares, a PPP is also an interesting form of coordination. Movares can initiate such a partnership and keep the initiative in the process of realising The Sustainable Highway. Due to the concept's high compatibility with the conditions for a successful PPP, this will be the further focus of this chapter. Other coordination mechanisms might be equally successful, however, this is no further subject of analysis. The possibility of a PPP will be further explored.

There are many functions in which public sector actors can cooperate with private parties to form a PPP. Private parties can commonly participate in designing, building, financing, operating and maintaining the infrastructure project. Combinations of these functions are possible which represent different degrees of Public Private Partnership. Figure 7-1 shows several common combinations of functions on a scale of public versus private responsibility.

Figure 7-1, Degrees of Public Private Partnership, based on Deloitte (2006)

There are different views in literature on whether an institutional arrangement can be considered to be a Public Private Partnership if no private financing is involved. This could also be considered a form of 'innovative contracting' rather than PPP, since no financial risk sharing occurs. However, both innovative contracting and forms of PPP which include private financing will be defined in this thesis as PPPs. In the Netherlands, the knowledge centre PPP has played an important role in defining and researching PPPs.

They distinguish between two different types of PPP: those in which the government actively participates, and those in which the government facilitates cooperation with private parties (Kenniscentrum PPS, 2001). The knowledge centre places both types of cooperation under the flag of PPP, while some might consider the second type of PPP to be a form of innovative contracting since no active participation occurs between a public and a private party.

In further analysis, only PPPs that include the function of 'Design' will be analysed, which limits the number of possible arrangements. The most important reason for this being that designing is the core activity of Movares, who's perspective is taken in this chapter. In addition, The Sustainable Highway is a concept which has been developed by Movares, which has the expertise to design such canopies. Rijkswaterstaat has no experience in the construction of highway, or railway canopies, meaning that this expertise is mainly present in the market. To optimally utilise the available expertise, private sector participation is required.

The following forms of Public Private Partnerships are common in infrastructure construction in the Netherlands (de Bruijn & Leijten, 2004-2005):

- Design-Build (DB): Under this type of contract, the government contracts a private partner to design and build an infrastructure project in accordance with requirements set forth by the government. A Design-Build contract deals with some of the problems encountered in traditional contracts. Allowing a private party to both design and construct a project ensures that problems in the design cannot be passed on to another party. This will ensure more conscious designing. Furthermore, the builder can more easily take opportunities to work more efficiently by accounting for its own building activities in the design.
- Design-Build-Maintain (DBM): This type of contract is similar to DB, except that the private party also maintains the infrastructure project. When maintenance is part of the project, the risk involved in the amount of maintenance that is needed is transferred to the private party. Since this party is also designing the project, any suspicions of large amounts of maintenance will be optimally dealt with in the design. Especially in projects where the maintenance effort is uncertain, this type of contract can offer large advantages to public parties.
- Design-Build-Finance-Maintain (DBFM): In this institutional arrangement, the private party has similar responsibilities to a DBM contract, but has to arrange (a part of the) financing of the project from private sources himself. The manner of reimbursement to the private party is often dependent on the availability of the infrastructure, which provides a financial incentive for a high quality design.
- Design-Build-Finance-Operate (DBFO): The private party designs, builds, finances and operates the infrastructure, but does not maintain it. The government can maintain the infrastructure themselves or enter into a separate contract with another private party. The party in a DBFO contract is granted a concession for a set period of time and can earn back its investment by charging users of the infrastructure, sometimes supplemented by a yearly reimbursement by the government.
- Design-Build-Finance-Operate-Maintain (DBFOM): This is the most comprehensive arrangement in which a private party is responsible for the entire process of designing, building, financing, maintaining and operating the facility for a set period of time.

As stated earlier, the first two arrangements are not always seen as PPPs, but as innovative contracting. PPPs, from a public perspective, are founded on the transfer of risk from the public to the private sector under circumstances where the private sector is best placed to manage these risks (Grimsey & Lewis, 2005). However, the most important aim for the public sector is to achieve better value for money in the services provided while ensuring that the public interest is safeguarded. When looking at different arrangements for The Sustainable Highway, it is important to take a closer look at each of the possible functions that can be performed by the private sector. This will help to determine in which functions the private sector can deliver optimal value for money while safeguarding the public interest.

7.2.2 Applying institutional arrangements to The Sustainable Highway

This paragraph will provide an exploration of the possibilities to apply a Public-Private Partnership to The Sustainable Highway. What specific arrangement is ultimately chosen to implement the concept into its context will have to be the outcome of a decision making process with the stakeholders which have been identified earlier in this thesis. However, further exploring which parties are most suitable to take on which responsibilities will provide valuable insights. The goal of this paragraph is therefore to illustrate possible ways in which responsibilities and relationships between different parties can be coordinated with regard to the unique nature of this project.

When looking at the first two functions which have been identified (Design and Build), private parties would be able to add value in both designing and building The Sustainable Highway. The concept currently only exists on paper, which means a substantial design effort is still required. The expertise to design and construct transparent canopies is mainly present in railway station design and construction; a field Rijkswaterstaat has no experience in. The lack of public expertise and the presence of private expertise in this area results in a large added value when these functions are performed by private parties. Furthermore, although the concept consists of mainly proven technologies, it is the first time that it will be built, inherently causing more risks then when constructing a 'common' infrastructure project. Transferring these risks to where the expertise is present would be sensible from both public and private perspective. The situation regarding the maintenance of the structure is relatively similar, although 'maintenance' regarding The Sustainable Highway consists of two components. There is the maintenance of the canopy and the maintenance of the road surface. Private parties have ample experience in maintaining these canopies. Furthermore, as was determined in Chapter 2, it is yet uncertain how often the glass panels will have to be cleaned. Transferring these (maintenance) risks to private parties that are also concerned with the design of the structure would ensure these concerns would be dealt with in the design. Road surface maintenance can remain the responsibility of Rijkswaterstaat, or be transferred to private parties, both of which has its advantages. Finally, the minister for transport, public works and water management has stated his concerns about the availability of the infrastructure during cleaning and maintenance. Coupling a financial incentive to the availability of the infrastructure would ensure these maintenance concerns would be addressed in the design.

Financing (and funding) of The Sustainable Highway can be done in a number of ways. Of course, full public funding is an option, with the national government both financing and funding the project. However, should The Sustainable Highway be constructed in a location where the area around the project will be spatially developed, (partial) private funding (and financing) becomes an option. Part of the project's investment costs will then be funded from the revenues that are achieved by marketing the building land around the infrastructure. A property developer could participate in the partnership, contributing financially to the project in exchange for the right to develop real estate in the area. In addition, revenues will arise from marketing heat and energy. Since it is unusual for infrastructure in The Netherlands to generate revenue (especially from marketing energy), it is unlikely that a public party will perform this task. The system to harvest the energy requires an investment (which is included in the budgeted costs) and financing. It could be possible to couple the investment costs of the energy systems to the exploitation benefits, should a business case prove this to be feasible. In other words: part of the funding and financing of the concept might be done by the party that later exploits the energy system and gains the benefits. Overall, there are many possibilities for both private funding and financing making (partly) private funding and financing a realistic option. However, full private funding seems to be unlikely since there are few places in which the revenues from building land and energy can account for the concept's full investment costs. This has been clearly shown in Chapter 4. A public contribution would then still be needed. However, this is quite common in Public Private Partnerships, since the project will also fulfil a public function. Investments in noise barriers and other measures will become obsolete, and less maintenance on the road surface is required. Public health and air quality will improve, making partly public funding a justified option. The Sustainable Highway is a feasible example of a project in which both public and private parties can gain added value by combined public and private funding and financing.

The final function that can be performed by private parties is the operation of the concept. Although this is often not included in road infrastructure, The Sustainable Highway has a unique position. After all, the energy and heat which is produced by the concept will have to be marketed. In addition, the technological system for energy production and distribution will need to be operated. The operator can generate revenues from operating this part of The Sustainable Highway. Again, this is not Rijkswaterstaat's area of expertise; therefore, a concession shall have to be granted to a private party (for instance an energy company) to operate the energy production of the concept.

In the construction of infrastructure projects, where the participation of private parties is judged to add value, commonly DBFM contracts are used in The Netherlands (Peijs, 2003; Commissie Private Financiering van Infrastructuur, 2008). In this type of contract, the private party is deemed to be able to determine the optimal proportion between the investment, availability of the infrastructure and maintenance over the entire duration of the contract. Under these contracts, which are normally concluded for twenty to thirty years (Commissie Private Financiering van Infrastructuur, 2008), the government generally pays an annual sum which will (at least for some part) be dependent on the availability of the infrastructure. Whenever a part of the infrastructure is unavailable, for instance due to maintenance, the private party does not receive that part of the reimbursement. This provides a stronger incentive to private parties to ensure a maximum availability of the infrastructure (Kennisinstituut voor Mobiliteitsbeleid (KiM), 2007). Fears of reduced availability of The Sustainable Highway can easily be dealt with in a DBFM contract.

When a DBFM (or DBFOM) contract is concluded in the Netherlands, commonly, only part of the financing will be arranged by private parties (Commissie Private Financiering van Infrastructuur, 2008). In general, national or local governmental authorities will contribute significantly by providing part of the financing that is needed for the project. The advantages of a PPP will still occur, even though only a part of the financing is from private sources. A successful PPP prescribes that clear agreements are made on the division of risk between parties, of which a significant portion should always be private hands to provide sufficient incentives to guarantee the public interest. Ideally, risks are allocated to parties that contain the expertise to control these risks. Based on the previous considerations, private participation can possibly add value in designing, building, financing, operating and maintaining The Sustainable Highway. However, the expertise to design, build, finance, maintain and operate a project such as The Sustainable Highway is unlikely to be present in a single private party. Private sector participation in this project is therefore unlikely to be limited to just one private party. A consortium of a number of private parties, each of which has its own specific area of expertise, will be able to perform all of the identified functions.

A consortium, with which the government concludes a PPP, generally consists of a number of parties belonging to two major categories (Commissie Private Financiering van Infrastructuur, 2008):

- Contractual parties: contractors, property developers, maintenance companies, engineering offices, etcetera. These parties provide the expertise to design, build, maintain and operate the project and often participate while bearing risk. In addition these parties sometimes introduce financial means to fund or finance the project.
- Financiers: financial institutions such as banks and institutional investors who provide the largest part of the financial means.

The contractual parties should possess sufficient expertise to carry out all of the functions which have been previously identified. When looking at these functions, it is possible to explore which parties are suitable to design, build, finance, operate and maintain the different parts of the concept. This is especially relevant in the early planning stages of the project, since it provides insight in which parties are needed in later stages. These parties can now be involved in planning as well as execution to increase the feasibility of the concept. A possible example of a consortium, able to perform all of these functions is given next.

If Movares, as developer of the concept, is taken as a starting point of the consortium, they could be made responsible for the design of The Sustainable Highway. Movares has already taken an active role in attempting to realise this concept. Therefore, they could provide additional services in managing the project, and the process of forming a consortium. Other private parties which could provide valuable expertise and cooperation towards realising The Sustainable Highway have been identified in Chapter 6. These actors are infrastructural building contractors, property developers and energy companies. The most obvious role for the infrastructure contractor is to be responsible for building The Sustainable Highway. In addition, involving this contractor in the detailing of the design would ensure a more efficient building process. Movares and the contractor would have to share knowledge and work together towards the common goal of designing and building the concept. In addition, this contractor could perform the maintenance of the structural part of The Sustainable Highway after it has been constructed. Maintenance of the road surface could also be performed by the infrastructure contractor. The advantage is that road surface maintenance can be coordinated with other structural maintenance. A disadvantage is that The Sustainable Highway is likely to only cover a part of a highway. Allowing the contractor to only perform road surface maintenance on the section covered by The Sustainable highway would fragment the maintenance of the highway into different sections, which will then be governed by different maintenance contracts. The responsibility for the road surface maintenance should be dealt with in the final institutional arrangement.

A property developer could play a critical role in the designing, building and financing of the spatial development around The Sustainable Highway. Maintenance of the developed real estate could also be part of its responsibility. The property developer is a critical member of the consortium due to its financial contribution. A large part of the concept’s potential benefits originate from the marketing of building land. The property developer would be investing in this building land, thereby funding The Sustainable Highway. Without a property developer, a substantial part of the private funding which is needed for the project will stay out of reach, decreasing the feasibility of The Sustainable Highway. An energy company could also contribute to a part of the design, building and maintenance activities, relating to energy generation and distribution. In addition, an energy company could be involved in operating the concept’s energy system and gain revenues from marketing heat and energy. In exchange for these long term revenues, the energy company could fund a part of The Sustainable Highway’s investment costs. Should no energy company be found which is willing to participate in the design, building and financing of The Sustainable Highway, the operation can also be decoupled from the institutional arrangement. After construction of the concept, the concession to operate the energy system could then be auctioned. However, when one party designs, builds, operates and maintains the energy system, most of the advantages of a normal PPP are to be gained.

In addition to these private parties, local public support will be needed to ensure the feasibility of the concept. The importance of the commitment of a ‘local champion’ has already been discussed in Paragraph 6.2.1. The example on ROM-Rijnmond illustrated that the process to study the feasibility of The Sustainable Highway rapidly progressed as they took an active role. Unfortunately, as Chapter 6 indicated, ROM-Rijnmond has been discontinued. Should a local governmental authority take over the role of local champion, it can have the formal authority to make decisions within its community, providing great value to The Sustainable Highway. In addition, they would have access to national governmental authorities, especially if their community is of substantial size. The influence and commitment of local governmental authorities will be invaluable to the realisation of The Sustainable Highway. Without local public support the feasibility of the concept will be greatly reduced. Finally, local municipal authorities have expertise in the form of their municipal divisions to implement The Sustainable Highway optimally into its local environment. Therefore, local governmental authorities can supply invaluable support towards the realisation of The Sustainable Highway. They can either be part of a consortium, or the consortium can cooperate with local authorities in a different form. The final institutional arrangement will be the outcome of a process including all relevant stakeholders. As discussed, each party has its own unique role and responsibilities within a PPP. A possible way to arrange the roles and responsibilities of each party is summarised in Figure 7-2.

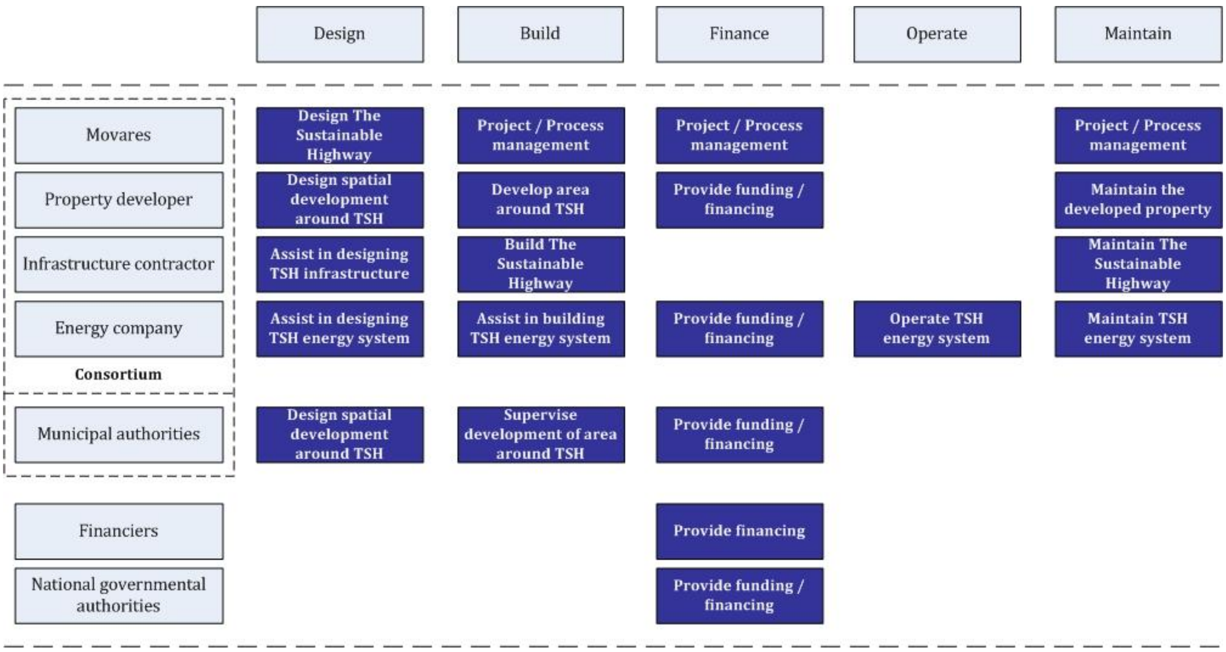

Figure 7-2, the roles and responsibilities of the partners in a Public Private Partnership

In addition to the previously mentioned parties, financiers and the national government also play an important role in both financing and funding The Sustainable Highway. Private financiers can provide the financing that cannot be provided by other private parties, but they will not participate in the funding of the project. The national government is likely to have to contribute financially to the project as is common in PPPs in the Netherlands. They can participate in both the financing and funding of the project, depending on the private financial means that can be obtained. The national government consists of several actors that are relevant to the project such as different ministries and the lower chamber. Although the different governmental actors can all have a different role in (and opinion on) the project, for this figure, they can be aggregated into 'national governmental authorities'. The reason is that in the five identified functions, these governmental authorities will only participate in financing the project. No matter what governmental actor will participate, the other functions can be fulfilled by private parties and a division of the aggregated actor into different parties will only complicate the overview. However, for the process leading up to an institutional arrangement, the different governmental actors are highly relevant. This will be dealt with in the next paragraph on process management and design.

As Figure 7-2 shows, an institutional design arranging all different responsibilities will have to cut through normal institutional domains. Energy generation, maintenance and distribution are normally not part of infrastructure, which means an innovative institutional solution is required. This makes the institutional arrangement highly complex. A certainty is that all the functions of Figure 7-2 will have to be accounted for, either in public or private hands. A way to place the project largely in private hands is by means of an integrated DBFOM contract. Another option is to cut the project into different parts The project can be divided into subcontracts for the infrastructure, canopy, energy system and spatial development. Although cutting the project into different parts reduces the complexity of the institutional arrangement as a whole, the complexity is increased by interfaces. Fragmenting the project into too many different parts will require much more attention to the interfaces between different contracts (Priemus, 2009). It is often on interfaces that problems in complex projects arise. Which type of arrangement is ultimately chosen depends on the preferences of different actors. The national government is often the responsible party for infrastructural projects related to highways, while local governmental authorities govern the area around the highway. These parties therefore have the final say in if, and if so in what way The Sustainable Highway will be realised. However, a consortium consisting of the parties outlined in Figure 7-2 might be able to influence political decision making if their instruments are optimally utilised.

If a consortium, willing to perform the functions that have been identified is formed, several barriers can be removed. The high investment costs, which were mentioned as a barrier, can now be borne by a number of different parties. This reduces the amount of funds the national government will need to contribute. Furthermore, if parties with different responsibilities and expertises cooperate in a consortium, the problem that costs come from a different source than benefits is removed. After all, the parties that contribute financially also gain (a part of) the benefits. How exactly the costs and benefits will be distributed, will be part of the negotiation process. Finally, by including a property developer in the consortium, the benefits from building land will become less difficult to realise. In addition to the removal of these barriers, the arrangement also contributes towards some of the mentioned solutions. By including local governmental authorities into an institutional arrangement, the local authorities commit themselves to the project. This creates the possibility of a local champion taking the lead in the process of realising The Sustainable Highway and generating support among other (national) governmental authorities. In addition, in the set-up of Figure 7-2, the consortium only contains parties which have an incentive to innovate, which means the project will not be hindered by scepticism towards new things and innovation. An innovative consortium, with parties that believe in the project can greatly influence the perception of national authorities. When parties are committed to the project, they can deploy their instruments and network to convince critical actors with conflicting perceptions to support the consortium’s goals.

A consortium has considerably more power than Movares as a single party. When once again, the perspective of Movares is taken, forming a consortium is the next logical step in attempting to realise The Sustainable Highway. Such a consortium takes away many of the barriers which have been identified by the respondents in Chapter 5 and increases the influence which can be exerted on behalf of the project. Forming this coalition however, is not an easy task. Currently, only Movares is committed to the project and no consortium is yet formed. Process management can play an important role in realising this consortium. When this consortium has come into being, the realisation of The Sustainable Highway will be substantially more feasible.

7.3 Designing the process to realise a consortium

To increase the feasibility of The Sustainable Highway, a next possible step is to gain support of both public and private parties. These parties can participate in a consortium which would have to be able to realise the concept, and would have to be able to mobilise support among other actors. To form such a consortium, a process will need to be started. This process will be finished when a consortium if formed. A new process will then commence in which the consortium attempts to acquire and realise the project. This paragraph will deal with the design of a process to form a consortium which is seen as the next step in increasing the feasibility of the concept.

7.3.1 The participants in the process

Movares, as the developer of the concept, will have to initiate the process and invite other participants to participate. Movares can play a facilitating role, similar to that of Fluor Infrastructure B.V in the Infraspeed consortium which has realised part of the high speed railway line (south) in the Netherlands (Infraspeed, 2009). Although Fluor was not the biggest party in the consortium, they facilitated and managed the consortium which could be exemplary of Movares' role. Movares is the initiator of the process and developer of the concept, which makes facilitating the process a natural task.

The stakeholder analysis of Chapter 5 has established that both private parties and local public parties are critical to the success of The Sustainable Highway. In Figure 7-2, the local municipal authorities have deliberately been placed on the edge of the consortium. Their participation is highly critical, although the manner in which they should participate is still open and should follow from the process. Without the support of local authorities, the concept is politically unfeasible for the specific location governed by these authorities. However, in other locations, local authorities might have a different view and support the concept. The manner in which local authorities wish to support the concept is also likely to differ for each location. Whilst in one city, authorities might support the concept from the background, in another city they might be willing to take a much more active role. As has been mentioned before in this thesis, having the support of a local champion will contribute towards the political feasibility of the concept. Therefore, locations in which the local authorities are willing to actively participate, are preferable to locations where these authorities will take a more passive role. In any case, be it active or passive, support from local authorities, besides support from private parties, is vital for the feasibility of the concept. The process should therefore aim to include actors from both categories.

The existence of a private consortium and the presence of public support cannot be seen as unrelated. On the one hand, finding private parties to form a consortium will be easier when local public authorities have already expressed their active support for the concept. On the other hand, gaining local support is easier when a private consortium exists which is capable of eliminating many of the barriers which are perceived by local parties. Although the support of both types of actors is related, public and private parties can have different notions on what they find attractive in a process. However, since they are both critical for the feasibility of the concept, the process design should appeal to each type of actor.

A possible outcome of the process of gaining support for The Sustainable Highway would be the commitment of a local champion to the project. In this case, a local champion can be both a private party or a public party. An example of a public local champion might be a local politician, which perceives The Sustainable Highway to be the solution for an urgent problem within his community. An advantage of a public party as a local champion is that it has easier access to other public actors and it has the ability to (in most cases) take formal decisions within its community. Furthermore, local public parties often have both realising and blocking power.

An example of a local champion from the private sector, is a property developer with strong local ties which is willing to invest both time and money in the realisation of the project. A public local champion would not necessarily have to be part of the consortium, while a private local champion should. Both types of local champions do not exclude one another and both have their unique advantages. Whether public or private, a local champion greatly increases the feasibility of the concept in that location. A local champion can inspire support for The Sustainable Highway in different layers of government and can actively take the concept that critical step further. The process design should strive to commit both public and private local parties to the process in order to find a local champion.

In the past, a number of 'local champions' have already attempted to realise The Sustainable Highway within their respective communities. The example of ROM-Rijnmond has already been discussed, but councillors from both the communities of Diemen and Venlo can also serve as examples. These councillors have provided their opinion on The Sustainable Highway in an interview in Annex 5. Although their efforts have so far been unsuccessful, they have taken the project further and still support The Sustainable Highway as a solution for their - and other – community(s). In both cases however, The Sustainable

Highway was not deemed to be the best solution by national governmental authorities for each respective location. This exposes the weakness of the concept of a using a local champion as an instrument: his influence on local parties is limited to a restricted location. When the project is proposed as an alternative in a different location, the influence of a local champion from a another region is limited. In any location, local parties are critical to the success of the concept in that location. Although previous local champions have not succeeded in realising the concept, they have succeeded in taking the project just a little further with each attempt.

A process to gain support for The Sustainable Highway can be started (and is already underway) within different communities. For each location, the relevant local public parties need to participate in the process. The situation is different for private parties. When attempting to realise a consortium of private actors, the same private parties can participate in each location (an exception of course being the case in which a property developer becomes a local champion). The fact that a private party can become part of the process in different locations might increase the attraction of the process for private parties. After all, by participating in talks on The Sustainable Highway, it gains the chance of realising the project in multiple locations. For both Movares and other private parties, conducting talks on different locations partly offers protection against the consequences of political and public discontinuity which have been discussed in Paragraph 6.2.1. It provides a form of redundancy, since a similar process is being conducted in different locations. Should a local champion be discontinued or leave his post for any reason, the knowledge gained from one location can be applied in a different one. Another way of protecting against the risks of discontinuity is including multiple local parties in the process. This increases the chance that the project will be continued even when a supporter of the concept is forced to leave the process. However, the loss of a local champion is difficult to cope with in any situation.

To summarise: local support is highly important in any location in which The Sustainable Highway is attempted to be realised. Local support from public parties is critical, whilst local support from private parties is highly preferred. In addition, a private consortium is needed to support the concept on a national level. This consortium can participate in multiple talks (or processes) in different locations. Whether local support, or a private consortium is realised first is irrelevant; they both increase the feasibility of The Sustainable Highway. The process should attempt to bind a local champion to the project, since this greatly increases the political feasibility of the concept in that location. Now that the critical participants of the process have been identified, the core elements of a process can be discussed.

7.3.2 The core elements of a process

A process will need to be attractive for parties to want to participate. Not only should the process design contain incentives for parties to participate, the process should also be designed in such a way that parties become dedicated towards reaching a common goal. The process design should ensure the composition of a strong and stable consortium and the commitment of local public parties. According to the theory of process design, the process should satisfy four core elements (de Bruijn, ten Heuvelhof, & in 't Veld, 2008):

- Openness;
- Protection of core values;
- Speed;
- Substance.

A process should feel attractive for parties to want to participate; without openness, the process will feel too much like a project in which the participants are being managed without being able to contribute as equals. Parties should also feel their core values are protected when they enter the process for them to feel safe to contribute towards the common goal. Furthermore, the process should contain incentives to keep the process moving along; to speed the process up. Finally, the process should be about substance and about realising a conclusion on a common goal.

Openness means that the initiator of the process (in this case Movares) does not take unilateral decisions, but adopts an open attitude. That might be hard for the initiator, since in this case, Movares might feel that the process should have a set outcome. Although Movares has a clear goal in mind (the realisation of The Sustainable Highway), the process should be open to suggestion and design alterations by other parties to incentivise them to participate. Although the process takes a technological design as a starting point, there are still numerous areas in which a contribution of other parties can add value. For instance, in spatial development, the institutional design, location of the project and technical details, substantial choices are still to be made. The expertise of parties, which are willing to participate in the process, can be optimally utilised by keeping the process open. For instance, the opinion of an infrastructural contractor regarding issues in maintenance and the construction of The Sustainable Highway, can lead to alterations in the technological design. In addition, a property developer might have suggestions on suitable locations and integrating the concept into its environment. By keeping the process open, all parties´ expertise can be optimally utilised. Openness can be guaranteed in most areas of the project and therefore parties can indicate what items are interesting to them and should be included in the process.

Openness should apply both to the content as to the parties which can be involved in the process. Although the actor analysis, institutional design and Paragraph 6.3.1 have provided a suggestion on which type of parties should participate in the process, no specific actors are named. In addition, during the process it might appear that a valuable potential partner is not among the previously mentioned categories. After all, Chapter 6 has already indicated that the performed actor analysis is a static tool. The dynamics of the actor field might result in an actor becoming critical to the success of the project, whilst this previously was not the case; the process should be open to include such a party. To guarantee openness, the way in which the process is managed should be transparent to all parties at all times; this can be laid down in formalised process agreements.

Openness however, can lead to very diverse suggestions which will not always have the approval of all participants in the process. It is therefore important to make arrangements to protect the core values of different parties. In order to achieve this, parties should only be asked to commit themselves to the process, not to the result. Initially, some parties might be reluctant to join a consortium. By asking them to simply commit to the process, rather than to the end result or solution they might be inclined to join the process more easily. In addition, parties should always have an exit option to ensure they feel free to join the process, without committing themselves to an uncertain outcome (de Bruijn, ten Heuvelhof, & in 't Veld, 2008).

Protecting core values can be especially important with regard to municipal authorities. Unlike private parties, who can explore any opportunity that fits their business strategy, governmental authorities are much more vulnerable in their position. Public opinion and party politics can influence decision making, reducing their room to manoeuvre. When public parties are simply asked to participate in the process, while not committing to any end result, with the option to leave the process at any time, they might be more inclined to explore the possibilities of The Sustainable Highway. When they are committed to the process, they might eventually also get committed to the result. After all, it is then the result they have jointly tried to achieve. Based on the principles of openness and protecting core values, rather than claiming to start a process to form a consortium, the process goal should be more neutral. An example of a process goal conforming to the principles of openness and core values could be: to investigate possibilities for a Public-Private Partnership in realising The Sustainable Highway, asking advice from different public and private parties. This is a much more neutral statement to which parties might more easily commit themselves. Movares' goal in this process might still be to form a consortium. However, since a process is intrinsically open ended in nature, there is no certainty that this goal will be achieved.

A process which is designed to be open and protects core values can become sluggish since parties can join, leave and constantly bring new suggestions to the table at their own leisure. Therefore, the process should contain incentives to speed the process along. What can keep parties incentivised to keep the process going is a prospect of gain. When parties sense that when the process is concluded there is some form of profit (financial or otherwise) to be gained, they are more likely to cooperate towards a common goal. The concept of 'gain' is very different for public and private parties respectively. For private parties this prospect of gain might consist of a financial benefits. For the infrastructure contractor it can be the prospect of participation in a large project. The same holds for the property developer and the energy company, of which the latter might perceive the exploitation benefits as 'gain'. In addition, there are the potential benefits to the image of the participants. Participating in such a high-profile, innovative, sustainable project will certainly have promotional value, which might be perceived as a prospect of gain by all participants. However, for municipal authorities, the gain might be solving a long lasting problem within their community. This might be the opportunity to reduce congestion by expanding a highway, while decreasing the burden of the highway on the environment. It could also be the possibility to develop an area spatially, which previously was impossible. However, financial gain is less likely to be of interest to public parties than it is to private actors. As long as participants to the process believe there is a prospect of gain when the process is concluded, they might be more inclined to speed up the process and cooperate towards a common goal. It is therefore important to remind participants of all that is to gain during the process.

When a process is purely based on openness, protection of core values and speed, there is a risk that the process will result in a compromise without substance. Therefore, the process should also contain incentives to work towards an end result which is based on content rather than just on compromise. To ensure the process does not drive out content, experts on the subject matter can be included in the process. These can draw the process back onto substance when the focus shifts too much onto the process, In addition, a sufficient prospect of gain in all parties can ensure a focus on substance. This is especially the case for private parties for which financial gain is in this case likely to be the main drive to participate in the process. Since this gain can only be achieved if the process ends in a conclusion based on substance, these parties will have an incentive to keep the process focussed on the content. The participants in the process should ultimately determine the exact content and flow of the process. However, the four core elements can serve as boundary conditions to set up the process and steer it towards a result. There should always be a trade-off between the four core elements in the process.

7.3.3 Incentivising parties to participate

Besides these four core elements, which should give guidelines and an idea of the boundary conditions of the process, parties should be incentivised to join the process. The previous paragraph has already mentioned that a prospect of gain should exist for parties in the process. This will not only speed up the process and provide it with substance; it will also make the process attractive to join. In other words: creating a prospect of gain incentivises actors to participate in the process.

Besides a prospect of gain, there is one critical condition which should be met to incentivise parties to join the process: actors should experience a sense of urgency (de Bruijn, ten Heuvelhof, & in 't Veld, 2008). This could be a sense of urgency on a problem in need of immediate solving, about a unique chance to make a profit, or about a project in which an actor feels it must participate. Each actor will experience a different sense of urgency. Private parties for instance, might feel a sense of urgency due to the unique nature of the project: if they participate in the process now, they might gain a first mover advantage against their competitors. Should highway canopies become a success, they will already have a head start over other parties in the market. This will incentivise them to join the process now rather than later, when a competitor might have already stepped in. After all, should The Sustainable Highway be realised, it might have great promotional value for the private parties involved. Energy companies for instance, go through a great deal of effort to convince the general public of their sustainability and participate in innovative projects with regard to renewable energy. The eye-catching nature of this project might incentivise energy companies to join the process before a competitor does, since the first to join the process will have this first mover advantage. In addition, being the first to actually participate in realising the project will have a great information advantage. This project has never been realised, but should it be successfully constructed, more highway canopies might follow. The parties that have been involved from the start would have more knowledge of the technology and construction process than other parties in the market, giving them an information advantage. The fact that this concept is so new can create a sense of urgency among private parties since now is the chance to be the first, resulting in an information – and first mover-advantage. These advantages should be emphasised whenever Movares approaches parties for cooperation.

For public parties to experience a sense of urgency, different conditions need to be satisfied. The concept is likely to have promotional value to the community; however this is unlikely to be their most important incentive. For local authorities to experience a sense of urgency, a problem is required within their community for which the concept provides a solution. Should local authorities experience a problem which is unsolvable (or very difficult to solve) within current means, this will provide them with a sense of urgency to look for alternative solutions. It is in these situations that a window of opportunity opens for The Sustainable Highway. If local authorities do not experience a sense of urgency about a problem which can be solved with The Sustainable Highway, there is no window of opportunity and no incentive for local authorities to participate in the process. When a location within their community can be found for which a solution is needed, they will be inclined to participate more easily. Looking back at Chapter 6, this is exactly why the A20 in Rotterdam would currently not be a politically feasible location for The Sustainable Highway: there is no sense of urgency. When a consortium of several private parties willing to realise The Sustainable Highway can be formed, they can anticipate to potential problem locations. When a window of opportunity opens, the consortium can introduce The Sustainable Highway to local parties. Another window of opportunity has already been identified in Chapter 5. The crisis and restoration law offers room for innovative infrastructural projects which generate renewable energy. As long as this (temporary) law is in effect, there is a window of opportunity to introduces The Sustainable Highway under this legislation.

When a consortium anticipates to locations where a sense of urgency and a window of opportunity exist, local parties are likely to be incentivised to participate in the process. In other words: the political feasibility of the concept is greatly increased when there is a sense of urgency about a problem for which The Sustainable Highway can be a solution. Whilst urgent problems provide incentives for local governmental authorities to participate in the process, private parties can be incentivised by the prospect of financial gain, publicitary value, information and first mover-advantages.

7.3.4 The power of a consortium

The goal of the process that has been discussed in this chapter is gaining support for The Sustainable Highway and forming a consortium. However, even though a consortium consisting of the parties selected in paragraph 7.2 would be able to realise The Sustainable Highway, the eventual decision lies with the national government. They are responsible for all national highways and even though local authorities might support the concept, the national government would have to comply with construction on a national highway. Furthermore, a financial contribution by the national government is more than likely to be needed. This is why national governmental actors have been marked as being ‘critical’ to the success of The Sustainable Highway in Chapter 6.

Both a private consortium and local public parties have the power to influence decision making. A consortium can remove a number of barriers that stand in the way of realising The Sustainable Highway and can convince other critical actors to participate. Since the concept is supported by a consortium, more possibilities arise to persuade critical actors, than would be the case when only Movares would support the concept. Since all actors’ positions are dynamic, the more powerful actors attempt to influence an actor's position, the more likely the position is to change. Furthermore, the consortium will be able to take away many of the barriers that actors might feel stand in the way of realising the concept:

- The consortium can arrange private financing and funding which compensates for the concept's higher costs;
- the consortium can bear some of the risk in the construction of the project, so this burden will be taken away from public parties;
- the consortium will experience gain from innovating, so they are unlikely to be sceptic towards new things;
- the consortium can distribute the costs and benefits, so any difference in who bears the costs and who receives the benefits initially, is compensated later following agreements;

In general, the consortium can take risk and responsibilities away from the parties which are most sceptical towards the project. This might persuade these parties to change their attitude towards The Sustainable Highway, since risks will no longer affect them directly. For national governmental authorities, this is one of the main advantages this potential PPP has to offer.

Perhaps one of the greatest powers of a consortium is its ability to influence other actors. All potential partners of the consortium have access to other actors, which they can mobilise in favour of their goals. Up until now, the reluctance and scepticism of Rijkswaterstaat and the Ministry of Transport has been the biggest barrier in progressing with the process of realising The Sustainable Highway. When a consortium is formed, besides taking away some of the barriers based on content, they can also lobby and influence these critical actors in several ways. For instance, local governmental authorities have periodic deliberations as a part of the MIRT (Chapter 5) with Rijkswaterstaat and the Ministry of Transport. When local governmental authorities support the concept, these deliberations offer a possibility (or window of opportunity) to introduce The Sustainable Highway on a platform which is inaccessible to Movares. Furthermore, an infrastructure contractor is likely to have worked with Rijkswaterstaat in the past. This has provided such a contractor with an informal network which he can exploit to the benefit of The Sustainable Highway. The same holds for property developers, which might also have contacts with the Ministry of Housing, and energy companies which might have contacts in the Ministry of Economic affairs. Expanding the coalition with influential actors greatly increases the platform which can be used to present The Sustainable Highway. This is one of the most useful instruments the consortium will have at its disposal.

The fact that several political parties have not yet taken up a position also works in favour of the consortium. As was concluded in Chapter 6, the lower chamber can force the Ministry of Transport to cooperate. When a majority vote is reached in the lower chamber in favour of innovative infrastructure projects such as The Sustainable Highway, this will greatly increase the chances of the project being realised. Such a majority vote is already within reach since a motion in favour of an experiment with The Sustainable Highway was nearly adopted by a shortage of only six votes (Tweede Kamer, 2009-2010). A consortium can exercise influence on local and national political parties in order to obtain the support of the lower chamber. Private parties will also have important local contacts, increasing the chances of a local champion supporting the project. A strong local actor, with national political influence supporting the concept, can greatly increase its chances in national politics. Such a local champion can gather support for the concept and influence decision making in favour of the consortium. To summarise: when a consortium is formed, this will commit more parties to the concept of The Sustainable Highway. This will remove several of the identified barriers and increase the effort which is put into realising the concept. Reluctant actors can be persuaded both from inside their own organisations (bottom-up) and by pressure from the lower chamber (top-down). Therefore, by forming a consortium the chances of The Sustainable Highway are greatly increased.

7.4 Conclusions on implementing The Sustainable Highway

Besides a technological design, The Sustainable Highway requires an institutional design and a process design to implement the concept into its institutional context. These designs should eliminate as many of the identified barriers as possible. The forming of a consortium and Public Private Partnership (PPP) offers several advantages to both Movares and governmental authorities. In a PPP applied to The Sustainable Highway, a number of different parties should perform a number of different functions. An institutional arrangement will coordinate the relationships between parties and attribute the responsibility for the designing, building, financing, operating and maintaining of (parts of) the concept. The final institutional design will be the outcome of a design process involving important stakeholders. However, for all functions a (public or private) party should be made responsible in the institutional design. To ensure all types of expertise are present in a PPP, a consortium can be formed.

To form this consortium and gain local support, a process has been designed. The process should investigate possibilities for a Public-Private Partnership in realising The Sustainable Highway, asking advice from different public and private parties. By formulating this goal in a neutral way, the process will remain relatively open ended, even though it takes a technological concept as its starting point. In addition, parties should feel their core values are protected in the process and perceive they can leave the process whenever they desire. Parties should experience a prospect of gain to incentivise them to join the process and they should feel that they have to participate now rather than later to collect this gain. This will make them experience a sense of urgency. When the process is underway, the speed and substance should be guaranteed.

The forming of this consortium will greatly increase the feasibility of The Sustainable Highway. The consortium will remove many potential barriers and have much more influence than Movares can currently exert by themselves. Parties in the consortium can use their informal networks to influence opposing critical actors and convince political parties to support the concept. When the process design is executed, this should increase the support for the concept in both the public and private domain. This will provide the possibility to implement The Sustainable Highway into its institutional context, making it a feasible concept not only technologically and socio-economically, but also politically.

8. Conclusions and recommendations

In this chapter, the conclusions and recommendations of this research project will be presented. The research questions which have been defined in Chapter 1 will be answered by using the results from the respective chapters. These conclusions will be discussed in paragraph 8.1 and will lead to recommendations which will be discussed in paragraph 8.2. This chapter will be concluded by a paragraph which reflects on the choices that have been made during this research project, and their influence on the conclusions. The main research question which was defined in Chapter 1 and which will be answered in this chapter is:

To what extent can the concept of The Sustainable Highway provide a technologically and socio-economically feasible solution to the negative side effects of road traffic and how could The Sustainable Highway be successfully implemented given the institutional context?

The results of this research project have provided interesting conclusions for multiple parties. First, there are the conclusions regarding the general feasibility of the project, which are relevant for both Movares, governmental authorities as well as other stakeholders. Second, there are conclusions on the implementation of the project which are of specific interest to Movares. Wherever conclusions and recommendations are only valid for a single party, this will be indicated. Now, each sub-question will be answered leading to a conclusion on the main research question.

8.1 Conclusions

The research question was clearly bipartite, leading to the splitting up of the research project into two different parts. The research questions belonging to each part will first be answered separately after which they shall be combined into an answer to the main research question.

8.1.1 Conclusions on Part I: technological and socio-economical feasibility

The research question for the first part of this research project was defined as follows:

To what extent can the concept of The Sustainable Highway provide a technologically and socio-economically feasible solution to the negative side effects of road traffic?

In order to build up to an answer to this question, Part I consisted of three sub-questions, each covering a different subject.

1. *To what extent do the sub-systems of The Sustainable Highway intend to mitigate the negative external effects of a 'normal' highway and to what extent is the concept of the Sustainable highway technologically feasible?*

In Chapter 2, the system of a 'normal' highway was analysed in order to identify its negative external effects. For the purpose of this analysis, a normal highway was deemed to be located in the Netherlands, in an area where local inhabitants would experience significant hindrance from the negative external effects of road traffic. Among these effects were: the emission of nitrogen oxides (NO_x), particulate matter (PM) and carbon dioxide (CO_2) in addition to noise nuisance. The Sustainable Highway makes use of the following sub-systems to mitigate these effects: a canopy of cold bendable laminated glass, electrostatic filtering, adsorption by active carbon, asphalt heat collectors and solar panels. The canopy prevents all noise and air pollution from reaching the environment next to the canopy. This will greatly reduce the burden on the health of local residents caused by these effects. Due to these effects, building restrictions next to the highway can be lifted, resulting in the possibility to construct houses, where this previously was not possible. In addition, since the highway is covered, a different type of asphalt can be used with an increased lifespan, reducing the need for road surface maintenance. Electrostatic filtering is used to cleanse the air of PM, whilst adsorption by active carbon is used to filter the air of NO_x (and SO_x). Innovatively shaped canopy entrances allow the air to circulate increasing the efficiency of the filters. Due to sunlight entering the structure, and vehicles emitting heat, the temperature under the canopy could rise in summer. To prevent this from happening, heat collectors are placed in the asphalt. This cools the asphalt and consequently the air under the canopy, whilst the heat is stored in the ground water. This stored heat can be used to heat the asphalt in winter, preventing it from freezing, but also to heat homes, consequently reducing the need for natural gas. This can cause a reduction in CO_2 emissions of 1000 tons per kilometre per year. Finally, solar panels can be placed between the sheets of glass to generate up to 1350 MWh of renewable energy per kilometre per year.

All the above mentioned effects are endorsed by an independent second opinion. However, some uncertainties can be derived from the technological system analysis. Although filtration technology has been proven in tunnels, The Sustainable highway has a much larger spatial profile. It is uncertain whether the levels of filtering which are required can be met with current technology. Furthermore, the harvested heat can only be used to heat homes if no district heating system is available in the location where the project is realised. However, heat can be used for different purposes.

During operation, no adverse affects on congestion are to be expected, while during construction effects will be limited. With regard to safety: The Sustainable Highway performs much better than a tunnel (often as good as a normal highway). However, it is uncertain how drivers will experience driving through The Sustainable Highway. Finally, the problem is dynamic in nature; concentrations of air pollutants are decreasing and transitions in technology might reduce other problems significantly. However, this concept is meant for problem locations, where local residents experience severe hindrance from the negative effects of road traffic. In these locations, the problems associated with road traffic are not expected to be eliminated in the near future. Therefore, for these locations, the concept seems to offer a feasible alternative. The most important conclusions with regard to uncertainty have been discussed here; other uncertainties are listed in Figure 8-1.

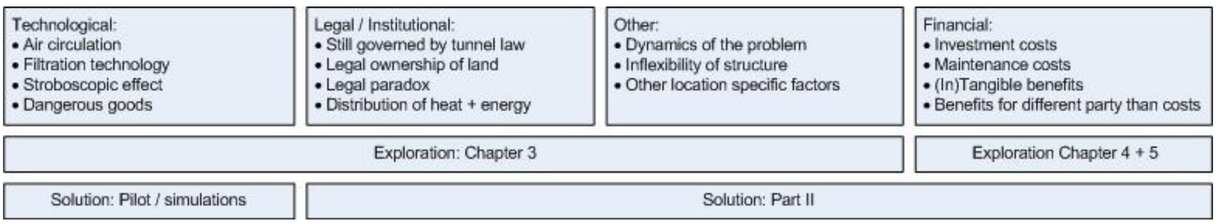

Figure 8-1, uncertainties following from technological system analysis

Despite several uncertainties affecting the feasibility of the system, on the whole in can be considered technologically feasible.

2. *What should a theoretical framework, that can be used to evaluate the socio-economic feasibility of The Sustainable Highway, look like?*

To assess the socio-economic feasibility of The Sustainable Highway, a social cost-benefit analysis (CBA) was carried out. Although CBA methodology has its weaknesses, throughout Europe it is by far the most commonly used (and in the Netherlands obligatory) form of project appraisal. A cost-benefit analysis can be a valuable tool in determining the socio-economic feasibility of a project. It can also function as a methodology to compare different alternatives in a systematic and objective way on several criteria. Furthermore, a CBA on an infrastructure project is never carried out in a vacuum; it is part of a complex political process. This attaches certain conditions to the way in which the analysis is carried out with regard to transparency and objectivity. Should the analysis either lack in transparency or objectivity, the understanding and valuation of the analysis by stakeholders might suffer and lead to conflicting perceptions between the analysts and stakeholders. The OEI-guideline has been developed to provide a common framework for CBA in the Netherlands. A four-phased approach based on the OEI-guideline was used as a framework in this research project to determine the socio-economic feasibility of The Sustainable Highway.

3. *What are the (social) costs and benefits of The Sustainable Highway and to what extent is the system socio-economically feasible?*

To answer his question, a social cost-benefit analysis was performed on a section of the A20 national highway in Rotterdam. This location was selected, due to the severe hindrance the highway causes in addition to the availability of potential building land alongside the highway. Other locations in the same region might suffer from even more severe hindrance; however, this location was chosen on the grounds of socio-economic criteria. In this location, the direct and external effects were analysed for five different alternative solutions: noise barriers (both 10 and 15 meters high, the zero and zero+ alternative respectively), The Sustainable Highway, a sunken highway and a tunnel. The Net Present Value (NPV) of each alternative resulting from the CBA is presented in Table 8-1.

Table 8-1, resulting NPV of socio-economic costs and benefits (in millions of euros)

	Zero alternative	Zero+ alternative	The Sustainable Highway	Sunken Highway	Tunnel
Balance of direct effects	-22,0	-34,6	-9,6	-90,0	-88,2
Balance of external effects	10,1	12,2	29,0	16,2	20,3
Total	-11,8	-22,4	19,4	-73,8	-67,9

The results of the CBA show a positive image of the socio-economic effects of The Sustainable Highway. It is the only alternative with a positive ratio and exceeds the other alternatives by far. The effects contributing most to this ratio are the building land benefits (39,6 million euros) and the benefits from the reduction in noise nuisance (20,3 million euros). Other contributing effects include financial benefits from marketing renewable energy (heat and solar energy) and a reduction in road surface maintenance. In addition, there are socio-economic benefits such as emission reduction and (marginal) traffic flow effects. These socio-economic benefits fully compensate the concept's high investment costs (56,7 million euros) and maintenance costs (7,1 million euros). With these investment and maintenance costs, it is less costly than a sunken highway or tunnel, but more costly than noise barriers. The second best alternative is the zero-alternative which only gains benefits from the reduction of noise nuisance. The Net Present Value of The Sustainable Highway is highly dependent on benefits from building land and noise reduction; however, the model is robust for changes in the starting assumptions regarding these factors.

The positive benefit-cost ratio of The Sustainable Highway shows that a socio-economically feasible location can be found for the concept. However, the location was chosen on grounds that the concept was likely to achieve substantial benefits from building land in that location, contributing towards the concept's feasibility. In locations where no building land is available, the Net Present Value of the concept is likely to be much lower. However, the CBA shows that in similar locations, The Sustainable Highway is a socio-economically feasible alternative. Similar in this case designates: a highway running through a densely populated urban area, where local residents experience severe hindrance from noise and air pollutants and where building land can be developed in the area.

In Part I of this research project, the feasibility of The Sustainable Highway has been analysed from a technological and socio-economical perspective. From a technological perspective, The Sustainable

Highway is a feasible concept. Technological systems which are applied in the concept have been to a large extent proven and a second opinion endorses the advantages which Movares claims the concept offers. Uncertainties around filtration technologies are still present, but a pilot project might provide more clarity on the subject, as it will to other technological uncertainties. From a socio-economical perspective, much depends on the location which is chosen for the concept. Benefits resulting from the development of building land alongside the infrastructure can compensate much of the concept’s high investment costs. Although it is uncertain if these benefits can be achieved, small plots of land can already yield significant benefits. In any case, the concept will provide an opportunity to increase urban quality and realise new inner-city residential property development in a more attractive living environment for local residents. Depending on the location that is chosen, The Sustainable Highway can provide a technologically and socio-economically feasible solution for the negative side effects of road traffic.

8.1.2 Conclusions on Part II: institutional context and implementation

The research question for the second part of the research project was defined as follows:

If deemed feasible, how can The Sustainable Highway be successfully implemented given its institutional context?

Since the concept was deemed to be feasible, the research project continued by answering the final three sub-questions.

4. *What components make up the general institutional context of The Sustainable Highway and how do these components influence the feasibility of the concept?*

The institutional context of The Sustainable Highway consists of several components which can be classified according to a four layer model. These layers make up the institutional context which consists of informal institutions such as norms, values and cultural aspects, formal institutions such as laws and decision making procedures together with the actors involved and their perception of The Sustainable Highway.

The second layer of the four-layer model consists of procedural aspects which could govern the eventual decision making process and realisation of The Sustainable Highway. Should the concept be realised as part of a capacity increase of a highway, it will be governed by the procedure which is defined in the tracélaw. When it is constructed on an existing highway as a stand-alone project, a building permit will have to be issued by local governmental authorities, which should comply with the zoning plan. Since it is unlikely that the latter is the case, the zoning plan will need to be changed which can be done by a ‘projectbesluit’. In addition, currently any tunnel longer than 250 metres has to comply with the tunnel-law. Although this might change in the near future, this imposes serious restrictions on the design of The Sustainable Highway. Institutional arrangements (placed in layer 3 of the four-layer model) governing The Sustainable Highway are not yet present. However, the ownership and governance of the spatial development, and the distribution and marketing of energy and heat - which are part of the concept - will need to be coordinated in such arrangements.

Interviewed stakeholders which are part of The Sustainable Highway’s institutional context all perceive the concept to be technologically feasible, whilst most of the respondents believe the concept to be economically feasible as well. Most respondents report that these views are not shared by the actors Rijkswaterstaat and the Ministry of Transport, which are critical actors to the success of The Sustainable Highway. In the opinion of several respondents, these actors appear to show a cultural resistance against innovation and change, which complicates the situation for The Sustainable Highway. Support from local actors, or a local champion, might influence the position of other actors. The institutional context constrains the possibilities of The Sustainable Highway and institutional arrangements need to be used to improve the compatibility of the concept with its institutional context. In addition, the institutional context will differ significantly for each location, influencing the feasibility of the concept.

5. *How can the institutional context of The Sustainable Highway be applied to a specific location, and how does this influence the compatibility of the concept with its institutional context?*

Based on socio-economic criteria, the A20 in the north of Rotterdam had been previously selected for analysis in the CBA. This location is equally suitable for analysis from an institutional perspective. Prior to detailed analysis, the contextual factors in Rotterdam appear favourable to The Sustainable Highway. The cultural attitude appears to be a mindset of ambitious climate goals and innovation; an environment which seems promising for The Sustainable Highway and a reason to select Rotterdam as location for analysis. Other locations in Rotterdam have equal or higher environmental burdens; however, these locations are less suitable for analysis due to the lacking of suitable building land. This is named as a prerequisite for a feasible implementation of The Sustainable Highway by various respondents.

In this location, many actors share the view that The Sustainable Highway might be a suitable alternative to conventional solutions in reducing the negative effects of road traffic. There appear to be only two opponents of the concept, which are among the most important ones: the Ministry of Transport and Rijkswaterstaat. Since these two actors are unavoidable in infrastructure construction on national highways in the Netherlands, the support of the local actors belonging to the institutional context becomes increasingly important. Support from local parties is vital; however, the actor context is characterised by political and public discontinuity. Therefore, support is difficult to win, but easy to lose. Typical for the current actor context is the large number of parties which have not yet taken up a clear position regarding The Sustainable Highway. This offers opportunities to increase the support for the concept. Besides local governmental actors, one is dependent on the support of private parties. Property developers, infrastructural building contractors and energy companies can provide the private support that is needed to convince public actors. These actors can also assist in providing private financing and bearing risk. In the location of the A20 in Rotterdam, achieving this private financing is possible due to the availability of building land.

Rotterdam appears to have a favourable institutional context for The Sustainable Highway. In addition, the A20 offers many socio-economic and institutional advantages. However, one factor makes the institutional context in this location an infeasible environment for The Sustainable Highway. There is no sense of urgency in this location to solve the problems associated with road traffic, which means there is no window of opportunity. If a location similar to that of the A20 can be found where a window of opportunity exists, this would ensure an environment with a high compatibility to The Sustainable Highway. By 'similar' in this case, reference is made to: a highway running through a densely populated urban area, where local residents experience severe hindrance from noise and air pollutants and where building land can be developed in the area. The local community should be characterised by a culture which supports innovation, by an investment climate where local (financial) support is achievable and by local parties with national influence in addition to a sense of urgency to solve the problems associated with road traffic. When these conditions are met, a location which is technologically, socio-economically and institutionally feasible can be found.

6. *How can the compatibility of The Sustainable Highway with its institutional context be improved?*

Besides a technological design, implementing The Sustainable Highway into its context will also require an institutional design and a process design. Institutional arrangements coordinate the functioning of the actors involved in the socio-technological system and formalise relations and responsibilities. The execution of these institutional arrangements only becomes relevant when The Sustainable Highway moves past the earlier stages of planning. However, in identifying a possible institutional design now, the required parties and their functions become clear, providing information on which parties should be involved in the process. A process design can be used to gain the support of local parties and to help form a consortium which is capable of performing the tasks which have been identified in the institutional design.

The biggest added value is created when The Sustainable Highway is realised in a Public Private Partnership. By doing so, risk can be shifted from parties that are the most sceptical about the feasibility of the concept to parties that have the expertise to realise the concept. For this PPP to be successful, a consortium is needed which can take on all of the responsibilities which are required to realise The Sustainable Highway. Functions include designing, building, financing, maintaining and operating the concept. This is far more complex than in normal infrastructure projects due to the involvement of both spatial development and the generation and distribution of energy. In a possible consortium, the responsibilities could be arranged as demonstrated in Figure 8-2.

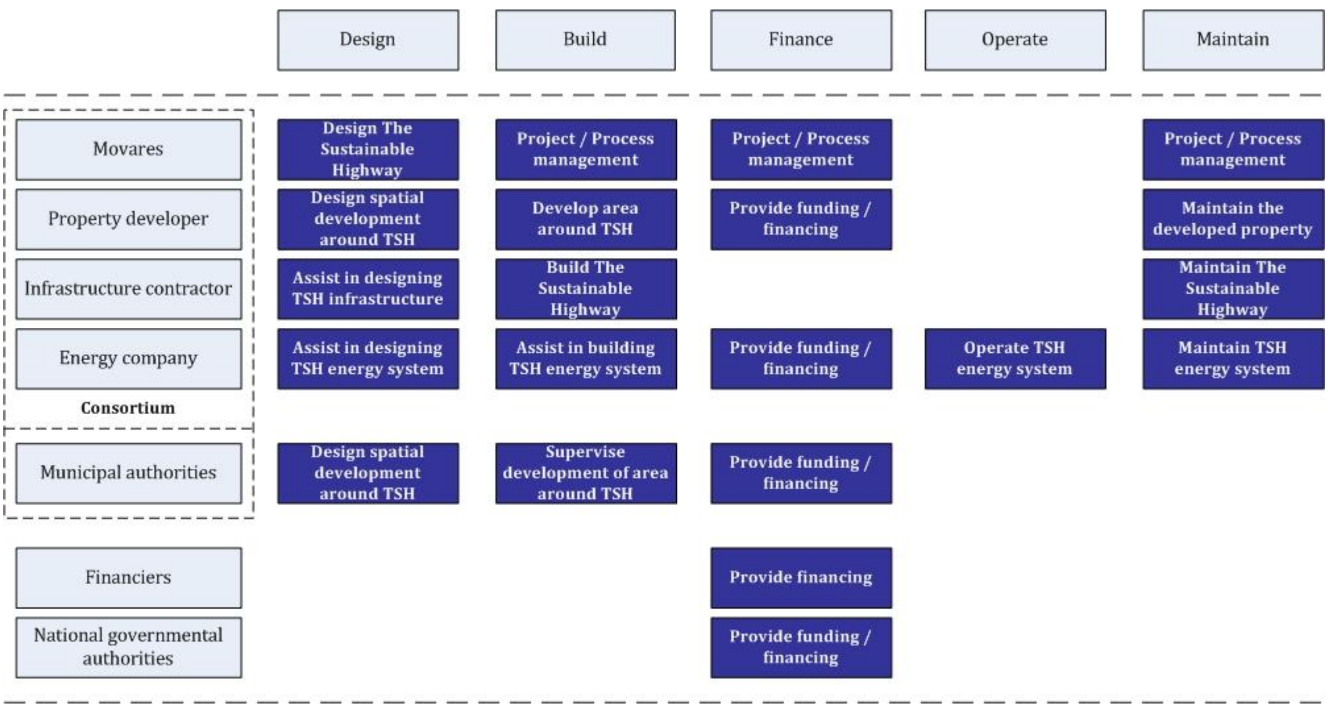

Figure 8-2, the roles and responsibilities of the partners in a Public Private Partnership

The next step in attempting to realise The Sustainable Highway, is to gain the support of local parties in order to find a local champion and to form a consortium to reduce all identified barriers.To realise such a consortium, a process design can be used. For the process to be successful, it should satisfy the four core elements of process design: openness, protection of core values, speed and substance. Furthermore, parties should be incentivised to participate in the process. Parties should experience a prospect of gain, in addition to a sense of urgency for them to participate in the process. The parties that have been selected in the institutional design all have something to gain, be it financially or otherwise, when the project is realised. Since there is competition between market parties, they might also experience a sense of urgency in joining the process. For municipal authorities to participate, a window of opportunity must exist on a problem location within their community. When such a window opens, a consortium should be ready to introduce The Sustainable Highway using any of their identified instruments. The true power of the consortium lies in: arranging private funding, transferring risks to private parties, distributing costs and benefits and influencing private parties. The existence of a consortium greatly reduces the barriers which have been identified earlier in this research project.

Answering the research question of Part II: The Sustainable Highway can be successfully implemented into its institutional context by selecting a location which is both technologically, socio-economically and institutionally feasible. In the later stages, all risks and responsibilities can be arranged in a formalised public private partnership. However, first the support of local parties is needed in addition to a consortium of private parties. This will greatly increase the compatibility of The Sustainable Highway with its institutional context and make The Sustainable Highway a realistic alternative.

8.1.3 Conclusions on the main research question

Now that all sub-questions belonging to both parts of the research question have been answered, it is possible to provide an answer to the main research question:

To what extent can the concept of 'The Sustainable Highway' provide a technologically and socio-economically feasible solution to the negative side effects of road traffic and how could The Sustainable Highway be successfully implemented given the institutional context?

From a technological perspective, The Sustainable Highway is a feasible concept. Technological systems which are applied in the concept have been to a large extent proven and a second opinion endorses the advantages which Movares claims the concept offers. Although several technological uncertainties still exist, on the whole, the concept provides a technologically feasible alternative to common practices such as a noise barriers or a tunnel.

From a socio-economic perspective, much depends on the location in which the concept is realised. Whether the concept is socio-economically feasible is to a large extent determined by the benefits that can be achieved from marketing building land. Therefore, when The Sustainable Highway is realised in a location where local residents experience severe hindrance from noise and air pollution and where building land can be developed in the area as a result of the project, the concept is socio-economically feasible.

Institutionally, The Sustainable Highway presents a challenge due to the unique nature of the concept. The concept will therefore require innovation not only technologically, but institutionally too. Opposition from critical actors such as Rijkswaterstaat and the Ministry of Transport - potentially caused by a scepticism to innovation - complicates matters. However, by selecting a location with a favourable institutional context for The Sustainable Highway, where local parties support the concept both financially and politically, this resistance may be reduced. A consortium, brought together by a process design, can form a Public Private Partnership and shift responsibilities to parties willing to carry them.

Just like a tunnel or noise barrier, The Sustainable Highway has particular applications. The Sustainable Highway is a feasible solution when: a highway runs through a densely populated urban area, where local residents experience severe hindrance from noise and air pollutants and where building land can be developed in the area. In addition, there has to be a window of opportunity and the institutional context should not pose additional limitations to the concept. In these locations, The Sustainable highway is a realistic alternative.

8.2 Recommendations

By answering the research questions, recommendations have been identified for several parties. The original goal of this research project, which was defined in Chapter 1, was:

To identify to what extent the concept of ´The Sustainable Highway' can be a feasible solution for the negative effects of road traffic and to make recommendations on ways to successfully implement The Sustainable Highway in the institutional context.

Whilst the first part of the goal is academic in nature, the second part specifically aims to provide Movares with recommendations on how its concept can be implemented. Therefore, the recommendations in this paragraph will be split into two parts: first of all, recommendations for Movares, second of all academic recommendations, and recommendations for other parties.

8.2.1 Recommendations for Movares

These recommendations are aimed at realising The Sustainable Highway. Following these recommendations will increase the feasibility of the concept.

<u>Additional research</u>
In answering the research questions, several uncertainties have been identified, which decrease the feasibility of The Sustainable Highway. It is recommended that Movares ensures that these knowledge gaps with regard to the uncertainty surrounding The Sustainable Highway are filled. Either by conducting research themselves, or by facilitating the conducting of the research by other parties.

- Research on the technological uncertainties which have been identified in Chapter 2 will need to be conducted. These uncertainties include: the efficiency of electrostatic filtering, and adsorption by active carbon in tunnels with a bigger spatial profile. Should these techniques not provide the required efficiency, research needs to be conducted on alternative techniques. In addition, research on the cleaning of the glass, air circulation and the way in which users experience the construction will also need to be conducted. These studies should be public, in order for them to be usable in the political debate.
- In addition to these generic uncertainties, there are certain factors which are dependent on the location that is chosen for the concept. Whenever Movares conducts a feasibility study on a certain location (commissioned, or on their own accord), several factors will need to be integrated into these studies. The reason for this being that The Sustainable highway is not a normal infrastructure project and therefore, the feasibility of the concept does not only depend on technological and financial factors. Additional location specific research is needed on the transportation of dangerous goods, and the ownership of land alongside The Sustainable Highway. This is needed to assess the ease of achieving benefits from building land and the possibility of building the foundation of the concept alongside the highway. Should the socio-economic benefits of The Sustainable Highway be of interest, then the potential noise reduction which can be achieved in the area needs to be determined. The potential noise reduction greatly influences the socio-economic benefits which the concept can achieve and is highly location specific. Finally, the actor context in the location which is being analysed needs to be mapped out, in addition to the possibilities to distribute heat. When these factors are known, the true feasibility of the concept in that location can be assessed.
- Besides technological and location-specific research, investigating additional benefits and markets will also increase the concept's feasibility. For instance, researching for which subsidies (both European and national) the concept is eligible will add value. These can be subsidies based on innovation or sustainability. In addition, by generating renewable energy, the sale of this energy might also be eligible for national subsidies. Furthermore, the institutional context abroad might be more favourable for The Sustainable Highway. Research on the applicability of the concept in other countries will broaden the market for the concept.

Manage the process and monitor the market

It is recommended that, besides researching the knowledge gaps that are still present around The Sustainable Highway, Movares focuses more on managing the process and contemplating the market.

- It is strongly recommended to implement the process, designed in Chapter 7. The existence of a consortium will greatly reduce the barriers which have been identified in this thesis. Furthermore, a local party might take the lead in attempting to realise the concept. Such a local champion is frequently mentioned as a potentially strong ally, or even a prerequisite for successful implementation. In addition, the existence of a consortium binds additional parties to the concept. These parties are then likely to actively attempt to realise the project. This will greatly increase the concept's chances than if Movares were to act alone.
- Monitor the market to identify chances for The Sustainable Highway. Whenever there is a problem with expanding infrastructure, this offers an opportunity for The Sustainable Highway. Should decision makers be forced to look for alternative solutions, this opens a window of opportunity for The Sustainable Highway to be introduced. Since decision makers will then have a sense of urgency, the concept's chances are greatly increased. The markets which should be monitored are not limited to domestic markets.

Movares has spent the last few years designing the technological side of The Sustainable Highway. Although technological aspects are extremely important, opponents of the concept will always find technological uncertainties to use in the political process. It is recommended that Movares changes its strategy from just focussing on technological design, to also focussing on managing the process. Cooperating with the right actors and introducing the concept at the right time on the right location is currently equally important to technological concerns. When this is carried out, The Sustainable Highway will become a more feasible concept.

8.2.2 Academic recommendations

During this research project, in addition to recommendations for Movares on implementing the concept, several more general recommendations have arisen.

Infrastructure policy

In the Netherlands, the Ministry of Transport, Public Works and Water Management is responsible for making decisions on national highways, whilst Rijkswaterstaat is responsible for executing road works and maintenance. In certain infrastructure projects, the Ministry of Housing, Spatial Planning and the Environment shares the responsibility for decision making. However, the Ministry of Transport is always the leading actor. This gives a great amount of power to an actor whose main focus is the accessibility of the Netherlands. Environmental problems resulting from road traffic are only a secondary concern. In addition, as has been identified by several respondents, these actors share a culture of scepticism towards innovation. This is understandable, since innovation inherently causes uncertainty, which may cause delays, budget overruns and political problems. However, this results in the neglecting of innovative infrastructural solutions which hold the protection of the environment and public health as their main goal. Therefore, the following recommendations regarding infrastructure policy are made:

- Although Rijkswaterstaat and the Ministry of Transport might doubt the technological feasibility of the concept, many other parties do not. An independent second opinion has identified the concept as technologically feasible and all interviewed respondents (which include councillors, engineers and civil servants working at relevant municipal divisions), identify the concept as technologically feasible. Part of this research project was to find a location for this solution. In an ideal world this should be the other way around: normally, a solution for a problem location should be found. However, now that it has been established that suitable locations for this solution exist, it is time to accede that in some locations this might be the best, or most feasible solution. It is therefore recommended to the Ministry of Transport to conduct a pilot project with The Sustainable Highway. Any technological uncertainties can be analysed during the construction and operation of the concept.

- Should the pilot project be successful, it is recommended to the Ministry of Transport to include The Sustainable Highway (or highway canopies in general for as far as the pilot project provides conclusions on this subject) as an alternative solution in the decision making process in infrastructure projects.
- It is recommended to the Ministry of Transport that the tunnel law should be updated in accordance with the advice of the commission for tunnel safety, to incorporate an exception for transparent highway coverings.
- Infrastructure projects have changed significantly over the years. Presently, many infrastructure projects already frequently include spatial (re)development. With The Sustainable Highway, energy generation and distribution is added to this. In addition, the road traffic using the infrastructure has significant negative effects on the environment and public health. The responsibility for these different policy areas is spread over different ministries in the Netherlands. This makes realising integral solutions for several of these problems much more difficult since cooperation between different ministries is required, which causes strategic behaviour of the actors involved. Research is recommended on how more integral policy making can be made possible in the Netherlands.
- Currently, public procurement of infrastructure projects hinders innovation. When a private company spends time and financial resources developing a solution, the contract for this solution might still have to be tendered for. This might cause the developer of an innovative solution not to be allowed to participate in their own project, since other parties could construct their solution in a less costly way. This does not incentivise innovation. Academic research is recommended on the influence of European public procurement rules on innovation.

<u>CBA methodology</u>

In chapters three and four a CBA has been developed and executed. Several interesting points on CBA methodology instigate the final recommendations.

- In the CBA which was performed by Decisio, all alternatives had a negative benefit-cost ratio (Decisio BV, 2009). In the CBA which has been drawn up for this thesis, all conventional alternatives had a negative ratio. In the CBA which has been conducted for the Zuidas project in Amsterdam, the tunnel had a negative ratio despite enormous revenues from building land (Eigenraam & Ossokina, 2006). These conventional infrastructural solutions, such as noise barriers, a sunken highway and a tunnel, are not beneficial to the socio-economic welfare of society as a whole, according to these CBA’s. What these projects have in common is that they rely heavily on external effects as benefits to compensate significant investment costs. Despite their negative results in CBA’s, these projects are common practice in reducing negative external effects of road traffic. It therefore seems socially acceptable to agree to construct measures with a negative CBA outcome as long as they compensate significant negative external effects. This might be an indication that these negative external effects are subconsciously valuated higher by society than is currently common practice in CBA. Additional academic research is recommended on the valuing of external effects and their compensatory measures by society.
- The OEI-guideline has structured cost-benefit analysis in the Netherlands. However, there is still much ambiguity on the way in which the effects in a CBA can be computed. In the calculation of the effect of noise reduction, Decisio uses statistical indicators based on the volume of traffic, whilst this research project uses the Noise Sensitivity Depreciation Index (NSDI). In addition, Rijkswaterstaat will use the new ‘doelmatigheidscriterium’ (Rijkswaterstaat, 2009) when computing the cost-effectiveness of noise abatement measures. Without doubt, these three

criteria will yield different results in any CBA, even if they are only slight. It is therefore recommended to further structure cost-benefit analysis in the Netherlands by providing additional standards on the computation of effects in a CBA.

8.3 Reflection

This research project has analysed the technological and socio-economical feasibility of the concept of The Sustainable Highway, developed by Movares. In addition, recommendations have been given on strategies to implement the concept into its institutional context. During this project, several choices have been made which affect the conclusions and their applicability. This paragraph will contemplate these choices and evaluate their consequences.

8.3.1 Reflection on answering the research question

The research question was split into two parts which have been answered separately. The first part of the question (on technological and socio-economical feasibility) resulted in an answer which can be summarised in a few sentences, whilst the answer to the second part (on institutional context and implementation) is not as straightforward. This can be explained by the fact that the first part of the research question poses 'to what extent' (or under which conditions) the concept is technologically or socio-economically feasible. The number of possible answers to this question is fairly limited. The second part of the question is a 'how'-question (how can it be implemented?). This is a more open question meaning the diversity in conclusions is far greater. This shows in the applicability of the conclusions on both parts.

The first part ends by concluding that in certain locations, The Sustainable Highway is a technologically and socio-economically feasible solution. Different parts of this conclusion are endorsed by an independent second opinion, an independent cost-benefit analysis, a cost-benefit analysis which has been specifically developed for this purpose, interviews with eleven relevant stakeholders and Movares' own research. This is a very strong conclusion which is well founded in independent sources.

Scientific literature and expert interviews form the basis of the second part of this research project. The final chapter of part II (Chapter 7) consists of a design activity. No precedents on implementing similar projects were available to study, which calls for a number of simplifications and assumptions. The fact that this concerns a design activity in a highly complex environment of which there is no precedent, means that possible conclusions are much more diverse and thus more prone to debate. However, reasoning from the available information, together with the opinions of relevant stakeholders, it can be stated that: when the process and institutional designs are performed in the way which has been described, this will greatly increase the feasibility of The Sustainable Highway. The presence of a consortium - as opposed to Movares alone - will decrease many of the identified barriers, whilst local parties together with this consortium can influence other important actors. As with all complex design activities, there are other solutions which can eventually turn out to be equally (or more) successful. Therefore, when executing the designs of Chapter 7, it is important to constantly be aware of the dynamics of the institutional context and adapt the designs accordingly.

8.3.2 Reflection on the choice of concept

This research project has analysed the feasibility of The Sustainable Highway, which is a specific technological concept developed by Movares. The construction consists of a canopy of cold bendable, laminated glass in which several sub-systems have been integrated. This type of concept is uncommon to road infrastructure, in fact, something similar has never been realised. This research project has focussed solely on this specific concept, but do the conclusions hold if the concept is adapted?

For the most part they do. From Movares' point of view, major changes to the concept are unlikely. The light canopy of cold bendable laminated glass is the core of the concept and is what makes it unique. Large changes to this part of the concept would fundamentally change it and therefore the conclusions would change as well. However, these major changes are very unlikely. All sub-systems (with the exception of solar panels) are needed for the concept to function and removing them without any replacement would damage the feasibility of the concept, making that unlikely as well. Sub-systems can be substituted for other technologies, but this would only be done for a good reason; when for instance a more efficient or lower cost sub-system has been developed. This would not hurt the concept's feasibility, it might even increase it. Furthermore, all sub-systems do not only have costs, but also benefits associated with them. Removing filtering, or heat collecting installations would decrease the cost of the system, but also the benefits. Any other small changes fall within the technological margins of the system and no far reaching consequences for the conclusion of this thesis are to be expected. The concept is flexible and conclusions regarding technological and socio-economical feasibility are fairly robust for small changes to the concept.

Currently, there are other engineering firms which have developed light highway canopies. However, none of these concepts incorporates systems to generate renewable energy or provide a sustainable solution for the rising temperature under the canopy. Furthermore, these concepts use different materials, such as a heavier type of glass or synthetic materials. This makes them differ quite significantly from The Sustainable Highway, other than that they also cover the highway with a transparent canopy. Since The Sustainable Highway is unique in most aspects, conclusions on technological and socio-economical feasibility can not apply to other types of light road coverings. However, there are some interesting conclusions which are likely to be valid for other types of innovative infrastructural projects.

These other concepts have never been realised and are innovative infrastructural solutions as well. There is no reason to assume they would be approached any differently by the Ministry of Transport or Rijkswaterstaat than The Sustainable Highway. This means that these concepts are likely to encounter the same scepticism towards innovation, whilst they might in fact be feasible alternatives just as The Sustainable Highway is. Furthermore, since these other concepts cover the highway, they can also generate benefits from building land. However, should they apply no filtering techniques, the concentrations of polluting substances at the canopy entrances might influence the ability to construct houses near the entrances. To acquire a true understanding of how these concepts would compare to The Sustainable Highway a separate study would need to be performed.

8.3.3 Reflection on the dynamics of the context

During the research project the dynamics of certain parts of the institutional context have been underlined more than once. The analysis of the institutional context and any conclusions derived from this analysis will be less applicable as time progresses. Both contextual factors as well as actors, their positions and perceptions, are subject to these dynamics. Procedures change which offers both chances and threats. An important chance is the window of opportunity the crisis and restoration law offers. The Sustainable Highway has been sent as an unsolicited proposal to the Ministry of Transport on a previous occasion with limited success. However, should the project be submitted again, this time with the support of a consortium, and in relation to the crisis and restoration law, it might be more successful. This is an example of the opportunities the dynamics of the institutional context offers. A threat of the dynamics of the context is the public and political discontinuity. Support is difficult to obtain and easily lost; the dynamics of the institutional context should inspire vigilance and a constant evaluation on whether the plans that have been drawn are still applicable.

8.3.4 Reflection on economic feasibility

The socio-economic feasibility of The Sustainable Highway has been extensively studied in Chapter 4 of this research project. However, there are other types of economic feasibility which have received fewer attention. Whether the concept would be feasible from a business-economic perspective (whether it would make a sensible investment for a private party), has not been specifically analysed in this thesis. However, the available data in Chapter 4 does give an indication of an answer to this question. When only the direct financial costs and benefits are taken into account, the concept costs €62,8 million (construction and maintenance) and yields financial benefits of €53,8 million (building land, marketing renewable energy and savings on road maintenance) in the analysed location. This only provides a very rudimentary indication on the business-economical feasibility of the concept. In a location where building land benefits would be higher, The Sustainable Highway might be a business-economically feasible solution. However, The Sustainable Highway is a concept which protects the public interest and is therefore a concept which will typically require (partly) public financing. In comparison, noise barriers would never be a feasible solution from a business-economic perspective (they have no financial benefits) and tunnels only in the case of benefits from toll. Furthermore, whether the concept is viewed from a business-economic perspective or a socio-economic perspective, the value of the concept to society remains equal.

An important factor in the socio-economic feasibility of The Sustainable Highway is the possibility to generate benefits from building land. These benefits are a condition for the socio-economic feasibility of the concept, but may be difficult to realise. Although this has been mentioned, no analysis has been performed on how to obtain these benefits. The reason for this is that this is highly location specific. Ownership of the land, the functions for which it is being used and the commitment of local parties to the project all contribute to how high the benefits in the location will be. Including benefits from building land in the evaluation of the economic feasibility of an infrastructural project is common if this project also includes spatial development. Two examples of this are the new railway tunnel in Delft and the Zuidas project in Amsterdam. Both of these projects are (partly) financed by the revenues which flow forth from spatial development. Therefore, although a specific analysis has not been performed, the assumption is that benefits from building land can provide a significant contribution towards the socio-economic feasibility of The Sustainable Highway. The ability to realise benefits from building land is therefore not dependent on the technological concept, but on contextual factors and actors.

Independent from any location, The Sustainable Highway will protect the quality of life and public health of local residents. Several studies have shown that The Sustainable Highway is a realistic alternative when compared to most other common solutions, such as noise barriers or a tunnel. However, the concept has not yet been given a chance to prove itself. This research project has shown that it deserves such a chance, since it truly is a realistic alternative.

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Annex 1: scientific article

This annex includes a scientific article written for the purpose of this thesis. An earlier version was presented at the 2009 CVS-congress in Antwerp and is available on their website. That article is currently only available in Dutch

'The Sustainable Highway'

"A realistic alternative?"

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Summary

Increasing volumes of road traffic in the Netherlands, lead to the increase of several negative effects. Not only do local inhabitants suffer from health problems and noise nuisance due to nearby roads, road traffic in the Netherlands is also a major contributor to the country's total emissions of CO2. In attempting to reduce these negative effects, the Dutch government reaches for proven solutions such as noise barriers, tunnels and measures at the source. New, innovative solutions, often encounter resistance.

One of these new solutions is 'The Sustainable Highway'. The Sustainable Highway is a glass canopy covering the highway and thereby eliminating all noise nuisance and air pollution alongside the road. The air will be filtered, so that the emission of pollutants at the canopy ends is reduced to a minimum. Heat, which accumulates under the canopy, can be used to prevent the road surface from freezing in winter and also heat nearby homes. Solar panels, which can be placed between the sheets of glass, generate renewable energy. By applying this concept, building land becomes available in places where currently environmental restrictions prohibit building next to the highway.

In this paper the technological and socio-economical feasibility of this new solution is discussed. An independent second opinion identifies the concept as promising, but determines additional research is needed on filtration technology and road user experience. However, the concept is sufficiently flexible to cope with these uncertainties. A study of two cost-benefit analyses shows that the concept can be socio-economically feasible. When the concept is applied in the right location, its net present value is far greater than that of noise barriers or a tunnel. However, this depends heavily on the availability of building land which is suitable for spatial development.

The Sustainable Highway can be a technologically and socio-economically feasible alternative in locations where the highway runs through a densely populated urban area, where it causes severe noise nuisance and poor air quality for local residents and where building land can be developed in the area.

Key-words: The Sustainable Highway, technological feasibility, socio-economical feasibility, cost-benefit analysis.

1. Introduction

The past decades in the Netherlands have been characterised by a growth in population, economic growth and an accompanying growth in mobility (Kennisinstituut voor Mobiliteitsbeleid (KiM), 2008). Mobility is not only influenced by economic growth, it is also a prerequisite for further growth. The role of mobility as a driver for societal and economic growth is underlined by the Dutch Ministry of Transport: "Whereas government policy previously viewed mobility as a problem or as something permissible, the assumption is now that mobility is a must. Mobility, for people as well as goods, is a prerequisite for society and the economy to function well" (Ministry of Transport, Public Works and Water Management (V&W), 2008). Consequently, mobility fulfils a critical societal and economical function and therefore limiting mobility will limit societal and economic growth. Unfortunately a growth in mobility, and especially a growth in road traffic, leads to several negative external effects. Not only do local inhabitants suffer from health problems and noise nuisance due to nearby roads, the traffic and transport sector in the Netherlands is also responsible for 19% of the country's total national emissions of CO_2 (Algemene Rekenkamer, 2009). The Dutch cabinet aims to reduce these negative effects: "This cabinet wants to let the economy grow and to provide space for traffic and transport while simultaneously limiting the negative effects of this traffic" (Ministry of Transport, Public Works and Water Management (V&W), the Ministry of Housing, Spatial Planning and the Environment (VROM), 2005).

All these efforts have resulted in a decrease of certain types of air pollution such as nitrous oxides (NOx) and fine particles (PM), which are both a cause of health problems of local inhabitants (Kennisinstituut voor Mobiliteitsbeleid (KiM), 2008). Despite this reduction, the original policy goals with regard to air quality are not met in time and it is uncertain whether the target figure for CO_2 reduction will be achieved (Algemene Rekenkamer, 2009). Norms are still being exceeded on specific locations, especially close to important national highways. Local inhabitants are experiencing significantly more hindrance from air pollution than the average nationwide. Furthermore, the number of people experiencing noise nuisance caused by road traffic in the Netherlands has increased from 27% in 1997 to 31% in 2008 (Centraal Bureau voor de Statistiek (CBS), 2009).

Although clearly, these negative effects are high up on the political agenda, the intended reductions are not being achieved. In the short term, innovative solutions to achieve these reductions often seem unfeasible, too costly, or simply lack the efficiency to provide a substantial contribution. Currently, the government heavily relies on proven technology, such as noise barriers, in an attempt to achieve its environmental objectives. However, private parties appear to have come up with a promising alternative: several concepts have been developed to cover highways with (transparent) canopies, providing the possibility to integrate several systems which mitigate the negative external effects of road traffic.

As yet, these innovative initiatives have been regarded with scepticism in national politics. Both technological and economical uncertainties play an important role in this. Therefore, further research is required on the presence and validity of these uncertainties surrounding such concepts. The concept of 'The Sustainable Highway', which has been developed by Movares B.V., will serve as the subject of analysis.

First, this paper will discuss several negative effects of road traffic in more detail. Second, the manner in which The Sustainable Highway aims to mitigate these effects will be discussed. Next, the technological uncertainties surrounding the concept will be discussed, which will be followed by an exploration of the economical feasibility of the concept. This will result in conclusions on the general feasibility of such a concept in the Netherlands.

2. Negative effects of road traffic

In the introduction, it has been established that the growing mobility in the Netherlands fulfils an essential function. Mobility should therefore be given space to grow, while its negative external effects should be limited. The Netherlands' Institute for Transport Policy Analysis (KiM) identifies three categories of external effects of road traffic, being: congestion, traffic (un)safety and the emission of polluting substances (Kennisinstituut voor Mobiliteitsbeleid (KiM), 2008). Other authors name similar effects, such as air pollution, traffic (un)safety, congestion, global warming and noise nuisance (van Wee & Dijst, 2002). In the Netherlands, when air pollution is discussed in this context, mainly nitrogen oxides (NOx) and fine particulate matter (PM) are meant. To a lesser extent, air pollution with regard to road traffic can also refer to sulphuric oxides (SOx). However, the emissions of sulphuric oxides by road traffic have been reduced to such an extent over the past years that in the near future this is not considered to be problematic anymore. Therefore, when this paper discusses air pollution, reference is made to the two earlier discussed pollutants.

These external effects of road traffic have several far reaching consequences. Air pollution in general, and specifically the emission of fine particulate matter and nitrogen oxides by road traffic, leads to severe health problems for local residents (World Health Organisation (WHO), 2006). Although air quality has improved spectacularly over the last few years, possibly still as many as 18.000 people die prematurely in the Netherlands as a consequence of poor air quality each year (Ministry of Housing, Spatial Planning and the Environment (VROM), 2009). In addition, noise nuisance caused by road traffic results in sleeping and health problems. The consequences of air pollution and noise nuisance have led to the establishment of environmental zones around infrastructure. This results in building restrictions and often a prohibition to construct new houses within a certain distance of the highway. This protects the living environment of local residents, but leaves potentially valuable building land unused. An alternative measure to reduce noise loads for local residents is the use of very porous asphalt (ZOAB). Although this reduces noise nuisance, the asphalt has a much shorter life-span than conventional non-porous asphalt. ZOAB has to be replaced more often and therefore results in additional costs and congestion during maintenance. Clearly, many direct and indirect negative consequences of road traffic can be identified.

There are numerous potential solutions which counteract some of the negative effects of road traffic. However, integral solutions are rare. Noise barriers can reduce noise loads around highways substantially, however, increasingly high barriers are needed to reduce noise nuisance at the house front of local residents to legally acceptable levels. Furthermore, noise flows over the top of the barriers and can be carried for great distances by the wind. Tunnels block all noise and air pollution alongside the highway, but pollutants exit at the tunnel entrances. Moreover, a tunnel is far more expensive than any other alternative solution.

The Sustainable Highway is a concept which has been designed to counteract a number of the negative effects caused by road traffic. The Sustainable Highway can be constructed over any existing, or any new to construct highway, and can thereby provide a solution for the most severe problem areas. However, the concept is very costly and some of the technologies used have not been proven at the proposed scale. The following chapter will explore the concept and clarify its relation to any of the negative effects of road traffic.

3. The concept of The Sustainable Highway

The concept of The Sustainable Highway consists of a glass canopy which is placed over both carriageways of a highway. The canopy consists of (patented) cold bendable laminated glass, which allows daylight to enter. The canopy blocks (almost) all noise nuisance and air pollution alongside the canopy. Without additional measures, the polluted air would exit at the canopy entrances. A reduction of these emissions can be achieved by filtering the air, both under the entire length of the canopy and at both entrances. By utilising the air flows caused by road traffic and innovatively shaped canopy entrances, a natural air circulation is created. This increases the percentage of polluted air which can be filtered. In summer, the temperature under the canopy may rise, making cooling a necessity. The concept provides for this by placing heat collectors in the asphalt. The heat, which is harvested in this process, can be stored in the ground water and be used in winter to prevent the road surface from freezing but also to heat nearby homes. Finally, solar panels can be placed between the sheets of glass to generate renewable energy. By utilising all of the sub-systems in and under the canopy, the concept can contribute towards the reduction of the negative effects of road traffic.

3.1 The construction

The canopy will consist of panels of cold bendable laminated glass. This glass (Freeformglass ®) is patented by Movares and relatively inexpensive when compared to other materials. In addition, it greatly reduces the cost of the bearing structure that is needed, when compared to normal glass. The structure is made up of arches, formed of castellated steel beams, supported on steel columns between the two carriageways. Cross beams between the arches form a framework to hold the bent beams carrying the laminated plates of glass. The total construction for a highway consisting of 2 x 3 traffic lanes will be approximately 50 metres wide making it large enough to accommodate all normal roadside structures comfortably. Each carriageway will have its own canopy, separated in the centre by a closed, sound-absorbing wall.

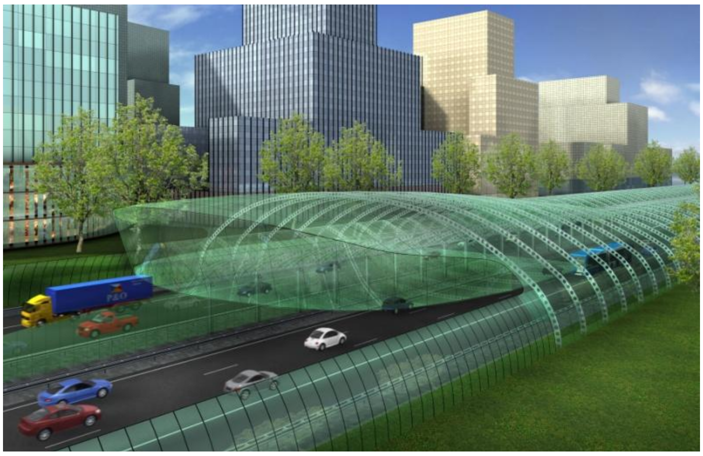

Figure 31, Artist impression of The Sustainable Highway (source: Movares)

The advantage of a transparent canopy is that daylight can enter, making daytime lighting superfluous and making the concept fundamentally different from a tunnel. Furthermore, in case of a calamity, emergency services can get an overview of the extent of the calamity from outside of the structure, making it easier to control. Although such a canopy has never been constructed over a highway before, comparable light canopies are regularly used in the construction of railway stations. Similar techniques have already been used in the construction of ‘s-Hertogenbosch’s central railway station in 1997 (Vákár L. I., 1998; 2000), while more recent projects include the bus station behind Amsterdam central railway station and the ‘Hemboog’ project of Amsterdam’s Sloterdijk railway station.

3.2 Contribution to noise reduction

By placing a canopy over the highway, the environment is shielded from any noise which is produced by traffic. The canopy performs approximately 5 dB(A) better than a noise barrier of maximum effectiveness and 20 dB(A) better than in a situation where noise barriers have little or no screening effect (Vákár L. , 2008). In 2009, an independent second opinion has been performed on the concept by the engineering office of the public works division of the city of Rotterdam, which confirms the reduction (Gemeente Rotterdam Gemeentewerken, 2009). The elimination of noise nuisance makes building restrictions relating to noise nuisance no longer apply, which results in the possibility to construct homes and offices close to the highway where this previously was not possible. Since highways in the Netherlands are often located in densely populated urban areas, high value building land may become available. It is important to note that building restrictions relating to air pollution may still prohibit construction of houses, if no additional measures to increase air quality are taken.

3.3 Contribution to the reduction of local air pollution

By covering the highway, the emission of pollutants by traffic no longer influences the environment alongside the canopy. This, in contrast to noise barriers, can lead to the elimination of building restrictions for both noise nuisance and air pollution. This is a significant advantage of The Sustainable Highway. A condition for this advantage is that the air at both ends of the canopy is cleaned, since highly polluted air can exit the canopy, and reach the environment. The air can be filtered of unwanted substances such as NOx, PM10 and SOx by using different filtering methods. Electrostatic filtering and ionisation can be used to cleanse the air of fine particulates. These filters can be placed at the canopy entrances. Adsorption by active carbon can be used to cleanse the air of NOx (and SOx). This technique can be employed in the centre wall along the entire length of the canopy, which is shown in figure 2.

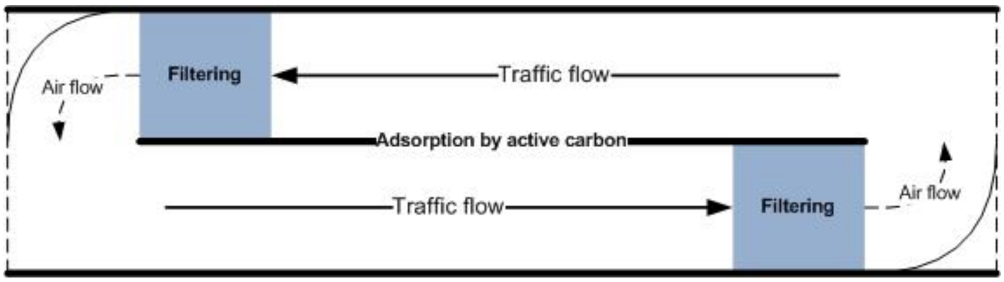

Figure 4, air filtration on The Sustainable Highway

By filtering the air, further consequences of air pollution on a local scale are prevented. This improves public health and quality of life of local residents in the long term.

3.4 Contribution to the reduction of CO2 emissions

In addition to increasing local air quality, The Sustainable Highway can also cause a reduction of the total emissions of carbon dioxide in the Netherlands. Since daylight can enter and vehicles emit heat, the temperature under the canopy may rise in summer, making cooling necessary. The concept accommodates this by placing heat collectors in the asphalt. These collectors cool the highway in summer, storing excess heat in the ground water and never allowing the temperature to rise more than eight degrees Celsius above the outside temperature. This heat can be pumped up in winter to heat the road surface and nearby homes. The natural gas which is saved by using this system to heat homes is equivalent to an emission of 1000 tons of CO2 per kilometre per year (Vákár L. I., 2008). This is equivalent to the heating needs for up to 2400 modern, well insulated apartments.

Solar panels can be placed between the sheets of laminated glass. This is not a prerequisite to make the concept succeed, but it is a non-recurring chance to further increase the sustainability of the concept. Because of the position of the solar panels no separate supporting structure is needed, causing significant cost savings. By integrating solar cells in 25% of the glass panels, 1350 MWh of renewable energy can be generated, per kilometre at a width of 50 metres. This corresponds to a net saving of approximately 750 tons of CO2 per kilometre of Sustainable Highway per year.

3.5 Effects on maintenance, road management and congestion

There are several additional effects resulting from the choice to cover the highway. Because of the canopy, the highway is always dry and clear of snow. Weather no longer has any influence on the wear and tear of the highway, increasing its lifespan and thus decreasing the cost of road maintenance. Furthermore, by cooling the asphalt the road surface remains a more constant temperature, further increasing its lifespan. For reasons of noise reduction in the Netherlands, mainly very porous asphalt is used, which has a theoretical life-span of around eight to twelve years in open air (IPG, 2008). However, in practice a lifespan of seven years is not uncommon. When The Sustainable Highway is constructed, it becomes possible to use non-porous asphalt which is less costly and has an expected lifespan of around 20 years in open air. When this type of asphalt is covered, the lifespan can be further extended, again contributing to a

further cost reduction of road maintenance. In addition, the reduced need for maintenance will decrease congestion during the lifespan of The Sustainable Highway. However, during the construction of the concept, congestion may temporarily increase, although a modular construction process can be employed which minimises effects on congestion (Gemeente Rotterdam Gemeentewerken, 2009).
As stated, an independent second opinion has been performed on the concept by the engineering office of the city of Rotterdam to assess the technological feasibility of the concept. This second opinion confirms many of the intended effects of the concept. However, just like any innovative concept, The Sustainable Highway inherently has some uncertain technological factors associated with it. Several of these technological aspects require a further exploration.

4. The technological feasibility of The Sustainable Highway

In the previous chapter, The Sustainable Highway and its intended effects were discussed. The technological feasibility of the concept has been analysed by conducting a second opinion on the concept for a virtual part of the Rotterdam ring road. The second opinion confirms several of Movares' claims regarding the concept, but at the same time a number uncertainties are identified. The most important points will be discussed in the following paragraphs.

4.1 Promising points

Firstly, it is important to note that the structural design of the canopy is technologically feasible. The canopy is a type of construction that has often been used in the context of railway stations, and no significant problems are expected when this design is implemented in road infrastructure. In addition, the assertions with regard to road surface durability are entirely supported by the second opinion. The Sustainable Highway offers a higher reduction of noise nuisance than noise barriers and local air pollution alongside the canopy is completely eliminated. The heat, which can be harvested by asphalt heat collectors, is suitable to use as heating for homes, should the area in which The Sustainable Highway is being constructed not yet be connected to a district heating system. In that case, the heat cannot be fed into the district heating system and an alternative destination for the heat will need to be found. The Sustainable Highway offers a possibility for spatial development alongside highways where currently building restrictions exist due to environmental regulations, resulting in the availability of valuable building land. This is caused by the complete elimination of air pollution and the strong reduction in noise nuisance. Finally, the generation of solar energy is considered to be a promising, but non-essential part of the concept. On these points, the concept is found to be technologically feasible.

4.2 Uncertainties

The concept has significant added value in relation to other solutions with regard to the reduction of local air pollution. Therefore, the efficient filtering of the air is a prerequisite for the concept to be successful. An important note is that the technologies which are proposed as filtering techniques have not been proven on the scale which has been suggested. Electrostatic filters have shown an efficiency of up to 90% (Cornelissen, 2007), although this has only been achieved in long, narrow tunnels with a high concentration of fine particles. These situations are difficult to compare to The Sustainable Highway, since such tunnels have a much smaller spatial profile. Additional research will have to demonstrate whether a comparable efficiency can be reached. However, an efficiency rating of 90% if not required to satisfy legal regulations on air quality. Currently, research on the development of fine particle filters in the open air is being carried out. The TU Delft and BAM are conducting tests with electrostatically charged wires in the open air which is a technique which can possibly be applied to the Sustainable Highway (Delft, University of Technology, 2008). In any case, the technology of electrostatic filtering is still in development; should it prove not to deliver the required efficiency, an alternative technology will need to be found. Regarding the adsorption by active carbon, no conclusive scientific research exists on filtering air in comparable situations to The Sustainable Highway. However, technological developments regarding these systems steadily progress and more research and testing will confirm whether or not these systems will provide the level of filtering that is needed. Furthermore, the efficiency of the filters depends on air circulation.

Testing will have to show whether the flow of traffic in conjunction with the innovatively shaped canopy entrances will provide sufficient circulation. Otherwise, mechanical ventilation might be needed, which can also take over in case of a prolonged period of congestion, Other uncertainties which have been identified in the second opinion are: the cleaning of the canopy, graffiti, and the way in which road users will experience driving through a construction made of glass (Gemeente Rotterdam Gemeentewerken, 2009). Uncertainties regarding these factors can be dealt with within the concept, since the design is still flexible, and fall within the financial margins of the concept. The efficiency of the chosen filtration methods is the most important technological uncertainty. Other sub-systems are proven and – in a technological context – feasible.

4.3 Safety

An aspect, which has been left out of the explorations in this paper so far, is the safety aspect of The Sustainable Highway. Safety is a broad notion which can refer to several different situations. Both the safety in a 'normal' situation can be concerned as well as safety in case of different types of calamities. In the case of a calamity, factors such as the ability of road users to get themselves to safety as well as external safety and structural integrity of the construction play an important role. In general, the second opinion states that the safety on The Sustainable Highway for the road user is comparable to that of a regular highway at ground level when a 'normal' situation is concerned (Gemeente Rotterdam Gemeentewerken, 2009). Reasons for this, are the fact that road users can orient themselves on the environment due to the transparency of the glass and that emergency doors can easily be integrated. These factors can possibly decrease panic in case of a calamity. Although heat and smoke will accumulate under the canopy in case of a fire, this will occur at a far greater height than in a tunnel due to the larger spatial profile of The Sustainable Highway; at eye level the air is relatively clear. The transparency of the canopy will make the calamity easier to approach for emergency services; this provides advantages both in relation to a tunnel and noise barriers, which are often not transparent.

In case of a fire involving three passenger cars (9MW) the safety situation on The Sustainable Highway is still comparable to that of a normal highway when controlling the calamity and escaping are concerned. The situation on The Sustainable Highway is in this case much better than that in a tunnel. In addition, in case of a large fire (70 MW) the glass will stay in its frame for 30 minutes, giving drivers enough time to escape. In case of a large truck fire (50 – 150 MW), a hydrocarbon fire (200MW) or BLEVE (Boiling Liquid Expanding Vapor Explosion), direct contact is likely to occur between the flames and the glass. In this case, the glass will immediately break, temporarily causing the danger of falling glass in the location of the flames. However, after the glass has shattered, an open air situation is created. This will allow flames, smoke and heat to escape with no more danger than on a normal highway. When dangerous substances would escape in case of a calamity, The Sustainable Highway shows more similarities to a tunnel. The safety aspect with regard to the transportation of dangerous goods is location specific and will require further research once a final location is chosen.

It has been clearly established that The Sustainable Highway performs much better than a tunnel (often as good as a normal highway) when looking at the safety aspect. However, currently the Sustainable Highway is categorised as a tunnel due to Dutch tunnel legislation, since it is a covered road longer than 250 metres (Wet aanvullende regels veiligheid wegtunnels, 2006). This means that strict rules and regulations apply, such as the provision that drivers are not allowed to change lanes 10 seconds prior to the entry of the tunnel. Consequently, under current legislation, no on and off ramps are allowed under The Sustainable Highway. However, an exception on tunnel legislation may be made for transparent canopies due to the clear differences in safety aspects. The commission for tunnel safety has recently recommended redefining the notion of a 'tunnel' in tunnel legislation (Commissie tunnelveiligheid, 2009). However, as long as The Sustainable Highway is governed by the tunnel law, this legal aspect constitutes a major uncertainty.

4.4 Location dependent factors

Based on the previous exploration of documents which have been provided by Movares and independent studies, The Sustainable Highway as a complete system appears to be a technologically feasible concept. The most significant added value of the concept lies in decreasing the environmental burden on areas which are already heavily affected by the negative effects of road traffic. However, the areas to which reference is made are often located in densely populated urban areas in which, besides technological uncertainties, also economical, legal and political uncertainties will play a role. Room for the foundation of the structure will be needed next to the highway and land which will need to be spatially developed is not always in the hands of the same party that will be realising The Sustainable Highway. Every location has its own unique uncertain factors which influence the feasibility of the concept. In addition, the marketing and distribution of heat and energy – which is technologically feasible – can encounter institutional barriers.

Due to increasingly strict European norms and regulations, the automotive industry is developing cars which produce less noise, provide a better fuel economy and fewer emissions. Although this will provide an indispensable contribution towards the reduction of negative effects of road traffic, it is also a very time consuming transition. The Sustainable Highway can be realised in the short to medium term on bottleneck locations where air pollution and noise nuisance are currently severe problems, surpassing legal norms. Measures at the source will in time need to provide a reduction of the national averages in polluting substances; however, The Sustainable Highway is a technologically feasible measure to improve the local living environment and public health. Even though it will barely have an impact on the total national emissions of polluting substances.

Based on an analysis of the technological feasibility, the concept appears to add value when applied in the right location. The right location in this case being a highway running through a densely populated urban area, where local residents experience severe noise nuisance and hindrance from air pollution. With regard to the technological feasibility of the system, it can be concluded that on the whole, the system can be considered to be technologically feasible, even though several factors require additional research. The most notable factors being filtration technology and the way in which road users experience the concept. In addition, the tunnel law currently introduces another source of uncertainty. In order to further compare the concept to alternative solutions, a clear socio-economical evaluation of the concept is needed. After all, socio-economical feasibility is just as vital as technological feasibility. In the next chapter, the socio-economical costs and benefits of the concept will be evaluated based on a social cost-benefit analysis.

5. Socio-economical feasibility of The Sustainable Highway

To assess the socio-economical feasibility of The Sustainable Highway, a (social) cost-benefit analysis (CBA) is performed. A CBA is mandatory for special infrastructure projects in the Netherlands and by far the most common form to appraise the socio-economical costs and benefits of an infrastructure project throughout Europe. A CBA is not only part of decision making procedures; it is also used as a tool to convince other stakeholders of the socio-economical effects of a project (Feitelson & Salomon, 2004). In order for other stakeholders to perceive the CBA to be valid, it must be transparent and objective. In order to guarantee transparency and objectivity in the use of cost-benefit analyses in the Netherlands, the OEI-guideline was drawn up by the Dutch government in the year 2000 (Eigenraam, Koopmans, Tang, & Verster, 2000). This guideline standardises the way in which cost-benefit analyses are conducted for infrastructure projects in the Netherlands, so political decisions can be made based on the correct information regarding cost and benefits of such a project. A four-phase approach developed by the consulting firm BCI, based on the OEI-guideline, is used to analyse the socio-economical costs and benefits of The Sustainable Highway (BCI, 2007).

5.1 A previous study

The goal of a social cost-benefit analysis is to provide information on the social costs and benefits of a project. The relation between benefits and costs, expressed in a benefit-cost ratio or net present value (NPV), determines whether a project contributes to the social welfare of a country. In early 2009, a CBA on The Sustainable Highway was already performed by an external agency based on the second opinion of the engineering office of the city of Rotterdam (Decisio BV, 2009). This CBA took the second opinion as a starting point to compare The Sustainable Highway to noise barriers and a tunnel for a virtual one-kilometre section of the Rotterdam ring road consisting of 2 x 3 traffic lanes. The net present value of each of the alternatives is presented in Table 1.

Table 2, net present value of each alternative, based on Decisio (2009), in millions of euros

	Zero+ alternative (noise barriers)	The Sustainable Highway	Tunnel
Balance of direct effects	-27,0	-46,5	-160,5
Balance external effects	10,5	17,7	14,0
Total	**-16,5**	**-28,8**	**-146,5**

In this study, all alternatives show a negative NPV, which means they do not contribute towards the social welfare in the Netherlands. The analysis concludes that noise barriers show the least negative ratio between benefits and costs, but also that The Sustainable Highway can be a feasible alternative in certain locations (Decisio BV, 2009). The negative ratios are mainly influenced by the significant investment costs associated with these alternatives. Important benefits for all alternatives include noise reduction, while benefits from building land have the largest influence on the NPV of The Sustainable Highway and the tunnel. However, since no specific location is chosen and these benefits are highly location specific, these benefits might be substantially more (or less) depending on the chosen location. In this analysis a land price of €125 per square metre was chosen, while in Rotterdam land prices can vary between €125 and €416. When a land price of €445 per square metre is assumed, the zero+ alternative will no longer have a negative BC-ratio. However, this break-even point is reached much sooner for The Sustainable Highway. The Sustainable Highway will break even at a price of €220 per square metre (the tunnel alternative requires a price of €615 per square metre), which does not appear to be unrealistic. Clearly, additional research is needed on this subject.

A negative NPV (or BC-ratio) does not always mean a project will not (or should not) be realised. An analysis of 46 cost-benefit analyses in the Netherlands has demonstrated that two thirds of all projects with a negative benefit-cost ratio were given green light by policy makers (although often after some adjustments to the project) (Kennisinstituut voor Mobiliteitsbeleid, 2008). This shows that a negative benefit-cost ratio does not always mean that a project will not receive the green light. However, it clearly reduces its chances of being realised in its current form. In contrast, all of the projects with a positive benefit-cost ratio received the green light. In any case, a CBA only aims to provide an objective and transparent way to present information on the costs and benefits of a project, without making a political decision on whether or not to realise the project.

5.2 A location specific CBA

Since many effects in a cost-benefit analysis depend heavily on the location which is chosen for analysis, a new CBA has been drawn up for a specific location in the Rotterdam region. The location was selected, not only on the basis of social and environmental criteria, but also on socio-economic criteria. After all, the objective of this CBA is to analyse whether The Sustainable Highway *can* be a socio-economically feasible solution. In order to answer this question, a potentially promising location from a socio-economical perspective has been selected. This location is a 715 metre long section of the A20 highway in the north of Rotterdam, between the Rozenlaan viaduct and the highway exit Crooswijk. Not only do local residents in this location suffer from severe hindrance by the A20, there is also potential room for spatial development resulting in significant financial benefits from building land. By including the development of building land in the project, the problem is reframed as a spatial development problem rather than just an infrastructural problem.

Where the previous analysis took three alternatives as a starting point for comparison to a 'zero'-alternative, this analysis will (partly) consider different alternatives. First, the previous analysis identified a 'normal' highway at ground level as the zero-alternative. However, in the adjustment of the OEI-guideline in 2004, the zero-alternative was explicitly stated to be something different than 'not doing anything' or 'existing policy'. "An OEI's zero-alternative can concern the application of minimal measures to reduce existing bottlenecks" (Koopmans, 2004). A normal highway without any noise reducing measures does not qualify as a zero-alternative under this definition. It is therefore redefined as a normal highway, lined with 10-metre high noise barriers, since noise barriers are common minimal measures to reduce noise nuisance along highways. This zero-alternative will be compared to a highway with 15-metre high noise barriers (the zero+ alternative), The Sustainable Highway, a 'sunken'-highway and a tunnel.

Building land benefits present an important opportunity to earn back some of the concept's substantial investment costs. The way in which these potential benefits can be determined, is subject to different interpretations. In Rotterdam, land prices are determined by the city's land development agency (OBR). In order to remain as close to reality as possible, the same method which is used by OBR is used in this CBA. The method used, functional residual land pricing, takes the function the land will fulfil after it has been developed as a starting point. For instance, the land price in case of apartment construction will be determined as follows: the final selling price of each apartment is determined and multiplied by the number of apartments that will be realised on the chosen plot. This results in the total benefits for the developer. Costs for building the apartments as well as other costs (such as realising parking spaces, making the land suitable for building etc.) are subtracted from this amount, together with the reasonable rate of return for the property. The residual amount that is left is used as the apparent price for the building land. The higher the market price of the real estate, the higher the land price will be. An example of such a residual calculation (performed by OBR) is shown in Annex 1 for the area around the A20 national highway. Since the plots of land which might be suitable for spatial development are all within 200 metres of the highway, only The Sustainable Highway and the tunnel qualify for these benefits. For the other alternatives, building restrictions based on air quality prohibit the construction of apartments within 200 meters of the highway. The benefits which can be derived from marketing building land, together with all other direct and external effects have been combined into an Overview Effects Infrastructure (OEI). The results of this location specific coast-benefit analysis are presented in Table 2.

Table 3, results of the cost-benefit analysis for a section of the A20 ring road in Rotterdam (in millions of euros)

Direct effects		**Zero alternative**	**Zero+ alternative**	**The Sustainable Highway**	**Sunken Highway**	**Tunnel**
Construction costs		-18,6	-29,3	-56,7	-82,4	-135,8
Implementation costs		PM +	PM +	PM+/--	PM --	PM --
Maintenance costs construction		-3,4	-5,3	-7,1	-7,7	-13,6
Maintenance costs road surface		0,0	0,0	4,1	0,0	4,3
Traffic flow effects		0,0	0,0	0,4	0,0	0,4
Renewable energy benefits		0,0	0,0	10,1	0,0	0,0
Building land benefits		0,0	0,0	39,6	0,0	39,6
Urban quality effects		0,0	0,0	0,0	0,0	16,9
Balance of direct effects		**-22,0**	**-34,6**	**-9,6**	**-90,0**	**-88,2**
External effects		**Zero+ alternative**	**Zero+ alternative**	**The Sustainable Highway**	**Sunken Highway**	**Tunnel**
Safety		PM+/--	PM+/--	PM+/--	PM+/--	PM--
Noise		10,1	12,2	20,3	16,2	20,3
Emissions	CO_2	0,0	0,0	0,4	0,0	0,0
	NO_x	0,0	0,0	1,7	0,0	0,0
	PM_{10}	0,0	0,0	6,6	0,0	0,0
Balance external effects		**10,1**	**12,2**	**29,0**	**16,2**	**20,3**
Total		**-11,8**	**-22,4**	**19,4**	**-73,8**	**-67,9**

The results of the CBA show a positive image of the socio-economic effects of The Sustainable Highway. It is the only alternative with a positive ratio and exceeds the other alternatives by far. The effects contributing most to this ratio are the building land benefits and the benefits from the reduction in noise nuisance. Other contributing effects include financial benefits from marketing renewable energy (heat and solar energy) and a reduction in road surface maintenance. In addition, there are socio-economic benefits such as emission reduction and (marginal) traffic flow effects. These socio-economic benefits fully compensate the concept's high investment and maintenance costs. The Sustainable Highway is less costly than a sunken highway or tunnel, but more costly than both types of noise barriers. The second best alternative is the zero-alternative which only gains benefits from the reduction of noise nuisance. This was to be expected, since noise barriers only solve a single issue (noise nuisance) while The Sustainable Highway attempts to solve multiple issues, resulting in multiple benefits. The tunnel alternative shares some of these benefits, however, it is much more costly than The Sustainable Highway (almost 2,5 times as costly), making its investment costs impossible to compensate. Although the BC-ratio of The Sustainable Highway is highly dependent on benefits from building land and noise reduction, the model is robust for changes in the starting assumptions regarding these factors. The effort which is required to obtain these building land benefits is highly location-dependent. Factors regarding the ownership of land and the procedures to follow to obtain the land are part of a highly complex institutional context. Realising these benefits will therefore require substantial effort, should the land not be in the hands of the same party which is realising the concept.

When the previous CBA is compared to the latter, some interesting differences become apparent. The ranking of all alternatives is similar, except for The Sustainable Highway. This can be attributed to the relatively large contribution of building land benefits in this location. These benefits also greatly increase the NPV of a tunnel; however its investment costs are so high that this does not provide sufficient compensation. In locations without any benefits from building land, The Sustainable Highway's net present value will be substantially less. Therefore, The Sustainable Highway is – from a socio-economical perspective – a feasible solution in locations where significant benefits from building land are to be expected.

6. Conclusions

In this paper, research has been conducted on whether The Sustainable Highway can be a realistic alternative to conventional solutions in reducing the negative effects of road traffic. To this end, both the technological feasibility (by means of a second opinion) and the socio-economical feasibility (by means of two cost-benefit analyses) have been analysed.

It was demonstrated that The Sustainable Highway can be a promising alternative to current common practices, such as noise barriers and tunnels. In the application of the concept, a higher noise reduction is expected in relation to noise barriers. In addition, the air quality around the infrastructure will be significantly better than in any of the other alternatives. A prerequisite is that filter technology will provide the intended efficiency in cleaning the polluted air at the entrances of the concept. Whether this is feasible is still uncertain, since the filter's current application is difficult to compare to the situation of The Sustainable Highway. In any case, air pollution alongside the canopy will be reduced to zero. From a technological perspective, The Sustainable Highway appears to be a feasible concept with a sufficiently flexible design to cope with technological uncertainty. The reduction of noise nuisance and air pollution are the concept's most significant advantages, however, the sustainability is further increased by the way in which the concept deals with matters such as generating heat and renewable energy. When local uncertainties are handled in the appropriate way, The Sustainable Highway is a technologically feasible alternative.

From a socio-economical perspective, much depends on the location which is chosen for the concept. Benefits resulting from the development of building land alongside the infrastructure can compensate much of the concept's high investment costs. However, it is uncertain if these benefits can be achieved even though small plots of land can already yield significant benefits. In any case, the concept will provide an opportunity to increase urban quality and realise new inner-city residential property development in a more attractive living environment for local residents. Depending on the location that is chosen, The Sustainable Highway can provide a technologically and socio-economically feasible solution for the negative side effects of road traffic.

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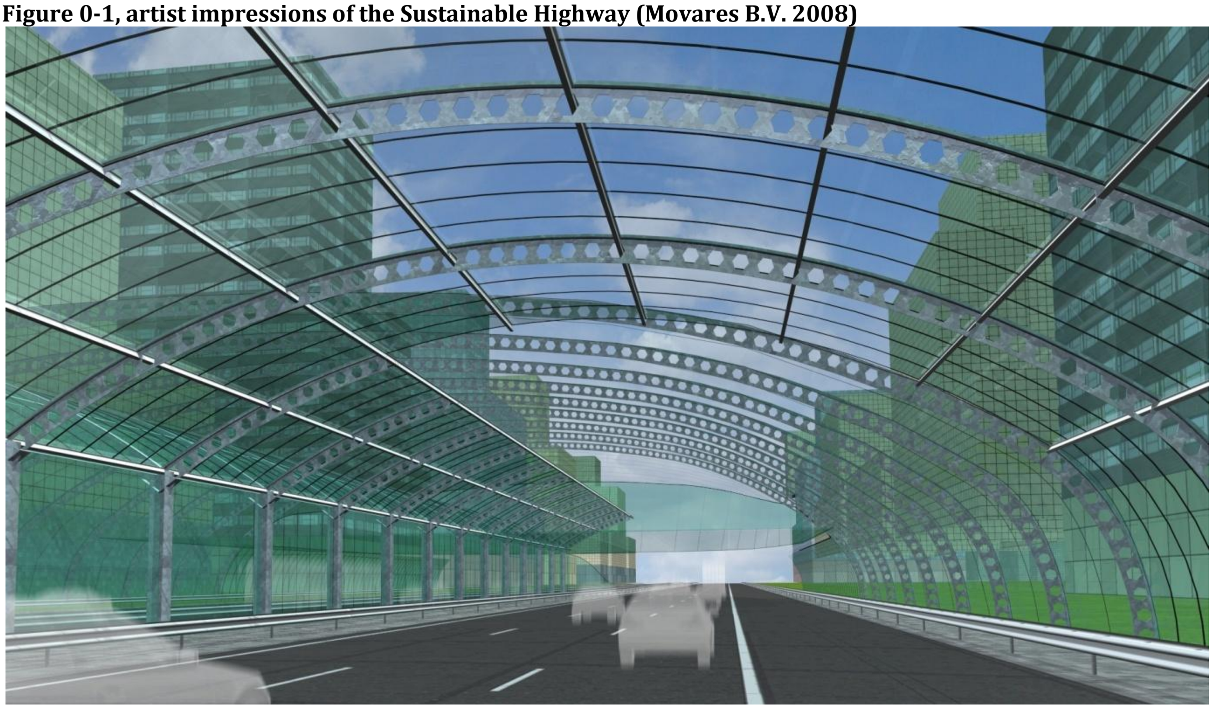
Annex 2, impressions of the Sustainable Highway

Figure 0-1, artist impressions of the Sustainable Highway (Movares B.V. 2008)



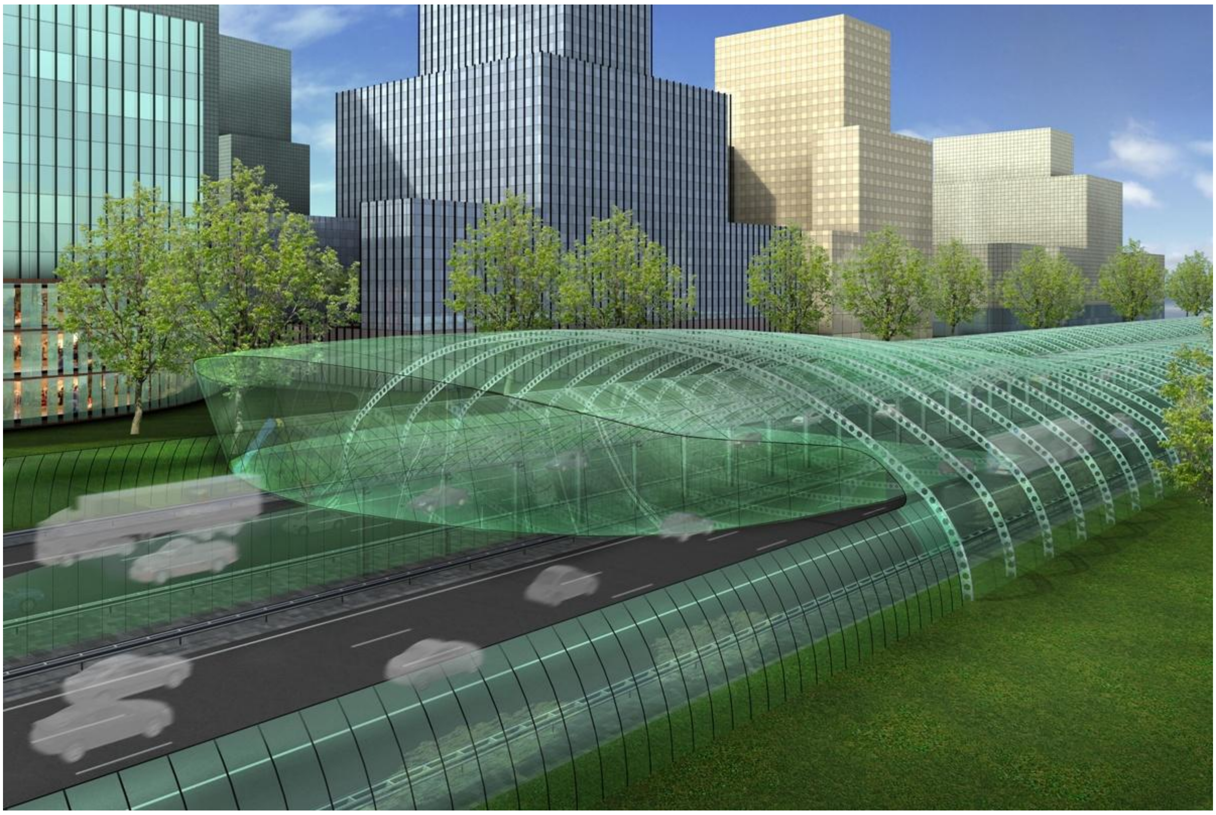


Figure 0-2, Solar panels and freeformglass (Movares B.V. 2008)

Annex 3: computations for CBA

This annex contains the calculations that were executed for the cost-benefits analysis of paragraph 4.2. The calculations are listed in the same order as in paragraph 4.2 and sorted by effect.

Direct effects

Investment costs (expert estimations Movares; Movares B.V., 2007; Decisio BV, 2009; Gemeente Rotterdam Gemeentewerken, 2009)

Zero-alternative

	Length	Height	Unit price (per m2)	Costs (X 1.000.000)
Noise barrier	1430	10	€1.000,0	€14,30
Engineering & Risk			30%	€4,29
Total				€18,59

Zero+-alternative

	Length	Height	Unit price (per m2)	Costs (X 1.000.000)
Noise barrier	1430	15	€1.050,0	€22,52
Engineering & Risk			30%	€6,76
Total				€29,28

The Sustainable Highway

	Length	Width	Unit price	Costs (X 1.000.000)
Foundation	715		€4.000,0	€2,86
Canopy	715	50	€740,0	€26,46
Installations	715		€10.000,0	€7,15
Renewable energy system	715		€10.000,00	€7,15
Engineering & Risk			30%	€13,08
Total				€56,70

Sunken Highway

	Length	Width / Heigth	Unit price (m2 / m1)	Costs (X 1.000.000)
Sunken highway	715	50	€1.500,0	€53,63
Noise barriers	1430	10	€1.000,0	€14,30
Minus Noise barrier foundation	1430		€-2.000,0	€-2,86
Engineering & Risk			30%	€19,52
Total				€84,58

Tunnel

	Length	width	Unit price (m2)	Costs (X 1.000.000)
Tunnel costs	715	50	€2.500,0	€89,38
Tunnel installations			20%	€17,88
Engineering & Risk			30%	€32,18
Total				€139,43

Maintenance costs (expert estimations Movares; Decisio BV, 2009; Gemeente Rotterdam Gemeentewerken, 2009; IPG, 2008)

Zero alternative

	Percentage of construction costs	Construction costs	Costs (euros)
Maintenance costs	1%	€18.590.000	€185.900
Total			€185.900

Zero+ alternative

	Percentage of construction costs	Construction costs	Costs (euros)
Maintenance costs	1%	€29.279.250	€292.793
Total			€292.793

The Sustainable Highway

	Frequency	length (km)	Unit price / construction costs	Costs (euros)
Painting	1	0,715	€100.000	€71.500
Cleaning	2	0,715	€125.000	€178.750
Maintenance on installations	1%		€7.150.000	€71.500
Maintenance on energy system	1%		€7.150.000	€71.500
Total				€393.250

Sunken Highway

	Percentage of construction costs	Construction costs	Costs (euros)
Maintenance costs	0,5%	€84.584.500	€422.923
Total			€422.923

Tunnel

	Length	Unit cost	Costs (euros)
Maintenance costs	715,00	€1.050,00	€750.750
Total			€750.750

Renewable energy (expert estimations Movares; Movares B.V., 2007; Senternovum, 2009)

	Length	M3 / m	MWh / m	Unit price	Benefits
Gas	715	1600		€0,40	€457.600
Electricity	715		1,35	€76,00	€73.359
Total benefits per year					€530.959

Building land benefits (Gemeente Rotterdam Gemeentewerken, 2009; OBR, Annex 4; OBR, 2008; ROM-Rijnmond, 2009)

Estimation of available apartment space

	Building land available (m2)	Max number of apartments (m2)	Floor space per apartment (m2)	Marketable apartment floor space (m2)
Area A	25600	500	120	60000
Area B	22600	441	120	52969
Area C	23300	455	120	54609

Urban quality effects (Decisio, 2009; NVM, 2009)

Affected area

Length (m)	Width (m)	affected surface area (m2)	occupied percentage	Surface per unit (m2)	affected units
715	1000	715000	50%	100	3575

Increased value of property

value per unit	value increase	Total value increase (X 1.000.000)
€189.000,00	2,5%	€16.89

<u>Indirect effects</u>

Noise reduction (DCMR, 2007; Nijland et al., 2002; Nijland, van Kempen, van Wee, & Jabben, 2002; Nijland & van Wee, 2008; NVM, 2009; Howarth, 2001; Wolfert, 2007)

Affected number of units

Length (m)	Width (m)	affected surface area (m2)	occupied percentage	Surface per unit (m2)	affected units	value per unit
715	1000	715000	50%	100	3575	€189.000

Increase in house prices by noise reduction

	Zero alternative	Zero+ alternative	The Sustainable Highway	Sunken Highway	Tunnel
number of units	3575	3575	3575	3575	3575
average unit value	€189.000	€189.000	€189.000	€189.000	189.000
Potential noise reduction (dB)	5	6	10	8	10
NSDI	0,3%	0,3%	0,3%	0,3%	0,3%
Total increase in property value (X 1.000.000)	€10,14	€12,16	€20,27	€16,22	€20,27

Emission reduction (expert estimation Movares; Division Traffic and Shipping (DVS), 2007; Planbureau voor de Leefomgeving (PBL), 2009)

Yearly emissions for 1 km of the A20 by passenger cars

	Passenger cars (car / km)	emission (g/km)	Total daily emissions passenger cars (g)	Total yearly emissions passenger cars (g)
CO2	162830	163	26541290	9687570850
NOx	162830	0,2	32566	11886590
PM10	162830	0,03	4885	1782989

Yearly emissions for 1 km of the A20 by trucks

	Trucks (car / km)	emission (g / km)	Total daily emissions trucks (g)	Total yearly emissions freight transport (g)
CO2	18872	164	3095008	804702080
NOx	18872	3,9	73601	19136208
PM10	18872	0,16	3020	785075

Yearly costs of emissions for 1 km of the A20

	total emissions (g / year)	total emissions (kg)	unit price (per kg)	Costs
CO2	10492272930	10492273	0,057	€599.004
NOx	31022798	31023	15,29	€474.339
PM10	2568064	2568	386,35	€992.171
Total				€2.065.514

Total benefits of direct emission reduction by The Sustainable Highway for the A20 trajectory

	External costs per km	trajectory length (km)	costs of trajectory	Emission reduction by The Sustainable Highway	Benefits of the Sustainable Highway for trajectory
CO2	€ 599.004	0,715	€ 428.288	0%	€ -
NOx	€ 474.339	0,715	€ 339.152	30,0%	€ 101.746
PM10	€ 992.171	0,715	€ 709.403	57,5%	€ 407.906
Total	€ 2.065.514		€ 1.476.842		€ 509.652

Total benefits of indirect emission reduction by The Sustainable Highway for the A20 trajectory

	Shadow-price (per kg)	emissions conventional energy generation (g per kWh /m3)	energy / heat generated by Sustainable Highway((kWh / m3) / year)	Total emitted substance prevented(kg)	Costs saved by renewable energy generation (per year)
Emissions saved by solar energy generation					
CO2	€0,02	644	965250	621621	€12.432
NOx	€7,00	0,206	965250	198,8415	€1.392
emissions saved by heat generation					
CO2 per ton	€0,02	607	1144000	694016	€13.880
				Total	€27.705

Total external benefits of emission reduction by The Sustainable Highway

	Zero alternative	Zero+ alternative	The Sustainable Highway	Sunken Highway	Tunnel
CO2 benefits per year	€-	€-	€0,03	€-	€-
PV CO2	€-	€-	€0,43	€-	€-
NOx benefits per year	€-	€-	€0,10	€-	€-
PV NOx	€-	€-	€1,67	€-	€-
PM10 benefits per year	€-	€-	€0,41	€-	€-
PV PM10	€-	€-	€6,60	€-	€-

Annex 4: functional residual land pricing

Quote of the land development agency Rotterdam (OBR) for a land price for the area near the A20.

Gemeente Rotterdam
Ontwikkelingsbedrijf
Bureau Waardebepaling & Prijzen

Notitie

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Betreft	:	De Duurzame Weg
c.c.	:	Johan van Driel
Datum	:	28 oktober 2009

Vraagstelling

Naar aanleiding van uw e-mail van 16 oktober j.l. inzake de residuele grondprijsberekening van woningbouw bij overkapping van de A20, treft u in onderstaand overzicht een nieuwe berekening aan van de grondprijzen per m² bruto vloeroppervlak.

Aan dit overzicht kunnen geen rechten worden ontleend.

Referenties woningen

Verkoopprijzen
Op basis van referenties die het Ontwikkelingsbedrijf zelf verzamelt, is een selectie gemaakt van referenties uit Rotterdam voor de periode 2005 – 2008.

Uitgangspunten

Voor de woningen is uitgegaan van middeldure appartementen van ca. 100 m^2 gebruiksoppervlak.

Voor de locatie Rotterdam-Noord is uitgegaan van referenties uit de deelgemeente Noord. Hieruit blijkt dat gemiddeld de VON-prijs per m^2 GO het volgende bedraagt:

- VON-prijs (incl. BTW) van € 2.250 per m^2 GO
- VON-prijs (excl. BTW) van € 1.891 per m^2 GO
- VVO/BVO-factor is 70%
- VON-prijs (excl. BTW) van € 1.324 per m^2 BVO
- bouwkosten van € 800 per m^2 BVO
- bijkomende kosten 28%
- bouwkosten incl. bijkomende kosten € 1.024 per m^2 BVO

Dit alles leidt tot een grondprijs van : **€ 300** per m^2 BVO exclusief btw (prijspeil 2009)..

Uitgaande van een parkeernorm van 1 parkeerplaats per woning en een gebouwde parkeeroplossing in de plint van appartementen gebouw zou op de grondopbrengst van een appartement een bedrag van **- € 5.000** per parkeerplaats in mindering moeten worden gebracht. Voor alle duidelijkheid: andere fysieke oplossingen voor het parkeren kunnen tot substantieel andere financiële gevolgen kunnen leiden.

Annex 5: interviews with important stakeholders

Interview A: Dolf de Gruijter, Ministry of Houding, Spatial planning and the Environment

How did you get to know The Sustainable Highway?

- I am a member of the jury of the National sound and vibrations innovation award, an award won by Movares for their concept of The Sustainable Highway in 2007.

In your view, is The Sustainable Highway a technologically feasible concept?

- Yes. I have no doubts about the concept's technological aspects.

In your view, is The Sustainable Highway economically feasible?

- If the concept is broadly executed, when income can be generated from the area surrounding The Sustainable Highway, the concept seems economically feasible. However, it is always a problem when costs and benefits do not come from the same source. When one party has to bear more costs, while another party gains more benefits, the concept loses some of its economical feasibility. This even counts, when the money originates from different sources within the government.

What are the biggest barriers that need to be overcome to realise the concept?

- Many people are very sceptical towards new things. There is always immediately a 'but', without an open attitude towards a concept. This culture is very dominantly present in people that make the decisions on these types of projects. Something new is perceived to be potentially troublesome and immediately encounters resistance. The fine process to realise an innovation is irrational, it is about people becoming enthusiastic about the concept.
- The concept is not only a technological innovation, it will also require an institutional innovation. There are may parties involved over a longer period of time. It will be difficult to organise this.
- It's an integral concept and although this is one of the strengths of the concept, it also causes the concept some problems. When the concept is seen purely as an alternative way to stop noise nuisance it is too expensive. When the concept is purely seen as a way to improve air quality, the same counts. Presently, this is how the concept is generally judged. It should be judged as an integral concept, but this is not standard, so problematic.
- Eventually some decision makers are afraid that it might be of a 'good' solution and serve as a precedent. What if the concept would work? Everyone might want it!

What needs to be done to overcome these barriers?

- When it is possible to get local parties to contribute financially it will become more economically feasible.
- Often realising such a concept is in part determined by coincidences. When the right person with the right connections becomes enthusiastic for the concept and exercises his influence at the right time, that can greatly influence the process. You have to find the right window of opportunity.
- It's difficult to convince someone who does not want an innovative solution that this is the best solution. People should be open minded towards it and maybe even be looking for something new.

Is this concept more difficult to realise than other infrastructural projects?

- Yes, because it is new.

What type of location would be most suitable for the realization of the concept?

- An example of a good location would be: a place with a high environmental burden. Preferably in the picture with the general public and national politicians: a problematic location. A location where land can be developed and a change is needed in the short term.
- A large infrastructural project in which the ministry of VROM is involved from the early planning stages, is a promising situation for The Sustainable Highway. This should for example be a national road where the area around the highway is being newly developed

Who should be involved in the further development of the concept?

- The ministry of VROM seems like a good party to take the lead, but the ministry of V&W is ultimately responsible, also financially. The minister of V&W will have to take the lead. VROM might be more susceptive to integral solutions, but the ministry of V&W always has the lead in infrastructural projects.

Interview B: Wout Goudswaard, The bureau of public works (GWR) of the city of Rotterdam

How did you get to know The Sustainable Highway?

- Pernis has been experiencing hindrance from air pollution and noise by the A4 for years. The Borough council want a solution for this. In the spring of 2008, councillor Harbers for environmental affairs gives the assignment to further investigate the situation. To achieve this, three knowledge-meetings (kennisateliers) are organised by ROM-Rijnmond. A road covered by a glass canopy appears to provide a solution for Pernis. To test the applicability, feasibility, and effects of this concept, the engineering office of the division of public works of the city of Rotterdam (IGWR) is given the assignment to perform a second opinion on the concept. The IGWR has drawn up this second opinion, together with ROM-Rijnmond and the dS+V, and presented the results to the Borough council and the responsible councillors.
- The second opinion was made up out of three parts: Technical concept (construction, technological installations, costs, environmental benefits, safety etc.), comparison of The Sustainable Highway to a tunnel, noise barrier and normal highway and finally the applicability of the concept. The second opinion concluded that the concept is technologically feasible and offers opportunities, however, it requires additional research on several points. These points are, whether the filtration technology (for NOx and PM10) offers the required environmental performance and whether The Sustainable Highway is governed by tunnel law. A pilot project would provide the best insight in how these aspects have been provided for in the concept
- The second opinion has been presented to the councillors. In fact, all parties responded enthusiastically, unfortunately the next day two of the responsible councillors suddenly resigned. Currently, we are working on obtaining the necessary financing for the secondary research projects.

In your view, is The Sustainable Highway a technologically feasible concept?

- Yes, although additional research on the mentioned points is needed., in addition to heat and energy distribution, behaviour of road users and feasibility, in addition to the costs and benefits per location. In a pilot project these points could be further researched. Another point of interest is the way in which the canopy will need to be maintained. Will the canopy get increasingly dirty? And if so, how and how often will it need to be cleaned.
- I have some personal doubts on the glass canopy itself. The double usage of land is not possible in this concept and the canopy will be difficult to implement into an urban environment. The concept (air circulation combined with air filtering) could also be applied in current tunnels by adapting the tunnel entrances. Another possibility is to construct an overground concrete tunnel in which the air can be circulated.

In your view, is The Sustainable Highway economically feasible?

- Economical feasibility is a bigger issue than technological feasibility. When the land surrounding the highway is marketed, the feasibility of the concept is increased due to building land revenues. Property development can deliver additional funds, but can be difficult to obtain in an urban area. However, in some projects cost effectiveness ceases to play a part. Sometimes a problem requires a solution and economical factors are of reduced importance.

In your view, what are the success-factors of the concept?

- The circulation of air is very promising and makes the concept unique. However, this can also be applied to longer current tunnels. Furthermore, the fact that the concept is an integral solution for both air pollution and noise nuisance. In addition, less maintenance to the road surface is needed since it is being protected from all weather influences. This is an interesting additional advantage. Although the harvested heat, cannot be applied in the district heating system in Rotterdam, other applications can be conceived. Outside of Rotterdam, the heat can be used in heating apartments and is therefore a promising part of the concept.

What are the biggest barriers that need to be overcome to realise the concept?

- Money and the development of cleaner cars. Technological doubts are almost irrelevant.

What needs to be done to overcome these barriers?

- By combining forces and where possible conducting research together with other municipalities and institutions will increase the feasibility and applicability. When a pilot has been realised, the concept can be more easily applied on a larger scale.

Is this concept more difficult to realise than other infrastructural projects?

- You encounter the same problems. You can construct this concept by using a modular building process , which makes it possible to minimise the hindrance for road traffic.

What type of location would be most suitable for the realization of the concept?

- The Sustainable Highway is undesirable in a relatively small scale urban area. For the pilot, it is important that a good impression can be obtained of how the concept behaves in practice. A problem in Rotterdam is that it is a very dense urban location. This decreases the space for land development. Pernis appears to large for a pilot project. The highway is too wide in this location. It might be interesting to execute the pilot project in a smaller location.

Who should be involved in the further development of the concept?

- Rijkswaterstaat has an important role. The concept could have a large impact on the plans for placing noise barriers. The Ministry of VROM could be involved more. This ministry also has funds available for innovative projects. The success also depends on an involved local politician.

Interview C: Peter Pol, The bureau of urban development (OBR) of the city of Rotterdam

How did you get to know The Sustainable Highway?

- I was directly approached by Movares. I then helped to get together several parties to discuss the feasibility of the concept in the Rotterdam region. ROM-Rijnmond was also involved at that time and eventually they took the lead.

In your view, is The Sustainable Highway a technologically feasible concept?

- Yes, although we need to make sure that some things are well taken care of. The concept is dependent on the filtering of the air and in practice it still remains to be seen how effective this will be possible. The way in which road users experience The Sustainable Highway is also very important. Solar cells are an interesting part of the concept, however it remains to be seen how the experience of road users will change when solar cells are added to the canopy. The temperature under the canopy needs to be watched and lowered should it get too high. A test or pilot project will clarify these things.

In your view, is The Sustainable Highway economically feasible?

- In principle, yes. The development of the area around The Sustainable highway will increase this feasibility. Unfortunately, because of the economical crisis, property developing is difficult. There already is a surplus of houses on the housing market and this will restrain people to develop new property. The market will have to recover to increase the chances of property development. A different economical situation will increase the feasibility of the concept. In for example Amsterdam or Utrecht the situation on the housing market is better than currently in Rotterdam.

In your view, what are the success-factors of the concept?

- In The Netherlands, we want to increase urban density, but we also want optimal accessibility. This concept can contribute towards the increase of urban density while keeping accessibility intact. The concept also seems like a way to travel through urban areas in a pleasant way, with an open construction instead of a closed tunnel. The city will remain visible for road users. This will increase the exposure of companies alongside the road and will keep the city looking attractive. It will provide the city with a good platform to present itself.

What are the biggest barriers that need to be overcome to realise the concept?

- The biggest barrier is the present culture in The Netherlands surrounding the realization of infrastructure projects. People are afraid of new things and are not looking for new ideas. Concepts should be extensively tested before they will be put to use, while an innovation often is not extensively tested since it is new. People do not want to leave the paths that are well known to them and they would rather compromise on known solutions. You'll experience this very strongly in political decision making.
- Furthermore, the concept is very hard to introduce when the decision making process is already underway. People are afraid of delays. The concept will be more feasible when it will be entered in the decision making process at the beginning.

What needs to be done to overcome these barriers?

- The ministries of VROM and V&W should cooperate more. VROM wants to decrease the effects road traffic has on the environment to a minimum and realise greats solutions. The ministry of V&W is mainly occupied with moderate solutions and attempting to just satisfy legal norms. V&W is purely occupied with the traffic component of infrastructural projects while spatial development can also be a very important aspect of infrastructure. Maybe the two ministries should ultimately be combined to have an integral view of a wide spectrum of interests.
- Another important solution is testing the concept. Somewhere, a pilot project has to be constructed to show that everything works. Maybe it is wise to construct this pilot in a place where only limited economical damage can occur should something happen to the concept.

Is this concept more difficult to realise than other infrastructural projects?

- Realising innovative solutions is always more difficult. People are afraid they might fail. If a pilot project would be realised, this would make a big difference.

What type of location would be most suitable for the realization of the concept?

- The decision making process around the A13-A16 national road has been delayed. A very high land price can be realised there and it is one of the nicest looking pieces of Rotterdam. It would be a very interesting location for The Sustainable Highway.

Who should be involved in the further development of the concept?

- At least both ministries (VROM and V&W), since the concept is most feasible on a national road. A powerful local (municipal) administration who really want to go for the concept and maybe some private parties which are willing to develop some of the area around The Sustainable Highway. These parties should form a long-term coalition.

Interview D: Rinus Huybregts & Jan Morren of DCMR environmental protection agency, part of the Rijnmond area regional authority

In your view, is The Sustainable Highway a technologically feasible concept?

- Yes, Every objection seems to solvable within the concept.

In your view, is The Sustainable Highway economically feasible?

- The economical feasibility is made or broken by the assumptions which are done in the CBA. A tunnel remains a more promising concept, since it truly eliminates any hindrance in a sustainable way en offers more perspective for (future) spatial development than The Sustainable Highway. Perhaps a tunnel will also become economically more interesting if the possibilities to build upon it increase.

In your view, what are the success-factors of the concept?

- The possibility to deal with local bottlenecks in the field of air- and noise-pollution on national highways in urban areas. The concept offers the perspective of a pleasant living environment by improving noise- and air-quality, improvement of external safety, optimally utilising energy and dealing with climate problems.

What are the biggest barriers that need to be overcome to realise the concept?

- The concept remains an end-of-pipe solution. Measures which are applied at the source truly solve the cause of a problem and certain politicians will therefore be difficult to convince of end-of-pipe solutions.
- The spatial implementation of the concept is an important barrier. Many perceive the concept to be a monstrosity. The concept should be mainly seen as an alternative for situations where the spatial quality is already poor. For instance, a situation where a polluting national highway is already close to houses and forms a significant barrier effect.
- Another problem is that parties which are required to invest will not always experience the benefits of the concept.

What needs to be done to overcome these barriers?

- There needs to be support from all stakeholders. These stakeholders are: local residents, road users, landowners, politicians etcetera. Futhermore, it is of great importance that both the environmental/climate side and the economical sight are made transparent. The concept will

need to be drawn up in a business case in detail for a specific location to gain a solid image of all effects.
- Furthermore, it will be important to choose the right time to introduce the concept into the decision making process. To introduce the concept from a people-planet-profit perspective (by Brundtland) will match the frame of reference of politicians, who are (possibly as part of an electoral campaign) focussed on sustainability ambitions.

Is this concept more difficult to realise than other infrastructural projects?
- This strongly depends on local circumstances. In Overschie, where the problems are already significant, the concept is likely to gain more support than locations where the problems are less urgent.

What type of location would be most suitable for the realization of the concept?
- Locations where a national highway causes environmental and health problems and the highway is already a large spatial barrier. For practical, implementation and financial reasons, The Sustainable Highway can perhaps be the best feasible alternative.

Who should be involved in the further development of the concept?
- The most relevant parties remain the Ministry of Transport and Rijkswaterstaat. The Ministry of VROM / regional and local parties can also play an initiating and stimulating role in the realisation of this concept.

Interview E: Twan Beurskens, city councillor for the city of Venlo & Leo Verbart, policy officer for the city of Venlo

In your view, is The Sustainable Highway a technologically feasible concept?
- Certainly in general, however, not all parts of the concept are equally feasible. Marketing heat is difficult when the concept is realised in an area which is already full wit real estate. Existing houses cannot be connected easily, and local residents possibly have no interest in this. If spatial development is possible around the highway the heat can be marketed more easily. Another possibility is to connect large-scale users such as hospitals or large companies to The Sustainable Highway. Furthermore, the cooling of the concept will have to be tested in practice. It is uncertain whether this will work as well in practice as it does in theory.

In your view, is The Sustainable Highway economically feasible?
- When the concept is compared to a tunnel on economical criteria, it is definitely feasible. Compared to a tunnel, the concept is very good. Compared to other alternatives, spatial development can ensure The Sustainable Highway becomes an interesting alternative from an economical perspective.

What are the biggest barriers that need to be overcome to realise the concept?
- A recent barrier is the 'Nationaal Samenwerkingsprogramma Luchtkwaliteit (NSL)' which has just been approved. Air quality is now governed by a different regime, which can have consequences for The Sustainable Highway since now legally, air quality is less of a problem.
- Another barrier is that Rijkswaterstaat still wants to conduct the realisation of infrastructure in the same safe way as 40 years ago, without change and innovation. The way Rijkswaterstaat works is not aimed at renewal. The way they work is not aimed at working in a context either. The context is dynamic and constantly changes, while the way Rijkswaterstaat works is static and does not move with this change.

- Another problem is the fear of delays in constructing infrastructure projects. This decreases the chances for innovative concepts. This fear of delays is understandable.
- Politicians will need to be brave and start an experiment somewhere.

What needs to be done to overcome these barriers?
- You need a heavy ambassador. Someone with great political standing. Someone with the right connections and influence on political and professional level. When someone like that will take the lead in the project, many doors will open.
- Furthermore, the concept should be managed more on process rather than substance. The discussion has been conducted on substance for long enough. Perhaps it is worth the effort to try and find the solution in the political process and less with Rijkswaterstaat.

What type of location would be most suitable for the realisation of the concept?
- It needs to be an area where local politicians have influence in national politics. From a technological perspective, where the concept will be realised is less of an issue, as long as it is somewhere. Perhaps in the form of a small pilot project, but at least we'll know if the concept works in practice.

Who should be involved in the further development of the concept?
- Policy should preferably be made from an integral point of view. The Ministry of Transport emphasises the transport side of the problem too much. The Ministry of VROM should be involved more in mobility policy, since they have more of an integral view of mobility. Perhaps the policy division of the Ministry of Transport should be integrated in the Ministry of VROM. In national politics, something has to change on a strategic level.
- When we look at what is currently needed to realise this concept, that would perhaps be an integral working group with politicians, public workers and technicians should formulate a plan for implementation and the process to facilitate this.

Interview F: Ferdinand van de Oever, city councillor for the city of Dordrecht

How did you get to know The Sustainable Highway?
- When I consulted with Hans Rutten of the Ministry of Agriculture, he brought the concept to my attention for the problems Dordrecht has with the national highway.

In your view, is The Sustainable Highway a technologically feasible concept?
- What I doubt, is whether the concept can avoid the tunnel law. I am not optimistic about that. When the concept is governed by tunnel law, this will seriously hurt its feasibility. I have no additional doubts concerning technology. In the further detailing of the concept surely some technological aspects which will need to be solved will come up. However, these seem solvable and controllable within the concept,

In your view, is The Sustainable Highway economically feasible?
- I think the concept can only be realised with a substantial financial contribution by the national government. The numbers which are used in the CBA are nice theoretical exercises , but in practice very hard to realise. By adding benefits from building land to a CBA, the concept can be calculated to be feasible, however in the current situation, these benefits appear very difficult to obtain To realise these benefits, many high-rise buildings will need to be realised around the highway. There aren't many places in the Netherlands which are attractive enough to realise this. It seems unlikely to me that a property developer willing to invest in such a project will rise in the

current climate. There is a surplus in supply in the housing market and the economical crisis makes investing not very interesting.

In your view, what are the success-factors of the concept?

- The success-factors of the concept can be divided over different phases: when a pilot is realised this will cause an enormous publicitary attraction. Should a pilot be economically feasible, it would be interesting for Dordrecht to have the pilot here.
- Furthermore, spatially, it will be a huge quality improvement. This concept can make cities more visible from the highway. This will demand substantial maintenance and cleaning of the canopy to keep the city visible.
- For several point in the urban area, the concept can provide an enormous improvement in the quality of living environment

What are the biggest barriers that need to be overcome to realise the concept?

- The prioritising of projects by politicians and the financing of the concept are the two most difficult aspects. Local governmental authorities often have other infrastructure projects which they value more than realising The Sustainable Highway. This will make them put less effort in.
- Furthermore, the definition of a tunnel in tunnel law is an important barrier

What needs to be done to overcome these barriers?

- A pilot project should be realised. This would give a much better insight into the project than when it only exists on paper. By constructing a pilot, it will become clear whether technological difficulties are solvable; it also provides more insight into the economical side of the concept. It would be promising for the concept if private parties would be willing to participate (financially).

Is this concept more difficult to realise than other infrastructural projects?

- Yes, I think so. The first priority in the Netherlands is in increasing the capacity of roads and not the quality of the living environment.

What type of location would be most suitable for the realisation of the concept?

- A pilot should be in a place without a large economical and political interest. The experiment should not be on a section of road where it is used as an alternative to a tunnel. That will apply an unbalanced political pressure to the concept. That being considered, the A16 near Dordrecht or Zwijndrecht would be a good location: de road cannot be expanded due to the space which is physically available and a tunnel is not an option. However, local residents do suffer from noise nuisance and a poor quality living environment.
- When the concept has been proven in a pilot, it can be applied in dense urban environments where local residents experience severe hindrance from the highway.

Who should be involved in the further development of the concept?

- Rijkswaterstaat will always be one of the most important parties to realise such a concept. When Rijkswaterstaat does not want to cooperate, the concept will be increasingly difficult to realise. The Ministry of Transport will always ask the opinion of Rijkswaterstaat before a similar concept will be applied. The Ministry of Housing could also play a role, but this is a ministry with a far more limited budget than the Ministry of Transport. The Ministry of Transport and Rijkswaterstaat will therefore have to take the lead.

Interview G: Lex Scholten, city councilor for the city of Diemen

How did you get to know The Sustainable Highway?

- In my position as local politician in charge of transport I was looking for an alternative solution to the negative effects of the highways that pass through our town. On the internet I found The Sustainable Highway and it seemed the most effective way to deal with our problems. I have attempted to realise the concept in Diemen. However, for several reasons I was unsuccessful.

In your view, is The Sustainable Highway a technologically feasible concept?

- Yes. It is not a very complicated concept and most technologies are already in use elsewhere. These types of canopies are already in use in railway stations en currently one is being built behind Amsterdam central station. I don't see any problems from a safety perspective. Cleaning remains difficult, but I think there is enough knowhow to come up with a solution. The same goes for potential damage that can be done to the canopy.
- In addition, I don't think there will be much hindrance to traffic using the highway when the concept is being constructed. Three years ago, when I tried to persuade the government to invest in The Sustainable Highway people were not yet so convinced of the technological feasibility of the concept. However, I think this has progressed over the years.
- Air quality at the canopy ends was a point of doubt en maybe it still is. But the technology has greatly advanced over the last few years. They can now make noise barriers with a special coating, or use electrostatically charged wires. These technologies can also be applied to The Sustainable Highway.

In your view, is The Sustainable Highway economically feasible?

- Yes, in certain circumstances. Sometimes building a tunnel is practically not possible due to the presence of too many buildings close to the highway or because of a limited budget. The Sustainable Highway is a good alternative to these situations. It is much easier to build over an existing highway and costs much less. In densely populated areas with lots of homes built close to the highway a solution needs to be found for noise nuisance and poor air quality. Present sometimes do not offer sufficient dvantages; The Sustainable Highway can be an alternative. It demands a large investment but also had many benefits.

In your view, what are the success-factors of the concept?

- Vital is the huge noise reduction and improvement in air quality. This is the primary goal of such measures and The Sustainable Highway scores extremely high.

What are the biggest barriers that need to be overcome to realise the concept?

- The tunnel law currently limits the applicability of the concept. On and off ramps f the highway are not allowed under the canopy. Since there are many on and off ramps in urban areas and these locations are the most suitable for the concept, this is a problem. The tunnel law will need to be changed to accommodate canopies such as this one.
- In addition, you are the first who attempts to realise the concept. This always makes things more difficult. Furthermore, the biggest barrier is money. Currently, improvement of the quality of life near highways is not specifically stated as a goal in plans for the realization of infrastructure. As a result, no money is available for projects such as The Sustainable Highway. The Sustainable Highway demands a significant investment and this damages the credibility of the concept. People tend to intensify their attacks on the concept as it costs more money. Finally, some architects do not find the concept esthetically attractive.

What needs to be done to overcome these barriers?

- The credibility of the concept is already rapidly improving. If the credibility is increased the investment that is needed will form much less of a barrier.

- When planning an infrastructure project, money will need to be reserved for the implementation of the project in its environment. This will pave the way for concepts such as The Sustainable Highway and they will easier find their way into other infrastructure projects. Improvement of the quality of life should be a goal with the realization of all infrastructure projects.
- The development of the area around The Sustainable Highway can contribute towards the economical feasibility of the concept. When this is possible, the city or town can also contribute financially to the project. However, this development is not always possible, since the problems with noise nuisance and air quality are the biggest in densely populated areas. In these areas, there is often no room to develop property.
- A possibility to bypass tunnel law is to only allow a maximum speed of 70 km/h. Then the tunnel law does not apply.
- Architects could take a look at the esthetic aspects of The Sustainable Highway.

Is this concept more difficult to realise than other infrastructural projects?

- It is more expensive and an it is innovation. So, yes.

What type of location would be most suitable for the realization of the concept?

- A densely populated area where local inhabitants experience a lot of problems with air quality and noise nuisance.

Who should be involved in the further development of the concept?

- The Ministry of Transport puts all emphasis on the traffic and capacity aspects of infrastructure. This is quite logical. Usually, this ministry also controls the budget for infrastructural projects which means that by far the biggest part of the budget is allocated to measures to increase capacity. Maybe the ministry of Spatial development and the environment can take a bigger part in these processes. They will have a broader perspective and are likely to be more susceptible to concept such as The Sustainable Highway.
- Members of the lower house could also play their part in pushing the issue in parliament. This might persuade the minister to look at the concept.

Interview H: Joris Wijnhoven, policy officer attached to the GroenLinks fraction of the lower chamber

How did you get to know The Sustainable Highway?

- Through the article in the newspaper “NRC”

In your view, is The Sustainable Highway economically feasible?

- The Sustainable highway is not that expensive when you compare it to the construction of a tunnel. Or to the entire budget of the ministry of transport. Still, getting the money together will be a problem because people are less inclined to spend money on things that they are not 100% obliged to do according to the law.

In your view, what are the success-factors of the concept?

- The possibility to expand roads while still keeping the problems for local residents to a minimum.

What are the biggest barriers that need to be overcome to realise the concept?

- Money.

What needs to be done to overcome these barriers?

- The financial benefits should be made clear. A location should be found where money can be made from developing property and where traffic causes big problems for local inhabitants.
- Another thing is coincidences. If a politician is originally from an area where there are lots of problems with noise nuisance and air quality, he or she will be more inclined to support the concept. A strong local lobby can help in realising the concept.

Is this concept more difficult to realise than other infrastructural projects?

- That its an innovation does play a part

What type of location would be most suitable for the realization of the concept?

- A location where local residents suffer greatly from the problems of road traffic and where land benefits can be obtained.

Who should be involved in the further development of the concept?

- Parties that want to develop land in urban areas could be involved. These parties might contribute financially towards the realisation of the concept. The ministry of VROM would be a good partner, however they will also be quite restrained. When VROM will be too active in stating they want this concept realised, they will be forced to pay part of the costs. Their budget is much smaller than that of the ministry of transport.

How do you see your own role in this process?

- GroenLinks might bring this subject up in the next debate on the Ministry of Transport's budget. We might try to find a majority for a motion.

Interview I: Mark Harbers, former city councillor for the city of Rotterdam, currently a member of the lower chamber for the VVD fraction.

How did you get to know The Sustainable Highway?

- The concept was presented to me in several different ways. In the first place, I followed the publicity in the media on this idea. And as is often the case in politics, shortly after, members of the city council asked me to propose Rotterdam as the location, if a pilot project would be realised.
- At the same time, as a representative of the college of mayor and councillors, I was involved in talks with the borough council of Pernis, to attempt to solve some long lasting issues the area has with environmental concerns (in the middle of the harbour area, close to the A4 Benelux-tunnel). In that period the borough council was concerned about the additional traffic the second Maasvlakte would cause, and wanted a solution for the problem with air quality.
- In that discussion, around the end of 2007, the start of 2008, we agreed to make a broad exploration of all the environmental problems around Pernis and to organise a number of workshops with experts of the DCMR in which also the feasibility of "new solutions" such as The Sustainable Highway would be involved.

In your view, is The Sustainable Highway a technologically feasible concept?

- In principle it seems technologically feasible to me, doubts exist on whether it conforms to all safety demands. I suspect the tunnel will ultimately be considered to be a tunnel, which means that you have to comply with all the demands for tunnel safety. That is something we've had some bad experiences with over the past few years (for instance the Roer- and Swalmtunnels on the A73). When the concept will have to comply with all these demands, the costs will increase.

- Furthermore, I doubt the affectivity of the cleaning of the air at the tunnel entrances. This is already a problem, solving this with chimneys does not eliminate the problem which means a costly investment in filtering installations is needed.

In your view, is The Sustainable Highway economically feasible?

- I have severe doubts about this. It seems to me the costs for the canopy are substantial (and significantly higher than noise- or air-barriers) and the costs for making the concept comply to all tunnel safety demands need to be added to this. Because of this, I think the concept only qualifies for busy sections of highway in dense urban areas, where the environmental profit is optimal, but the investment costs can also be earned back by building on land close to the highway (which was previously impossible). However, the question is, whether this is sufficient compensation.
- Another point is that it is difficult to convert an existing highway to The Sustainable Highway, while the road remains open for traffic (as opposed to noise barriers, where the road can remain open).

In your view, what are the success-factors of the concept?

- A solution for multiple environmental problems: air quality, noise, climate problem, shortage of building land in urban areas.

What are the biggest barriers that need to be overcome to realize the concept?

- Arrange financing
- On the basis of a conclusive business case
- You actually need a whole new section of road to construct (a part of) it as The Sustainable Highway. That means you have to focus on building projects which are now (in the beginning of) the planning phase. That allows you to perfect the design and construct the concept while no traffic is passing underneath.

What needs to be done to overcome these barriers?

- Mainly gather political-governmental support, which means take away all possible questions and worries that politicians and (mainly) government workers may have. Their concern will mainly be in three subjects: time (to realise a project) / money (will it remain within budget) / technology (are there no unexpected problems). On these three point the concept will need to be water tight.

Is this concept more difficult to realize than other infrastructural projects?

- Yes, for the reason that it is a new technology, which consists of proven parts, but as a whole is new. That makes politicians wary to connect their reputation to it.

What type of location would be most suitable for the realization of the concept?

- A new section of road in a dense urban area (as previously described).

Who should be involved in the further development of the concept?

- Rijkswaterstaat for the concept itself. If Rijkswaterstaat does not believe in it, it will not get through. Next, select a (pilot)location and then it is a matter of mobilising local governmental authorities. But their role will quickly be to be very positive. Since it solves environmental problems in their local area.
- Next it is very important that builders will step forward who want to realise the concept for an acceptable price. The builders can improve the concept by them being prepared to take some of the risks of construction (meaning giving guarantees on price so not all setbacks and risks are the responsibility of the government).

Annex 6, aggregated information from stakeholder interviews

Technological uncertainties	No. of times mentioned
Temperature under canopy	3
Filter technology	3
Road user perception	2
Cleaning	2
Implementation in urban environment	2
Distribution of heat	2
Tunnel law	2

Conditions for economic feasibility	No. of times mentioned
Benefits from private sources	6
A tunnel is not possible	5
Assumptions from CBA are correct	2
State willing to make a substantial contribution	1
Road must stay open	1

Success-factors	No. of times mentioned
Integral solution for noise and emissions	9
Investment costs compared to tunnel	3
Ability to increase urban density / quality	3
Visibility of the city from the road	2
Pleasant road use	1
Less maintenance on road surface	1
Air circulation	1
Publicitary value	1

Barriers	No. of times mentioned
Scepticism towards innovation / new things	5
Investment costs	5
Fear of delays	3
Spatial implementation	3
Costs from a different source than benefits	3
Benefits from building land are difficult to realise	3
End-of-Pipe solution	2
Tunnel law	2
Fear of a precedent	1
Institutional innovation needed	1
Policy problems of an integral solution	1
Priorities of local politicians	1
Improvement of local quality of life no national objective	1
Difficult to find the right moment of introduction	1

Solutions	No. of times mentioned
Build a pilot project	5
Financial contribution by local parties	3
Local champion	3
Window of opportunity	3
Business case	2
Attention for the political process	2

Characteristics of a suitable location are:	**No. of times mentioned**
A high environmental burden	7
Land development is possible	3
Small scale	3
In the picture / a known problem location	2
Highway forms a barrier	2
A new highway	2
Local politicians have national influence	2
No big political / economical interests	2
National highway	2
Ministry of VROM is involved in decision making procedure	1
The A13 / A16 traverse	1
Not used as alternative for a tunnel	1

Annex 7: actor analysis

To draw up an overview of all actors which can be involved in the realisation of The Sustainable Highway five questions need to be answered:

- *Which actors are actively involved in the problem?*
- *Which actors have the authority to play a part in the creation or solving of the problem situation?*
- *Which actors have other resources that are of importance to the problem?*
- *Of Which actors can be expected that they would like to be involved at any time?*
- *Which actors will not participate actively, but are affected by the problem or the solution?*

Actors that are already actively involved in the problem tend to include themselves in discussions relating to the problem. It is therefore the most obvious type of actors to include in the analysis. Actors belonging to this group are for instance private parties such as Movares and public parties such as Rijkswaterstaat and certain municipal authorities. In addition to this there are some actors which are not yet actively involved in the problem, but who do have the authority to be a part of the problem or a solution to the problem. These actors involve both actors which have stayed deliberately inactive but also actors who are yet unfamiliar with the problem. These actors include parties such as the Ministry of Transport, Public Works and Water Management and the Ministry of Housing, Spatial Planning and the Environment and political parties. Besides parties with the authority, there are also parties with different resources such as money or knowledge which can be vital to the problem. Parties that hold and can provide vital information can be for instance universities or research institutes and for parties which can contribute financially different private parties could be suggested. Finally there are actors which would like to be involved such as interest groups and parties that are affected by the problem such as unorganised local residents.

The list of actors, which was identified in the analysis of the institutional context (Chapter 5) will need to be further detailed for the chosen location (the A20 in Rotterdam). This will be done separately for each category of actors that was identified. When the actors for the chosen region are specified, their interests, objectives and perceptions can be analysed.

<u>Governmental authorities:</u>

The governmental authorities need to be further specified for the Rotterdam region. The city of Rotterdam is part of the province of South Holland and of the urban region of Rotterdam. Furthermore, national infrastructure in the region is being constructed and maintained by Rijkswaterstaat South Holland. Within the city of Rotterdam, the following municipal division exist:

- **College of Mayor and Councillors:** the daily government of the city of Rotterdam
- **City council:** elected representatives verifying all policy
- **GWR:** responsible for all public works in Rotterdam
- **OBR:** responsible for spatial development in Rotterdam
- **dS+V:** supports living, building and traffic policy in Rotterdam
- **DCMR:** environmental agency of the Rijnmond area of which Rotterdam is a part
- **Rotterdam Climate initiative: a**iming to reduce CO_2 emissions in the Rijnmond area
- **Borough councils:** local government at sub-city level

By asking the following questions, the positions of actors can be further detailed:

- *Interests: Why is the problem situation of importance to an actor? How are actors affected by the problem and why do they care?*

- *Objectives: What does and actor want to achieve when it comes to the problem situation? Which specific costs and benefits are associated with the problem situation or the proposed solutions for a certain actor?*
- *Perceptions: What is the perception of an actor of the problem situation?*
- *Perceptions: What are the main causes of the problem according to an actor?*
- *Perceptions: What possible solutions do they distinguish with regard to the problem situation and its causes?*

With the answers to these questions a table can be compiled which summarises each actor’s interests, objectives and problem perception. This table can be used to identify where perceptions of actors differ and where they are similar. It may also be used to identify possible proponents of the same solution as the problem owner and similarly to identify opponents.

From each category of actors the most important organisations have been analysed in more detail. The interpretation on their perceptions is based on their official websites, but also on statements done by individuals from these organisations in the interviews from Annex 5 Statements on their own, as well as on other, organisations have been used to gain a complete image of stakeholders positions. Where no clearly stated problem perceptions were available, stakeholder positions are interpretations on information that was available.

Of the actors from the governmental organisations, the Ministry of Transport, The Ministry of Housing, provincial authorities of South Holland, Rijkswaterstaat and the Urban region of Rotterdam will be discussed in detail first.

In the next table, the local authorities will be discussed in more detail. The local authorities that will be discussed are: College of Mayor and Councillors, City Council, GWR, OBR, dS+V, DCMR and the Rotterdam Climate Initiative

Actors	Interests	Desired situation / objectives	Existing or expected situation and gap	Causes	Possible solutions
The ministry of Transport, Public Works & Water Management (V&W)[8]	Ensuring people in the Netherlands can move around smoothly and safely. In doing so contributing to a dynamic and sustainable society.	To improve accessibility by expanding infrastructure, while keeping to legal norms that safeguard public health from the negative effects of increased mobility.	Expansion of infrastructure is not always possible due to effects on the environment and public health. Large amounts of (public) money are invested to implement infrastructure into its environment.	Road traffic emits too much noise and damaging substances.	Shield noise from the environment by conventional methods; Stimulating the reduction of emissions at the source.
The Ministry of Housing, Spatial Planning & The Environment (VROM)[9]	Keeping the environment that we live, work, and recreate in liveable for current and future generations.	To improve local living quality and environmental conditions while developing urban areas spatially without compromising mobility.	Local residents around highways experience severe noise hindrance and poor air quality. To protect these local residents spatial development around these highways is often prohibited. Funds to reduce these problems often have to be invested by the Ministry of V&W.	Road traffic emits too much noise and substances damaging local health and reducing living quality of local residents.	All solutions that improve local living and environmental quality are welcome. Integral solutions that include spatial development are of specific interest.
The Ministry of Economic Affairs[10]	Strive to achieve a prosperous, sustainable and enterprising Netherlands as part of an open global economy.	Make the Netherlands one of the most attractive knowledge economies for innovative development and facilitate the increased use of renewable energy	Innovation in infrastructure is lacking. Only incremental innovations are adopted, while radical innovations are not implemented. The use of renewable energy increases, but not fast enough.	Parties lack sufficient incentive to adopt innovations and use and produce only renewable energy	Provide subsidies for the use and generation of renewable energy. Invest in the knowledge economy
Provincial authorities of South-Holland[11]	Ensuring optimal accessibility of the province and a good balance with safety and environmental quality.	Decrease congestion, improve environmental and living quality while keeping the province safe and accessible	Currently, roads in the province are congested daily, air is not always clean and residents experience noise hindrance	Insufficient capacity of roads causes congestion, while the increased mobility causes more noise hindrance and poorer air quality	Cooperate with municipalities to increase air quality, expand provincial roads to decrease congestion and decrease noise hindrance bottlenecks
Rijkswaterstaat South Holland[12]	Rijkswaterstaat South Holland is responsible for stewardship, maintenance and construction of national	Increase accessibility of South-Holland by increasing the quick and safe flow of traffic.	Rijkswaterstaat has much experience in the construction of conventional infrastructural solutions that reduce the negative	Increased mobility causes increased emissions of noise and damaging substances. Measures need to be taken to	Noise barriers, tunnels, silent asphalt and source measures are all possible conventional solutions.

[8] Information retrieved from the ministry of V&W's official website: http://www.minv&w.nl (consulted on 04-12-2009) and interviews (Annex 5)
[9] Information retrieved from the ministry of VROM's official website: http://www.minvrom.nl (consulted on 04-12-2009) and interviews (Annex 5)
[10] Information retrieved from the ministry of Economic Affairs' official website: http://www.minez.nl (consulted on 24-12-2009)
[11] Information retrieved from the province of South-Hollands official website: http://www.zuid-holland.nl (consulted on 04-12-2009)
[12] Information retrieved from Rijkswaterstaat's official website: http://www.rijkswaterstaat.nl (consulted on 04-12-2009) and interviews (Annex 5)

	infrastructure in the province of South-Holland.		effects of road traffic. Constructing new, expensive, unproven solutions will delay construction, decrease the budget and cause unknown safety situations	comply to legal norms.	
Urban Region Rotterdam (SRR)[13]	A well accessible region with a strong competitive position and an attractive living and settlement climate.	To achieve results that cities cannot achieve on their own in traffic & transport, spatial development and the environment	Mobility and accessibility are of vital interest to the region, however these cannot be achieved at the expense of quality of life.	Accessibility is one of the preconditions for economic success of the region, however places a heavy burden on air quality	All solutions that improve accessibility and quality of life can be supported by the Urban Region of Rotterdam

Local actors	Interests	Desired situation / objectives	Existing or expected situation and gap	Causes	Possible solutions
College of Mayor and Councillors[14]	Make pleasant living in a world city possible; increasing welfare with as most important precondition that environmental quality does not decrease	Create a sustainable balance between economic development, accessibility and an attractive living environment. Create a smart, clean and quiet traffic and transport network	Traffic on the Rotterdam ring road is expected to increase. This already causes unacceptable nuisance for the citizens for which no easy solution is available. Urban density around polluting infrastructure cannot be increased.	The second Maasvlakte will cause additional freight traffic while the Rijnmond area is already one of the most polluted areas in the Netherlands	The A13 / A16 traverse will reduce traffic on the A13 and A20 but is difficult to implement. Tunnels can provide a solution but are very expensive. The Sustainable Highway might be an alternative solution.
GWR[15]	Shaping Rotterdam and keeping it in shape by constructing and maintaining al public provisions in Rotterdam and directing major infrastructural projects in the region	Create and maintain high quality public provisions.	Successfully implementing infrastructure in Rotterdam is difficult. Laws and regulations on environmental quality require complex and expensive infrastructural solutions. Rotterdam is a very dense urban environment requiring the efficient use of all land available.	The demand for mobility is large in the Rotterdam area and only expected to increase with the construction of the second Maasvlakte.	Tunnels provide a good way of implementing infrastructure into its environment. However, they do not improve air quality, are expensive and time consuming to construct. The Sustainable Highway might be an alternative solution.
OBR[16]	Connecting economy and spatial development in Rotterdam.	Help shape the economic future of Rotterdam by facilitating, influencing and participating in spatial development.	Spatial development is limited in a dense urban. Areas in prime development locations are currently not being used to their fullest extent.	The negative external effects of road traffic limit possibilities for spatial development.	Measures that shield infrastructure from the environment make spatial development of previously restricted areas possible.
dS+V[17]	To help shape Rotterdam's	Translate socio-political	The living environment of	The negative external effects	All sorts of plans and

13 Information retrieved from the Urban Region Rotterdam's official website: http://www.stadsregio.info (consulted on 10-12-2009)

14 Information retrieved from the city of Rotterdam's official website: http://www.rotterdam.nl (consulted on 10-12-2009)

15 Information retrieved from GWR's official website: http://gw.rotterdam.nl (consulted on 10-12-2009) and interviews (Annex 5)

16 Information retrieved from OBR's official website: http://obr.rotterdam.nl (consulted on 10-12-2009) and interviews (Annex 5)

	building, living and traffic policy.	wishes into projects that contribute towards a pleasant living and working environment in Rotterdam	Rotterdam's citizens is heavily affected by the negative effects of road traffic. For several bottlenecks solutions need to be found which are not always easily available.	of road traffic limit the quality of the living environment in Rotterdam	projects that increase living quality in Rotterdam
DCMR[18]	As the environmental agency for the Rijnmond area DCMR contributes to the decrease of the environmental burden for companies and the increase of the environmental quality and safety in the area.	To advise on- and monitor the environmental quality in the Rijnmond area. To help develop environmental policy.	DCMR measures air quality loads in the Rijnmond area. Around infrastructure, this air quality often exceeds European norms and regulations. The current air quality potentially forms a serious barrier for the regional development of real estate and infrastructure.	The Rijnmond area is a highly populated areas and experiences a more intense flow of traffic than other areas of The Netherlands.	Advise on and participate in projects that increase environmental quality in the broadest sense.
Rotterdam Climate Initiative[19]	Realising a better climate for people, the environment and the economy	Reduce CO_2 emissions in the Rotterdam area by 50% in relation to their 1990 levels, prepare for climate change and reinforce the Rotterdam economy.	Road traffic is responsible for a large part of the CO_2 emissions in Rotterdam. These emissions need to be decreased.	The Rijnmond area is a highly populated areas and experiences a more intense flow of traffic than other areas of The Netherlands in addition to much heavy industry	Solutions that greatly reduce the emission of CO_2
ROM-Rijmond[20]	Facilitate the strengthening of economic structure of the mainport Rotterdam and increase the quality of life and living in the Rotterdam region	Accelerate promising processes which increase the quality of living in the Rotterdam region	Currently, local residents in Rotterdam experience severe hindrance from road traffic. For the situation near Pernis ROM-Rijnmond attempts to facilitate the finding of a solution for that community's problems.	Nuisance from road, industry and shipping is only expected to increase for Pernis due to the second Maasvlakte	The Sustainable Highway could present a solution to Pernis' problems

[17] Information retrieved from dS+V's official website: http://dsv.rotterdam.nl (consulted on 10-12-2009) and interviews (Annex 5)

[18] Information retrieved from DCMR's official website: http://dcmr.nl (consulted on 10-12-2009) and interviews (Annex 5)

[19] Information retrieved from the Rotterdam Climate Initiative's official website: http://www.rotterdamclimateinitiative.nl (consulted on 10-12-2009)

[20] Information retrieved from Rom-Rijnmond's official website: http://rom-rijnmond.nl (consulted on 24-12-2009)

Private parties

This section contains a detailed analysis of some of the private parties that can be involved in the realisation of The Sustainable Highway in the area. The following private parties are identified for the Rotterdam area:

- Movares
- Building contractors
- Property developers
- Energy companies (Nuon, Essent, Eon, Eneco)
- Energy distributor Stedin
- Housing corporations
- Suppliers of components
- Universities
- Research institutes (TNO, CPB, RIVM, PBL)

Since this section if more applied to groups of private parties which can be involved in the solution rather than be affected by the problem the analysis is more applied to what part these parties could play in the realisation of The Sustainable Highway. The most important private parties are discussed in the following table:

Actors	Interests	Desired situation / objectives	Existing or expected situation and gap	Causes	Possible solutions
Building contractors (infrastructure)	Guarantee continuity of business, increase turnover and profit	Acquire assignments to construct infrastructure projects which help guarantee continuity, increase turnover and profit	The construction of new infrastructure requires (both incremental and radical) innovation. Building contractors will be eager to participate in new projects if this will seem like a good business idea and corresponds to their interests and objectives	Innovation is a vital part of staying ahead of the competition.	Building contractors might be interested to participate in the construction of The Sustainable Highway is such an assignment is available.
Property developers	Guarantee continuity of business, increase turnover and profit	Develop and market real estate to guarantee continuity, increase turnover and profit	There is a surplus on the housing market in Rotterdam. Property developers will exercise extreme caution when (or if) participating in the development of new property.	The economic crises has caused housing prices to drop and demand to fall.	Although the housing market is currently slow, property developers will always look for interesting investment opportunities.
Energy companies	Guarantee continuity of business, increase turnover and profit, ensure a stable supply of energy.	Generate and purchase energy to increase market share, guarantee continuity and increase profit.	The market for renewable energy is growing and is expected to grow over the coming years. Energy companies will be looking to invest in opportunities that increase the stability of supply and increase profit.	High oil prices, unstable supply of conventional energy and an increased governmental emphasis on green energy.	Investing in the generation of renewable energy. The Sustainable Highway might be an interesting opportunity

Interest groups and non-organised actors

In the final detailed analysis of the actors involved the interest groups and non-organised actors are discussed. These are not further detailed for the Rotterdam area, since no specific parties from these categories have yet expressed an opinion on The Sustainable Highway. However, they can play an important part when they do take up a position. The most notable change from the table of Chapter 5 is that the political parties are split into parties Pro and Contra to express to possible views that could be taken in politics.

Actors	Interests	Desired situation / objectives	Existing or expected situation and gap	Causes	Possible solutions
Political parties Pro	Representation of their respective voters and re-election	Increase accessibility of The Netherlands while reducing / eliminating the negative consequences of road traffic	Residents surrounding infrastructure experience severe hindrance from local highways. Public health and quality of life is damaged. Current measures to reduce these consequences do not offer sufficient possibilities to reduce these consequences	Road traffic increases and damaging substances are emitted.	No expansion of the road network, expansion with mitigating measures, tunnels, The Sustainable Highway, various policy measures.
Political parties Contra	Representation of their respective voters and re-election	Increase accessibility of The Netherlands while reducing / eliminating the negative consequences of road traffic	Residents surrounding infrastructure experience severe hindrance from local highways. Public health and quality of life is damaged. Current measures offer sufficient possibilities to reduce these consequences	Road traffic increases and damaging substances are emitted.	Expansion of the road network by using noise barriers, sunken highways and tunnels, various policy measures
Residents' organisations	A pleasant living environment	Reduce or eliminate noise hindrance, poor air quality and the barrier effect caused by local infrastructure	Hindrance from nearby infrastructure will increase causing more damage to the living environment and residents' health	The increase in road traffic caused by increased mobility and the second Maasvlakte.	Shield the living environment from the negative effects of road traffic. Although The Sustainable Highway does not decrease the barrier effect, it might be perceived as a positive solution.
Road users	A safe, quick and pleasant driving environment	Reduce congestion, increase safety and keep the road a pleasant place to drive	Congestion on the Dutch road network causes severe delays. Traffic accidents frequently occur. Building tunnels decreases road safety and the pleasant perception of the environment	More traffic and too little investment in infrastructure	Highway expansion, possibly with mitigating measures for the environment. The Sustainable Highway will be an attractive solution if this makes road expansion possible and does not affect safety and the quality of the perception of road use.

The following table summarises all actors important for the Rotterdam area:

Category	Actor
Governmental authorities	The lower chamber
	Ministries of: Transport, Public Works and Water Management; Housing, Spatial Planning and the Environment;
	Rijkswaterstaat South Holland
	Province of South Holland
	Urban region Rotterdam (SRR)
	Municipal authorities (College of Mayor and Councillors, city council, GWR, OBR, DCMR, dS+V)
	Borough councils (Rotterdam Noord, Hillegersberg-Schiebroek)
	Rotterdam Climate Initiative
	Commission for tunnel safety
Private parties	Movares B.V.
	Building contractors (infrastructure)
	Property developers
	Energy companies (Nuon, Essent, Eon, Eneco)
	Energy distributor Stedin
	Housing corporations
	Suppliers of components
	Universities
	Research institutes (TNO, CPB, RIVM, PBL)
Interest groups	Environmental groups
	Residents’ organisations
	Road users’ organisations (ANWB, TLN)
	Political parties
Non-organised actors	Road users
	Local residents
	Energy consumers

Critical actors

The list of actors can now be expanded to determine the respective actor's instruments and the problem owner's dependency on these instruments.

Actor	Instruments	Degree of replaceability	Dependency	Critical actor?
The lower chamber	Authority to make decisions / access to other actors	Limited	High	Yes
Ministry of Transport	Authority to make decisions / knowledge / money	Limited	High	Yes
Ministry of Housing	Authority to make decisions / knowledge / money	Limited	High	Yes
Rijkswaterstaat South Holland	Knowledge / access to other actors	Limited	High	Yes
Province of South Holland	Authority to make decisions / money / access to other actors	Medium	Medium	No
Urban region Rotterdam (SRR)	Authority to make decisions / money / access to other actors	Medium	Medium	No
College of Mayor and Councillors / city council	Authority to make decisions / money / access to other actors	Limited	High	Yes
Municipal divisions (GWR / OBR / dS+V)	Knowledge / man power / access to other actors	Limited	High	Yes
DCMR	Authority to make decisions / knowledge	Limited	Low	No
Borough councils	Access to other actors	Large	Low	No
Rotterdam Climate Initiative	Access to other actors / money	Large	Low	No
Commission for tunnel safety	Authority to make decisions	Limited	High	Yes
Movares B.V.	Problem owner			
Building contractors (infrastructure)	Ability to bear risks in the project / knowledge	Medium	Medium	Yes
Property developers	Ability to bear risks in the project / money / knowledge	Medium	Medium	Yes
Energy companies	Ability to bear risks in the project / money / knowledge	Medium	Medium	Yes
Energy distributor Stedin	Knowledge	Limited	Low	No
Housing corporations	Money	Large	Low	No
Suppliers of components	Knowledge	Large	Low	No
Universities	Knowledge	Large	Low	No
Research institutes	Knowledge	Large	Low	No
Environmental groups	Access to other actors / organisation power	Large	Low	No
Residents' organisations	Access to other actors / organisation power	Large	Low	No
Road users' organisations	Access to other actors / organisation power	Large	Low	No
Political parties	Access to other actors / organisation power	Large	High	Yes
Road users	Organisation power	Large	Low	No
Local residents	Organisation power	Large	Low	No
Energy consumers	Money	Large	Low	No

Dedication of actors

The final step in the actor analysis is to determine the dedication of the actors to either the solution, the problem or a different solution. The actor's dedication is shown in the following table:

Category	Actor	Dedicated?
Governmental authorities	The lower chamber	Yes
	Ministries of: Transport, Public Works and Water Management; Housing, Spatial Planning and the Environment;	Yes
	Rijkswaterstaat South Holland	Yes
	Province of South Holland	Yes
	Urban region Rotterdam (SRR)	Yes
	Municipal authorities (College of Mayor and Councillors, city council, GWR, OBR, DCMR, dS+V)	Yes
	Borough councils (Rotterdam Noord, Hillegersberg-Schiebroek)	Yes
	Rotterdam Climate Initiative	Yes
	Commission for tunnel safety	Yes
Private parties	Movares B.V.	
	Building contractors (infrastructure)	No
	Property developers	No
	Energy companies (Nuon, Essent, Eon, Eneco)	No
	Energy distributor Stedin	No
	Housing corporations	No
	Suppliers of components	No
	Universities	No
	Research institutes (TNO, CPB, RIVM, PBL)	No
Interest groups	Environmental groups	Yes
	Residents' organisations	Yes
	Road users' organisations (ANWB, TLN)	No
	Political parties	Yes
Non-organised actors	Road users	No
	Local residents	Yes
	Energy consumers	No