Tools for Evaluating the Decision to Ban Diesel Cars in Stockholm

Sara Jawad
Bergros Arna
Richard Budianto
Bilal Siddique
Mahmood Shah
Jwalith Desu

Supervisor: Miguel Mendonca Reis Brandao

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Abstract

The air quality in Stockholm is a growing issue due to pollution caused by some cars. The Swedish Government has decided to implement a new policy, allowing municipalities to ban diesel cars in specific zones. One of the zones where diesel cars may be banned is central Stockholm. This report discusses and evaluates different tools for environmental system analysis and their effectiveness for evaluating the decision to ban diesel cars in Stockholm, given the following criteria: costs, air quality and social aspects.

The results showed that SEA, CBA, ERA and TCA are all relevant tools for assessing the decision, but that SEA would fit best for the evaluation of the policy, as it can assess the different criteria we have put up for the decision, by taking into account environmental, social and economic aspects of the proposed policy.

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1 Introduction

1.1 Background

The air quality in Stockholm is a growing issue due to pollution caused by some cars. Diesel cars are especially problematic as they release nitrogen oxides, which are poisonous for humans. Moreover, they also release carbon dioxide and contribute to global warming. The nitrogen oxide emissions are more problematic in populated cities, such as Stockholm, and therefore, the Swedish Government has decided to implement a new policy, allowing municipalities to ban diesel cars in specific zones. One of the zones where diesel cars may be banned is central Stockholm. Before such a decision is taken, the environmental impacts of it must be evaluated, in order to determine whether the policy will result in the desired effects, as well as determining potential costs.

1.2 Aim

There are various tools that can be used to evaluate an environmental decision. The aim of this report is to discuss and evaluate different tools for environmental system analysis and their effectiveness for evaluating the decision to ban diesel cars in Stockholm. The results will show which tools are relevant for this specific case and which are not, by defining a criterion.

2 Analysis of the Decision

The Swedish Government has taken the decision to allow diesel cars to be banned in central Stockholm. In this chapter, the decision is analyzed using the Sexton method (Sexton et al., 1999).

Societal level

The societal level of the environmental decision that will be implemented may be based on municipality level, but the impacts on climate change will affect the whole world.

Substantial domain

The problem area of the decision of banning diesel cars in central cities is both related to air quality control and the effects on human health. The spatial extent of the problem are socially constructed scales for the most part but could also be related to natural system scales as air pollution. From the perspective of temporal factors, the decision is easily reversible, and it can have immediate and long-term effects.

Social aspects

The key decision-makers in this decision are the Minister for Infrastructure and the Minister for the Environment, as representatives of the Government. Participants in the decision procedure include Government members. The decision is considered to be urgent, as air pollution is getting progressively worse, and firstly affects municipalities, as the decision gives them the right to decide upon zones where certain cars may be banned. Thereafter, other stakeholders, such as individual citizens, transport businesses, and car companies are affected by the decision.

Type of decision

The decision on banning of diesel cars involved many factors to be considered. Thus, in our opinion, it was a complex and analytics-based decision involving ripple effects which had to be anticipated well before it could start creating any undesired effect.

The reasons for the problem

The problem of pollution and various other chain effects of pollution have forced us on to investigate this matter seriously. Vehicular pollution being one of the considerable contributors of the air pollution in the cities. The following points listed are the reasons for some actions have to be taken:

1) Diesel vehicles are high polluting because of its technology
2) Bad air quality in the city centers
3) Adverse effects on ecology and health of all organisms in the system
4) Targets of reducing the GHG emissions.
5) Dependency on fossils fuels.

The criteria

The criteria for the evaluation of the environmental decision are costs, air pollution and social aspects. When limiting one way of transportation people tend to compensate by other available transportation. In our case, we choose to compare the alternatives of the use of electric and biodiesel vehicles and see if our decision will have positive or negative effects on air quality when looking at the whole picture. The direct costs should also be compared, both on the public stakeholders and the government.

3 Tools for Environmental System Analysis

In this chapter, various tools that may be used for environmental system analysis are described, from a general perspective.

3.1 Strategic Environmental Analysis

Strategic Environmental Assessment (SEA) is an evaluation of possible environmental impacts from a policy, plan or a program and comparison of different alternatives. SEA also compares the proposed policy to the "no act" alternative, which is the alternative where the proposed policy is not implied. The evaluation should be reported and made early in the process of decision making. Both direct and indirect impacts are evaluated (Runhaar et al., 2007). SEA can also provide mitigation measures for the possible impacts, which can help in the follow up on the policy, plan or the program.

The information needed are various. The scale and purpose of the SEA must be clearly defined in the beginning of the process, all stakeholders have to be listed down and what their interests and stakes are, and baseline information need to be collected (European Union, 2017; Runhaar et al., 2007). All kinds of data can be useful in the process, it all depends on the scope. Public participation is necessary and required by law and that can bring important thoughts and knowledge into the evaluation (European Union, 2017).

The disadvantages of SEA can be several. For example, uncertainties can be quite high and there is not always an agreement on what is "right" or "wrong". Lack of data or knowledge is also another factor. There can be general disagreements between stakeholders and different aspects on the list of factors to be evaluated (Runhaar et al., 2007).

3.2 Environmental Impact Assessment

Environmental Impact Assessment (EIA) is similar to SEA but on the project level. EIA is an evaluation of possible environmental impacts from a proposed project and a comparison of alternatives. Just like in SEA, the "no act" alternative must be included in EIA and public involvement is also necessary. The same information requirements and disadvantages given in the SEA description can also be listed in terms of EIA.

3.3 Environmental Input-Output Analysis

Environmental input-output analysis (Env. IOA) is a form of macroeconomic analysis based on interdependencies between industries and how this impacts the final demand for labour and capital within an economy (Wrisberg et al., 2002). The analysis makes distinction based on two factors: the goods and services sold to the final demand, and the total output of different sectors.

Env. IOA is an extension of traditional input-output analysis where additional conditions are included to ensure consistency in production, pollution generation and abatement activities among industries. The analysis can be divided into three main models:

1. Generalized Input-Output Models: are constructed by adding rows and columns for pollution generation and abatement activities to the coefficient matrix.
2. Economic-Ecological Models: extends the generalized IO model by including flows from ecosystem sectors.
3. Commodity-by-industry Models: takes environmental factors as commodities in the input-output table.

3.4 Environmental Risk Assessment

Environmental Risk Assessment (ERA) is the examination of risk resulting from technology that threatens ecosystems, animals and people. An approach to estimate the risks related to substances, processes and technology is either quantitative or qualitative. Risk assessments can be done in two ways namely, effects on human health (health risk assessment) and ecosystems (ecological risk assessment). Apart from this, differences in toxicological endpoints, spatial and temporal scales, complexity of exposure and several other parameters can be identified, explaining that variability in exposure and effects assessments is crucial for ecological risk assessment, necessitating an extreme use of simplifications of reality, via models. Risk characterization is carried out for a product or technology to estimate the incidence and severity of the adverse effects on human and environment due to exposure of the fuel. Based on which a risk estimate is calculated to quantify the effect (Wrisberg et al., 2002). However, there is always a possibility of excluding some parameters, which could mislead the performer or the reader to interpret the results. Thus, it should always be kept in mind, by the performer or the reader, what the outcome is and how it should be handled in each case.

The complete risk assessment of the desired product or technology can be assessed by the following steps:

a) Hazard identification: which helps studying the relationship between different levels of exposure and the incidence and severity of the effects, may be toxicological or eco-toxicological.

b) Effects assessment: which determines the indicators such as PNEC or PNEL i.e. Predicted-No-Effect Concentration or Level for effects defined by hazard identification.

c) Exposure assessment: is determined by measurement or assessed – including description of nature and size of exposed targets, as well as magnitude and duration of exposure.

3.5 Life Cycle Costing

Life cycle costing (LCC) analyzes all real money flows associated with the life cycle of a product, process or activity (Gluch et al., 2000; Wrisberg et al., 2002). LCC also takes into account the external costs. These monetary values can be on emissions, the resources needed, on the environment and on human health and therefore this information needs to be available (Wrisberg et al., 2002). LCC does not include the costs of future generations and can be oversimplifying problems by assessing only the monetary aspect of them (Gluch et al., 2000).

3.6 Life Cycle Analysis

Life cycle analysis (LCA) is commonly used to assess the environmental consequences of a service or a product. It follows cradle to grave approach and analyze all the process and stages involved in the manufacturing of a product in order to evaluate the impact on environment. It helps to identify a specific process or stage, among the whole process, that can be optimized to increase efficiency and to reduce environmental impact (Wrisberg et al., 2002).

There are huge variations in LCA approaches subjected to difference in scope, availability of resources and data, and variations in environmental conditions. However, the most important thing about LCA is its comprehensive analysis that encompasses all the processes of supply chain and offer comparisons between different options to fulfill a particular function.

The first stage of LCA assessment studies is setting scope and goal. This is the question around which LCA study should be conducted to find appropriate answers. While setting the boundaries of scope, availability of desired data and impact assessment must be kept in mind. It should be ensured that boundaries are clear as it will help to collect accurate data about material flows in and out of boundaries. The second stage is modeling the various processes, like input and output, and efficiency of a process. This is followed by building life cycle inventory, which includes all resources utilized and emissions resulting from all the processes involved to supply the given function. Once life cycle inventory is completed, impact assessment of emissions and resources used is done in form of impact indicators. The last stage is interpretation of results (Wrisberg et al., 2002).

LCA is comprehensive and avoids shifting of problem form one stage of life cycle to another. LCA is standardized internationally by ISO. However, LCA being comprehensive, makes it complex and a lot of data is required and hence, sometimes such data may not be available. Another limitation in LCA is that it does not consider rebound and societal impacts.

3.7 Cost Benefit Analysis

Cost benefit analysis (CBA) is used to make a social evaluation of a proposed policy or investment that affect the environment by putting an economic value on environmental impacts (Kuosmanena et al., 2007). CBA can also be defined as a societal LCC which takes into account monetarised externalities, from an environmental, economic and social aspect. When used by governments in their decision-making process, social benefits and costs are considered in the analysis, rather than private benefits and costs (Brent, 2006). In order to conduct a social CBA, all tangible and intangible, direct and indirect costs and benefits should be considered. Boundaries surrounding the decision must be defined, stakeholders must be identified in order to map out all parties and factors impacted, and time needs to be delimited. Thereafter, the indirect and direct costs and benefits can be monetized and discounted for present value. The advantage of using CBA is that it can guide a decision-maker as to whether a given project should be subsidised or restricted, based on its impact on society as a whole (Brent, 2006). The difficulties with CBA are that it can be quite challenging to measure intangible and indirect costs and benefits, such as the impact on the quality of life or happiness. Putting a value on these things can also be controversial and carry uncertainties (Brent, 2006).

3.8 Total Cost Accounting

Total cost accounting (TCA) is a dynamic subset of LCC and it includes all the long-term internal costs and savings resulting from pollution prevention or other environmental measures taken by an entity. It includes all the hidden costs. The distinct features of TCA are, comprehensive costs and saving inventories, precise allocation of costs, long horizons to account for long term costs and savings, and accounting for time value of money (Wrisberg et al. 2002).

It requires, in addition to direct and Indirect costs, the contingent costs for potential liabilities and other less quantifiable costs like damage to corporate image. In short, TCA goes beyond conventional analyses and includes long term costs and savings to give a complete picture. TCA put focus on monetary values and hence, leaves out the societal impact and process or resource efficiencies. TCA, however, has the ability to reduce uncertainties associated with probabilistic costs by doing a sensitivity analysis.

3.9 Material Input per Unit of Service

Material input per unit of service (MIPS) is used to analyses the basic environmental impact for certain activities. It has been created as a measure for material flow in terms of order of magnitude related to environmental impact potential. MIPS tool can be used to compute eco-efficiency of a product or service and can be applied from a scale of single product to a complex system.

It takes into account the Material Input (MI) and the Service Unit (SI). MI involves all man-moved materials that are required in a life cycle of a product or service. The total MI of the analyzed product during the life cycle consists of material used indirectly or directly. The second component is Service Unit (SI), considers the function or utility of a product to satisfy human needs (Wrisberg et al., 2002).

There is another tool called as Resource-Efficiency Accounting (REA), which is based on MIPS concept. It has two main objectives, which are to reveal the hidden cost of environment and to explore potential for cost reduction related to environment.

3.10 Material Flow Accounting

Unlike MIPS, that only considers the material input, material flow accounting (MFA) considers both input and output of material. It can be divided into two approaches: bulk material flow analysis (b-MFA) which takes into account the flow of a bulk material, and substance flow analysis (SFA) which considers the flow of single substances with specific environmental effects (Wrisberg et al., 2002).

MFA may follow cradle-to-grave approach, it studies from extraction of the resources until the final disposal. The advantage of MFA is that it may encourage government or companies to look beyond their area and detect the unexpected side effect. MFA can be used to identify important stocks and flows, it can also spot trends and development at an early stage and provide early warning for future environmental issues.

SFA model can be used to evaluate the source of pollution and consequence of a certain inflows. It also can be used to assess future trends. This model has been used mainly to support government, it can identify and calculate effectiveness of some measures.

4 Discussion and Evaluation of Tools

In this chapter, the application of different tools for analyzing the decision to ban diesel cars in Stockholm are discussed and evaluated.

4.1 Strategic Environmental Assessment

As explained in chapter 3, SEA is a Strategic Environmental Assessment of possible environmental impacts from a policy, plan or a program. Therefore, SEA is suitable for evaluating the policy of banning diesel cars in central cities. The criteria for the evaluation are the aspects of direct costs, climate change and the compensated transport with either electric or biodiesel vehicles, SEA could compare those different alternatives. It also compares the alternatives to the baseline ("no act" alternative) and that can be one way of evaluating the need for a decision like that.

CBA could be used within the SEA to see if the benefits exceed the costs of the different alternatives. For example, will the benefits of less need for healthcare exceed the costs that are needed to switch over to other transportations? It can also compare the emissions from the different alternatives, for example with some kind of life cycle assessment for the different types of vehicles. The boundaries play a big role here, where it can be tricky to decide what to take into consideration. For example, the production of new cars that happens outside of Sweden or only the direct emissions from the use of these cars in the Swedish cities.

SEA looks at all the stakeholders, who in this case are the government, the municipalities and the public residents, and evaluates the effects of the policy on them. There could be several conflicts between stakeholders, such as between the owners of diesel cars and the ones who walk in the city centers and could be affected by the pollution. Policies affect a lot of people, and SEA can play an important role in informing and providing information to those affected. It can help in keeping decisions un bias and in making decision making a process that is not taken by random people in closed rooms, rather a process where every aspect should be taken into consideration.

4.2 Total Cost Accounting

Since TCA is used to account for long-term internal costs and savings for a pollution prevention measure, it could be a suitable choice for our case to evaluate the cost associated with the transition towards non-diesel vehicles. TCA is commonly used to assess the attractiveness of a pollution prevention investment by considering all long-term internal costs and savings. In our case, the possible internal cost could be the cost of a new product like EVs or biofuel-powered vehicles, charging stations in case of EVs, R&D cost to drive down the manufacturing cost of alternate product and possible incentives, in the form of tax reductions or subsidies, to manufacturers to bring the new technology in the market. The possible cost savings could be fewer health facilities due to reduced health issues, new employment opportunities and less dependence on imports of fossil fuels.

Next step in TCA is cost allocations, in this stage a precise picture of material flow in, out and through the system in the form of a mass balance is required. However, since the diesel cars and their alternative a well-researched, such allocations should be easy or not too difficult as compared to the first stage. Time horizon of analysis is another important parameter and since we are dealing with improving air quality, more time is required for the results to surface. The policy measures, like subsidies or tax incentives, at government level should start before the ban on vehicles in order to prepare the market for the transition. These measures should continue even after the ban is implemented to ensure no market failures. Hence, the time horizon for the TCA studies could be a decade.

The implications of using TCA in our case could be difficulty in assessing the benefits of improved air quality in monetary terms. Improved air quality could have a lot of benefits and some of these benefits are quite obvious, like fewer health issues related to breathing or lungs, while some could be less obvious and hence very hard to evaluate in term of monetary values, like improved air quality of city might attract more tourists. Such implications in assessing the benefits could lead to a negative conclusion of TCA study.

Another implication that makes TCA study very complicated is the number of different alternatives that could replace diesel cars and that list is quite long, like electric vehicles, biofuel, hydrogen/fuel cell vehicles, natural gas-powered vehicles, and even gasoline cars. The TCA study could be simplified by further looking into what alternative technology government wants to replace the diesel cars by assessing some important indicators like it is logical for the Swedish government to use EVs instead of Hydrogen powered vehicles as EV industry is easy to promote in Sweden.

It is important to mention here that a very comprehensive TCA study of internal costs and savings does not necessarily yield attractive results in terms of investment decision (White, 1993). Hence, care should be taken to make a final decision based on findings of TCA study alone.

4.3 Environmental Risk Assessment

A part of analyzing the decision-situation is to determine the effect of other alternatives to diesel on the environment and their effect on improving the air quality of Stockholm. Here, the alternatives considered for diesel are electric vehicles and biofuels. These would be assessed based on the criteria based on climate change effects and human health. Since the boundary here is assumed to be Stockholm, the assessment beyond this would not be considered. But for a more realistic assessment, we suggest the assessment beyond the boundary considered here. Environmental Risk assessment is broadly done in two different approaches, namely, Human Risk Assessment (HRA) and Ecological Risk Assessment (EcoRA). Since the decision-situation affects both climate change and human health, we may proceed with both EcoRA and HRA. As mentioned earlier in chapter 3, this tool analyses the effect of the technology with three steps and their subsequent indicators.

Decision of banning diesel has given rise to many alternatives like electric and biofuel vehicles. This tool needs information on by-products of such a fuel or technology and its effects on the ecology and human health. The size of such a technology in the system, also gives a fair idea on the level of exposure. There are various mathematical equations and models used for such an assessment.

4.4 Life Cycle Costing

Since LCC analyses only money flows related to the life cycle of a product, process or activity, LCC itself is not suitable for our case. However, LCC could be used along with other tools, for example in SEA or CBA when comparing costs and benefits of different alternatives.

4.5 Life Cycle Analysis

As LCA is a complicated and comprehensive assessment tool which requires a lot of data and it is primarily suited for the assessment of a product life cycle with an aim to improve certain processes and make them eco-friendly by increasing the resource efficiency. Hence, it is not suitable for our case and it will be more efficient to use some other tools to evaluate the environmental impact of alternatives to diesel cars, rather than LCA.

4.6 Cost Benefit Analysis

CBA can be used to analyze the impact on society of a proposed policy and therefore the decision to put forth a policy to ban diesel cars for improved air quality can be evaluated with CBA. Since CBA provides information regarding the impact of the policy on society, it is a useful tool in this case as it can help to determine to what extent the improved air quality as a result from banning diesel cars impacts society. For a policy to be considered necessary, the benefits that arise as a result of it must outweigh the costs. This approach is different to SEA, where the benefits are instead compared to the result of taking no action. Hence, both the benefits and the costs of banning diesel cars must be considered. Generally, societal CBA should be based on the principles of economic welfare when determining costs and benefits. To do this, stakeholders must first be identified. In our case, potential stakeholders are individuals living in the areas where diesel cars are to be banned, owners of diesel cars, companies that produce or sell diesel cars, car-service and taxi companies, public transport companies that operate in areas where diesel cars are to be banned, and possibly many more depending on where the system boundary of the analysis is drawn. Thereafter, information from for example an LCC analysis can be used to identify the costs associated with the different stakeholders at different stages.

Although the tool in itself is useful for this case, uncertainties and limitations may occur when the decision-makers decide upon the costs and benefits. This is because the analysis requires a system boundary, a limited time perspective and the valuation of intangible costs and benefits. For the decision to ban diesel cars to improve air quality, a measurement of the improved health and quality of life for those affected by the policy must be made. This can be made partly by calculating the decreased need for healthcare as a result of healthier air leading to healthier individuals, but also partly by evaluating the increased sense of well-being amongst these individuals and this is where difficulties in the analysis may arise. Putting a value on an individual's and society's sense of well-being, or happiness, is not as accurate as calculating the decreased cost in healthcare because the value is intangible and depends upon a system of ethics, which may vary from person to person and therefore also cause some controversy. However, these should be determined based on the basic principles of economic welfare.

4.7 Environmental Impact Assessment

EIA is not suitable for the decision of banning diesel cars. As mentioned in chapter 3, the EIA process involves the evaluation of an implementation of a project, and that is not the case.

4.8 Environmental Input-Output Analysis

Since Env. IOA is primarily a method for evaluating the relationship between economic activities of industries and environmental impacts, it is not applicable to our specific problem because of the lack of electric and biofuel car manufacturers within the Stockholm region. Analyzing the pollution generation and abatement activities will require expanding our boundaries from Stockholm to other cities of Sweden. On the other hand, one could argue that the banning of diesel cars can lead to an increase in the number of electric vehicles and consequently higher electricity demand, which could lead to higher emissions in Stockholm due to power generation from fossil fuels. If this were the case, then EIO's generalized input-output model could be applied to analyze the environmental impacts of the generation industry. However, in the context of Stockholm this is highly unlikely.

4.9 Material Input per Unit of Service

Since the MIPS tool considers the material input of a system, it is favorable for an industrial type of problem. However, it does not suit very well for our case, since the boundary inside Stockholm has been set and there is no industry related to battery production or any other substitute for diesel engines that can be analyzed inside the city of Stockholm. Unless there will be any similar industry inside the city in the future, this tool cannot be used to analyze our decision- situation.

4.10 Material Flow Accounting

Since MFA takes into account material inflow and outflow, it is more appropriate for industrial type of problems. Similar to MIPS, this tool is only applicable if an industry that impacts the environment is built inside the city of Stockholm as a direct result of the banning of diesel cars, for example building an electric car production industry in Stockholm in order to replace diesel cars with electric cars. If this is to happen, the SFA model would be a better tool compared to the bMFA, since it is better in assessing the origins of pollution.

5 Results

Table 1 summarises the final decision regarding the relevance of each assessment tool for our case. Certain tools are rejected based on their complete irrelevance to our case like MIPS or MFA, while other tools are rejected based on the fact that they are already taken into account by another tool, like SEA takes LCC into account and therefore, LCC alone is irrelevant to our case.

Assessment Tools	Relevance	Reasons
Strategic Environmental Analysis (SEA)	Relevant	Assessment of possible environmental impacts from a policy, plan or a program.
Environmental Impact Assessment (EIA)	Not Relevant	EIA involves the evaluation of an implementation of a project, and that is not the case
Environmental Input-Output Analysis (env.IOA)	Not Relevant	Since it is for evaluating the interindustry economic activities and environmental impacts, it is not applicable within the boundaries of Stockholm.
Environmental Risk Assessment (ERA)	Relevant	Determine the effect of other alternatives to diesel on the environment and its effect on improving the air quality of Stockholm.
Life cycle costing (LCC)	Partly Relevant	LCC analyses only money flows related to the life cycle. However, it could be used as a part of SEA/CBA.
Life Cycle Assessment (LCA)	Partly Relevant	Complicated and comprehensive assessment tool which requires a lot of data and it is primarily suited for the assessment of a product life cycle.
Cost Benefit Analysis (CBA)	Relevant	Analyse the impact on society of a proposed policy.
Total Cost Accounting (TCA)	Relevant	Accounting for long-term internal costs and savings for a pollution prevention measure.
Material input per unit of service (MIPS)	Not Relevant	This tool consider the material input of a system, this tool is favourable for industrial type of problem. However, it does not suit very well for our case
Material flow Accounting (MFA/SFA/EFA)	Not Relevant	Similar to MIPS

***Table 1**: the relevance of assessment tools for the decision to ban diesel cars in Stockholm.*

6 Conclusion

Our conclusion is that Strategic Environmental Assessment (SEA) would fit best for evaluation of the policy to ban diesel cars in Stockholm. We think it is a good tool to assess the different criteria we have put up for the decision, taking into account environmental, social and economic aspects of the proposed policy.

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Name	Contribution
Bilal	Studied and Analyzed TCA and LCA for our decision. Contributed in final report writing and presentation.
Bergrós	Contributed in forming the decision and writing the final report, together with the presentation. Studied and analyzed SEA, LCC and EIA.
Jwalith	Evaluated ERA and Ecological Footprint tools for this decision, same on writing report and presentation. Also with setting in the direction for boundaries and criterias.
Sara	Evaluated CBA in the report and presentation. Wrote the abstract and introduction to the report. Helped to form the decision criteria and wrote about the decision situation. Fixed the format + references in the report.
Mahmood	Evaluated environmental IOA for our decision along with MIPS, MFA for presentation. Contributed in forming decision criterion and writing final report.
Richard	Evaluated MIPS and MFA tools in the report. Contributed in the introduction during the presentation.