# Understanding the Dutch municipal air quality policy process and the role of models therein: a case study of Eindhoven

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by

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# Dedication

*This thesis is dedicated to Oma Sloot. I miss you.*

# Preface

This work was written as a thesis for the MSc Engineering and Policy Analysis at the Faculty of Technology, Policy and Management of Delft University of Technology. It was completed during an internship with the Dutch research organisation TNO.

From the former, I would like to sincerely thank professor van Daalen, who was incredibly patient and considerate throughout this process. Balancing multiple course loads at once was tougher on me than I expected, but your guidance helped me through it many times. I would like to also thank professor Lieu, whose input on developing especially the methods for this research was very welcome.

From the latter, I would like to extend my thanks to I. Super. If not for the meetings in which you pushed me to start writing, I might still have all of these pages stuck in my head. A plane ride filled with writing here and there was invaluable. The same goes for R. Dröge, your help in getting me in touch with the right people was incredibly important to the progress I made, and I really appreciate it.

I would like to also extend my thanks to my whole family, who were incredibly supportive throughout, as well as Madison and Morris, for their proofreading skills as well as their feedback which was always of the highest quality.

Finally, I would like to extend my sincerest thanks to Bo, for your support, wit and feedback. Whether it is from across the world or right next to me, I am always grateful for your input.

Onto the next thesis!

*M. van Dalsum*
*Delft, April 2023*

# Executive Summary

Ensuring the air we breathe is clean and healthy is one of the core tenets of developing a more sustainable living environment, but even in the Netherlands up to 11,000 premature deaths occur every year (RIVM, 2021). These deaths could be prevented once the air quality standards outlined by the World Health Organization are achieved (World Health Organization, 2016). To achieve these standards however, significant changes have to be achieved in Dutch society. Reducing air pollution is an intensive and difficult process, due to its associated characteristics. Firstly, there is a very wide range of activities that cause the emissions which contribute to air pollution. Among others, traffic, energy generation, industry, agriculture (livestock farming) and wood burning are some of the biggest sources in the Netherlands (Denissen, 2022). Secondly, air quality is an interconnected problem, due to the atmospheric nature of it (European Environment Agency, 2016). This means that emission and deposition often occur at different places, sometimes even different countries, requiring comprehensive and cooperative approaches to combatting it.

In the Netherlands currently, air quality is regulated at all four of the major levels of government, that is the supranational, national, provincial and local (municipal) level. At the national level, air quality standards are established (based on standards agreed upon in the European Union, the supranational level), which need to be met across the country. Regulations on the permitting, monitoring and enforcement of general emissions are also coordinated on a national level. The permitting standards for industry are the jurisdiction of the province, which coordinates with the municipalities within it. These municipalities' biggest responsibility concerns the spatial development within their boundaries, and the traffic on its roads. Monitoring and ensuring that the air quality standards are reached within their jurisdiction is one of their key tasks.

The monitoring of air quality standards in the Netherlands occurs through two separate but connected pathways. The most obvious and straightforward pathway is the direct measurement of air quality at select sites throughout the country by the RIVM (the national health institute). The RIVM is also chiefly responsible for the development of the second pathway, namely the modelling (or calculation) of air quality. Modelling is done by all government levels for their respective jurisdictions, which is all coordinated through the Nationaal Samenwerkingsprogramma Luchtkwaliteit (NSL). Under this program, municipalities report the air quality in their areas yearly, based on calculations from the modelling tools. In addition, they also report their policy measures and the associated effects through these tools.

Even with all of the above however, air quality still causes a significant health impact, signalling the need for more ambitious air quality policy. To achieve this however, clearly there is a need to improve the government processes and framework that lead to the current situations.

For our research, we investigated the air quality policy process at the municipal level, which until now has been relatively neglected when compared to the national and supranational level. We focused on the municipality of Eindhoven, which is working hard to improve the air quality within its borders.

To summarize all of the above then, the problem at hand is as follows.

**There is a lack of understanding on which improvements could be applied to the municipal air quality policy process, and what possible contributions improved modelling tools could make.**

The goal of this thesis was thus to develop an understanding of the municipal air quality policy process in our case study of the municipality of Eindhoven, including the role of air quality models in it. Based on this, we could then determine where these models can be improved, and how that could aid the municipality. Furthermore, we could also investigate what larger developments are needed to improve the air quality policy process.

The adopted research question based on this problem statement and societal relevance is then as follows.

***What potential improvements in the Dutch municipal air quality policy process can be made, and what role can models play in this?***

To answer this question, we have split it up into four parts. Firstly, we investigated the structure of the municipal air quality policy process and which parties are involved in it. Subsequently, we determined which models are used in this process and by whom. Based on this, we could evaluate how improvements in modelling tools might be applied to this process. Finally, we could then hypothesize how we might improve this process more generally, including the improvements from better modelling tools.

To arrive at these answers, a combination of research methods were adopted. Firstly, the research was of an exploratory nature, which means that we attempted to create a conceptual framework of the municipal air quality policy and then hypothesize how it might be improved. The research was performed in a specific case study of the municipality of Eindhoven, the results of which we attempted to generalise to other municipalities. To achieve this, a combination of qualitative methods were adopted to obtain the necessary information and data.

The methods that were used for determining the structure of the municipal air quality policy process and the models used therein were a combination of grey literature (government documents and websites) and semi-structured interviews with experts from relevant organisations. These include policy makers involved with both decision making and modelling from the municipality, as well as from the two advisory organisations. These are the GGD Brabant Zuidoost (the regional health service) and the Omgevingsdienst Zuidoost Brabant (the regional environmental service), experts from both of which were interviewed. In addition, interviews were held with the RIVM, the research institute TNO and the DCMR (the environmental service for the Rijnmond region) and the municipality of Utrecht.

To determine the improvements that modelling tools could be used, a literature review was performed on developments in scientific literature. This was combined with a group interview with modelling experts with expertise in areas like emissions, atmospheric modelling and large-eddy simulations.

Investigating the more general improvements to municipal air quality policy process was done through reviewing literature on multi-level governance, as well as the aforementioned interviews.

Finally, to generalise our findings, we drew on the aforementioned interviews with a policy advisor from the municipality of Utrecht and a modelling expert from the environmental service for the region Rijnmond.

With all of the information from the methods discussed above, we arrive at the following results for the research question.

Firstly, we recognized that the structure of the municipal air quality policy process can be represented by five core phases, as presented in Figure 1. These are the policy initiation phase, where new policy gaps and problem areas are identified. The policy measures and solutions are then worked on in detail in the policy development phase, where alternative policy options are explored. The selection of the final policy option is then made in the decision making phase, where the political decision makers decide on the option that aligns most closely with their approach and that of their constituencies. The policy is then implemented in detail in the second to last phase, policy implementation, after which its effects are monitored in the final stage, policy evaluation, which can then be fed back into the first phase and the process starts anew.

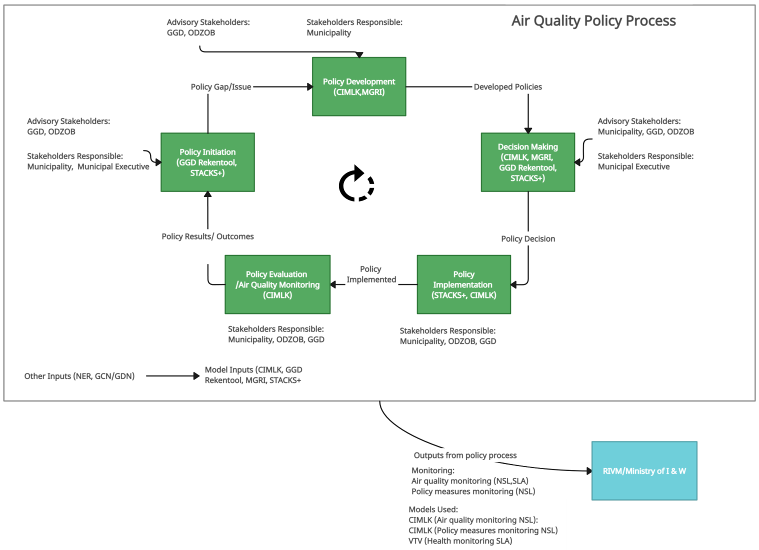


Figure 1: The municipal air quality policy process.

In this process, the most important model that is used is the CIMLK tool, which combines the air pollution determined in other models and then combines it with the the emissions from traffic to calculate the final concentrations of pollutants. It is also used to report the concentrations as required under the NSL, in addition to the policy measures adopted in the decision making phase. In Table 1 the models and their most important characteristics can be viewed[1].

Table 1: Models Currently In Use.

| **Model** | **Model Type** | **Calculation Method** | **Used By** | **Developed By** |
|---|---|---|---|---|
| CIMLK | Air Quality | SRM 1 & 2 | Municipality | RIVM |
| Nieuw Nationaal Model | Air Quality | SRM 3 | ODZOB | WLM |
| Nationale Emissie Registratie | Other | n.a. | GGD | RIVM |
| OPS/GCN/GDN Maps | Other | Background concentrations of air pollution | Municipality, GGD, RIVM, ODZOB | RIVM/TNO |
| GGD Rekentool | Health | n.a. | GGD | GGD GHOR |
| VTV | Health | Dynamo Health Impact Assessment | RIVM | RIVM |
| Milieu Gezondheids Risico Indicator | Health | Milieugerelateerd gezondheidsrisico | Municipality, GGD | RIVM |

Subsequently, we investigated how these models could be improved, as visualised in Table 2. Each column includes an improvement in one specific aspect of the modelling or air quality.

Table 2: Improvements in policy process through modelling tools.

| | **Resolution (Temporal/Spatial)** | **Input Data** | **Integral Modelling** | **Functionality** | **Measurements** |
|---|---|---|---|---|---|
| **Policy Initiation** | Identify problem areas | Identify problem areas | Combining policy challenges | Accessible information about air quality for citizens | Identify problem areas |
| **Policy Development/ Participatory Input** | Source apportionment | Source apportionment | Combining policy challenges | Accessible information about air quality for citizens | n.a. |
| **Decision Making** | Source apportionment for political support | Source apportionment for political support | Combining policy challenges | Accessible information about air quality for citizens | n.a. |
| **Policy Implementation/Evaluation** | Determine compliance | Determine compliance | n.a. | n.a. | Determine compliance |

Subsequently, we investigated the main bottlenecks in the municipal air quality policy process, which are presented in Figure 2.

[1]Schone Lucht Akkoord, a voluntary accord signed by the national government, provinces and municipalities (including Eindhoven) which aims to create a knowledge exchange network and to aim for a 50% reduction in health impact of air quality by 2030 with respect to 2016

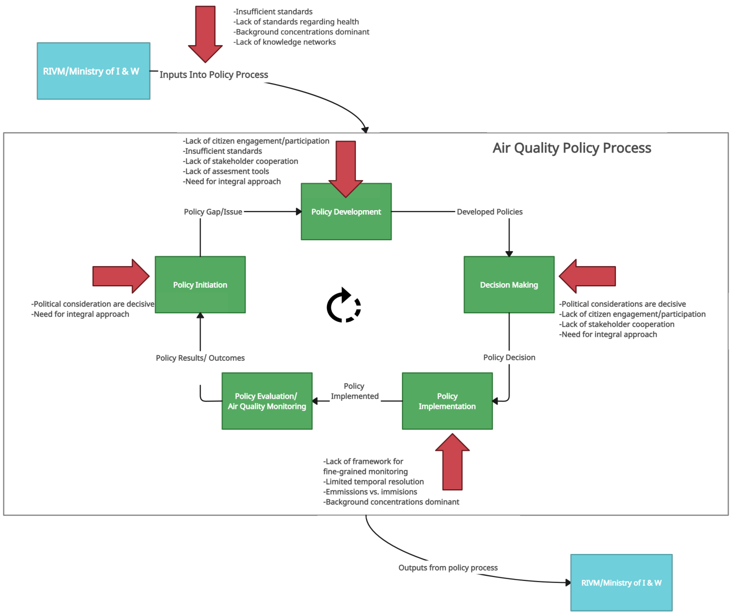


Figure 2: Bottlenecks in the air quality policy process.

To overcome these bottlenecks we found that there are four main areas in which the air quality policy process needs to be be improved. Firstly, the legal framework set out by the national (and supranational with regards to the EU) government should be updated continuously in the form of more ambitious air quality standards, the linking of air quality to health and increased cooperation between different levels of government. Secondly, efforts should be put towards increasing citizen engagement and awareness surrounding the topic of air quality in order to increase political support for policies improving it. Thirdly, air quality and sources of air pollution (emissions) should be targeted and tackled in an integrated fashion. Air quality should be coupled to other relevant issues to municipalities like the housing crisis, climate change and the healthy living environment. Furthermore, integrated policy making also means coordinating and tailoring policy options across multiple levels of government, with active participation from municipalities, provinces and the national government, as well as citizens across the country. The final area for improvement concerns the second part of the research question, namely the improvement of modelling tools for simulating air quality.

With regards to improving modelling tools, we found that there are a few main characteristics which are valuable. These are improved source apportionment, more integral modelling, and a more diverse functionality set. Improved source apportionment will allow for more tailored and specific policy approaches, as well as a facilitated approach across multiple levels of government through a clearer distinction of responsibilities. More integral modelling will allow the combining of policy challenges like noise pollution, heat stress and health with air quality, which will give policy makers to opportunity to identify and target potential compound gains from policies which address multiple issues. Finally, improvements in functionality will allow for better communication of air quality information to citizens, improved emissions management and the comparison of policy alternatives and scenarios. Combining all of these improvements brings us back to the main goal: supporting policy and decision makers in their process and facilitating their efforts.

These conclusions were also verified in other areas in the Netherlands, namely the region of Rijnmond and the municipality of Utrecht. It was found that for both of them, there is a demand for a multi-level governance solution to improving air quality. It was also found that if sufficient political support can be rallied, significant policy initiatives can be undertaken, but that all of this will still fall short if policy is not coordinated across multiple jurisdictions and governments.

To conclude then, we found that there is a need for an approach across multiple levels of government to improve the air quality policy process, wherein multiple initiatives like improving air quality modelling tools are combined to structurally overcome the obstacles that are currently holding it back.

# Contents

# 1

# Introduction

## 1.1. Air quality in Dutch municipalities

Ever since the explosive growth in airborne pollutants following the industrial revolution, governments have been attempting to combat the health issues that accompany lacking air quality. Local governments have played a significant part in these efforts, and this for quite a while now (Bondarouk & Liefferink, 2017). The Netherlands is no stranger to this distributed policy approach, where every level of government plays a key part in effective mitigation and adaptation policies (Kenniscentrum InfoMil, n.d.-p).

The current governance structure for air quality regulation reflects this: the standards adopted by the Dutch government flow forth from air quality standards set out in the European Union's air directive 2008/50/EC (Publications Office of the European Union, 2008). These are translated in national law through the *Wet Milieubeheer* (environmental management law) (Kenniscentrum InfoMil, n.d.-t). In this law, there is also a clear distribution of responsibilities with regards to combatting air pollution, which gives different layers of government, from national down to the provincial and then municipal level, different areas of responsibility (Kenniscentrum InfoMil, n.d.-t). Municipalities currently mostly focuses on the emissions of air pollution from road traffic and construction, which are their main areas of responsibility (VIII). To aid the regulation and governance of air quality however, there is a multi-level governance program, namely the *Nationaal Samenwerkingsprogramma Luchtkwaliteit* (NSL). This provides municipalities with some tools to combat air quality, like a knowledge sharing program and modeling tools, but it also carries significant obligations (Kenniscentrum InfoMil, n.d.-h). These obligations include such things as monitoring requirements and significant restrictions on projects that would noticeably contribute to air pollution (Kenniscentrum InfoMil, n.d.-w)

However, even with this comprehensive approach of multi-level governance, air quality levels in the Netherlands still leave a lot to be desired (RIVM, 2012). The RIVM, the Dutch public health research institute, still estimates that the country sees a couple of thousands of premature deaths as a result of air pollution yearly. The European Environment Agency estimates an even higher number, at 11,000 premature deaths every single year, resulting from excessive exposure to particulate matter and other pollutants in the air (RIVM, 2021). Premature deaths are those that occur before the average death rate, equal to 79.2 years for men and 83 years for women according to the National Statistics Office (Centraal Bureau voor de Statistiek, n.d.). The efforts by municipalities also vary significantly from one location to another, with Bondarouk and Liefferink (2017) finding that the implementation performance of air quality measures are strongly dependent on local problem framing, policy entrepreneurs and the size of municipalities. As a result, in Dutch cities, the European limit values were achieved for some pollutants like $PM_{10}$ and Ozone but not for finer ones like $PM_{2.5}$ (European Environment Agency, 2022). Furthermore, the guidelines set out by the WHO which are stricter than those set out by the European Union, are still far from being achieved (World Health Organization, 2016).

Finally, the Dutch independent research organisation TNO has advocated for an alternative approach, which does not base compliance solely on concentration levels but takes a more integrated and local method of quantifying air quality (TNO, 2022). Such an approach would focus on expanding the measuring process beyond averages and towards a more comprehensive temporal and spatial coverage. They also emphasize the need to consider the chemical composition of pollution, with the health effects of particulates being critical. They argue that the focus should shift towards narrow local efforts in municipalities, which would not only concentrate on the sources of pollution but also consider the transport and deposition of harmful particulates.

From the above it is clear that there is still a significant amount of work remaining to be done with regards to the local governance of air quality in Dutch municipalities. The potential for improvement also means that it is ideal to research what changes are necessary to achieve these gains. Therefore, we believe it to be an appropriate place to study the successes and failings of the policy procedures and gain a more intricate and detailed perspective on the role of models in these processes and their use in the day-to-day activities of officials working on this issue.

## 1.2. Model Usage in Local Government Policy Processes

More generally, the use of modelling and simulation tools in government policy processes is a relatively recent development which only became feasible after the widespread proliferation of computers in the second half of the twentieth century. At first, solely affluent organisations like national governments and big companies had the required means available to make use of these new programs. However as these devices became more affordable and accessible, their adoption by lower levels of government also became common-place (Agar, 2003). These computer models permitted the development of ”new insights into future states of fairly complex systems” (van Ittersum & Sterk, 2015). These characteristics allowed for the assessment of possible outcomes of a system based on simple initial inputs and an understanding of the interactions between the elements of that system (van Ittersum & Sterk, 2015). Nowadays, the usage of computer models for policy appraisal and simulation in government processes has become ubiquitous and their use has become key in developing more empirical and ”model-based” policy, which allows decision makers to frame their choices as being grounded in science as opposed to originating from a political process (Parkhurst, 2017).

However, their contribution is not solely limited to knowledge based input to political decisions. If we review the stages of the policy process as discussed in Howlett and Howlett (2019), namely: agenda setting, policy formulation, decision making, implementation and evaluation, we can see potential for every one of these stages to be supported and improved through the use of appropriate models (van Ittersum & Sterk, 2015). The aid these tools provide can range from simple cost-benefit calculations between different policies, to intricate simulations of different street layouts and their effects on air quality (Gusev et al., 2015; Kurppa et al., 2018).

On the other hand, it has been found that the simple existence of these models does not suffice for their adoption (Kolkman et al., 2016). Rather, there is a host of criteria that drive their acceptance in governance circles (Diez & McIntosh, 2011). Currently, a large focus is placed on the technical aspects of these tools, such as resolution or accuracy, in both their development and in scientific literature. On the other hand, little attention is given to the other characteristics that lead to model adoption (McIntosh et al., 2007). McIntosh et al. (2007) outlined critical ”soft” characteristics like the contextual aspects that the model might be used in and the role of the end user in the policy process. Kolkman et al. (2016) further investigated this issue and identified that certain key aspects like aligning perceptions between users and developers and designing for flexibility are paramount for modelling tools to actually be used in practice. They also underlined the different levels of model acceptance, ranging from knowledge about the model to regular usage in policy processes. To obtain high levels of acceptance and use, it is therefore essential that scientists and developers of such models have a keen understanding of the target audience they are developing their models for. Due to the incredible variety of models however, recommendations for drivers of model acceptance in literature are of a general nature, and applicable only insofar that they apply to the larger design philosophy of modeling and simulation design (Kolkman et al., 2016). This point is further underlined by van Ittersum and Sterk (2015) who call for additional research into documenting the drivers behind not only use and non-use, but also cases of partial use. They justify this based on the idea that in these cases there are clearly more intricate and context specific obstacles which are hampering full adoption. In their work, they also recognize the need to expand the field horizontally as the conclusions they identify will only remain of general applicability otherwise. Such a horizontal expansion would entail researching the drivers of acceptance in different fields, such that later meta analyses might be used to locate areas of overlap.

As was discussed in the previous section, air quality is such a topic in which modelling tools are paramount to support policy processes. This coupling can be further justified however. Firstly, the relation between emissions and measured concentrations are indirect and convoluted, making urban air quality a complex system (Fenger, 1999). To make decisions on this topic, there is a need for a heuristic framework, which allows decision makers to do their work in an informed manner. An example of the effectiveness of such a heuristic in this context, is the provision of air quality indices to citizens which allows the general public, but more specifically vulnerable individuals, to avoid excessive exposure to air pollution and to reduce health risks (Spurr et al., 2014).

Secondly, air quality is an issue that is particularly relevant not only to national governments but also to provincial and municipal authorities. As was discussed in section 1.1, local governments in countries like the Netherlands have a significant amount of freedom when it comes to implementing air quality measures like making city centers car-free, zoning residential areas away from highways and stimulating the use of different modes of transport like cycling by creating safe and inclusive infrastructure (Ministerie van Infrastructuur en Waterstaat, 2011; RIVM, n.d.-b). Local governments are heavily involved in the use of appraisal and modelling tools for this subject, which makes it suitable for performing research on the use of models in the policy process (Beattie et al., 2001).

Finally, mitigating and reducing the effects of air pollution requires policies and initiatives which lead to strong value disputes between different interest groups and large uncertainties surrounding the outcomes of policies, leading to models being adopted to serve political ends (Harish, 2021). An example of such a value dispute was included in the work by Bondarouk et al. (2020), where they discovered opposition from city center shop owners to the policy proposal of making the center car-free. To them, the economic value derived from easy access to the center heavily outweighed the costs that the emissions from these cars brought with them. This a simple example of a dispute where a cost-benefit model might be placed opposite an environmental impact or health exposure model, leading to the politicisation of scientific modelling tools. From this it is clear that the use of air quality models is not solely relegated to the policy formulation stage, allowing for a richer analysis on what drives their acceptance and for which purposes they are used.

It is therefore now also apparent that air quality is a topic in which the adoption and use of models is rather diverse, and therefore we will be targeting the specific academic literature gap on the use of models in the air quality policy field.

## 1.3. Problem Statement and Research Question

To finish off this introduction into air quality governance, let us discuss what specific problem statement we will be focusing on, and the research question we have posed to aid in overcoming the problem. We can then also briefly discuss the contents of this work.

### 1.3.1. Problem Statement

Based on this combination of the issue of air quality in Dutch municipalities, and the uncertainty around the role that models play in governance and policy contexts, we can now formulate the following problem statement.

***There is a lack of understanding on which improvements could be applied to the municipal air quality policy process, and what possible contributions improved modelling tools could make.***

From this problem formulation, we can already theorize on the potential answers that we will be attempting to deliver as a result of this work.

Firstly, we will be able to identify where in the policy process the major obstacles to improved air quality policies lie. The outcomes of this will be able to inform both policy maker and model developer, with the former being able to improve their process whilst the latter can perform more targeted development of their model.

Secondly, there will be a clearer understanding of the current roles of models in local governance policy processes. Are models used to formulate policy or to support decision making? Or are they used solely to justify political compromises? These answers are valuable not only due to their potential to improve the policy process, but also as possible additions to the literature on the political decision making process with regards to air quality governance at the local government level and t.

### 1.3.2. Research Question

To obtain these answers however, we are going to need a succinct research question and associated sub-questions which will lead us to the deliverables that we seek. We have formulated it as follows.

***What potential improvements in the Dutch municipal air quality policy process can be made, and what role can models play in this?***

The focus of the research question is thus twofold, similarly to the answers described above: firstly we must investigate what is currently holding back the air quality policy process, and secondly we need to determine which of these obstacles fall within the areas in which improved modelling tools might play a role.

## 1.4. Objective and Deliverable

Per the problem statement, the main objective of this graduation project was to provide a better understanding of the Dutch municipal air quality policy process and the role of models therein. As will be further discussed in chapter 2, this was be accomplished through the use of a case study on the Dutch municipality of Eindhoven. The conclusions from this case study were then validated in a selection of other municipalities with similar characteristics. The recommendations were then tailored to aid municipalities (but also other levels of government like the national government) in adapting their policy processes to more effectively make use of the benefits that models might bring.

With regards to the the appearance of the final deliverable, the structure is as follows. Firstly, a description of the air quality policy process. Secondly, an analysis of the models used in this air quality policy process. Thirdly, a discussion on potential areas of improvement for the modelling tools that are used. Finally, a discussion on how the more general policy process might be improved. The final deliverable will thus be useful to multiple parties. Organisations that develop these tools, like TNO, will gain a perspective on which models can be applied where. Moreover, it also gives them insight into who would gain from the adoption of those tools, allowing for direct collaboration on model development. Municipalities on the other hand, will also be able to make use of the recommendations, giving them a new picture on the obstacles that are hampering their policy processes. Other levels of government could then also incorporate both their relevant recommendations, but also consider how they might facilitate the recommendations aimed at the municipality.

This thesis can then also contribute to the wider scientific knowledge base on the role of models in air quality governance, and what drives the acceptance of these models by decision makers.

We can now move on to the next chapter, where we will discuss the methodology that we will use to answer our research question.

# 2 Methodology

In this chapter, we will go into further detail on the research question identified in the previous chapter, splitting it up into distinct sub-questions in section 2.1. Based on these sub-questions, we can then determine the structure of the answers that we are looking and how that leads to our chosen research approach in section 2.2. The research methods, literature and data that was used to achieve our results follows then in section 2.3. The literature used will be expanded upon in section 2.4. In section 2.5 this is then all brought together in the research flow diagram.

## 2.1. Sub-Questions

In the previous chapter, we arrived at the main research question for our research, as repeated below.

**Research Question:**

***What potential improvements in the Dutch municipal air quality policy process can be made, and what role can models play in this?***

To answer this research question, we have split it up into four distinct sub-questions. To determine which improvements can be made to it we must first focus on investigating the general structure of air quality governance, with an emphasis on the legal framework which shapes it. This flows forth in the framing of the first sub-question. In order to then determine the role models play in it, we investigate their use and role in the second sub-question. Based on this we can investigate avenues of model development in the third sub-question. These can then compared against the bottlenecks that we find in the policy process in the fourth sub-question, where we will then also determine how we can improve it even further. These questions are then summarised as follows.

**Sub-Questions:**

1. What is the current multi-level governance structure of the air quality policy process in Dutch municipalities?

2. By whom and in which manner are air quality modelling tools used to support the policy processes in this structure?

3. What are the current developments in air quality modelling, and how can these be applied to improve the municipal air quality policy process?

4. What obstacles currently exist in the municipal air quality policy process, and how can these be overcome?

In the next section, we can now use these research sub-questions to discuss how we arrived at the chosen research approach, and which methods are then adopted to obtain answers to each question.

## 2.2. Research Approach

The chosen research approach and the selection of sub-questions are strongly intertwined, therefore we will justify our selection of research approach based on the goals that each sub-question attempts to achieve.

With the first research sub-question, we are attempting to capture, evaluate and describe the intricacies of the air quality policy process. We will commence by taking a top level view, discussing the relevant legislation, and then zooming on the local level, to determine the features of the municipal air quality policy process, and which parties are involved in which role.

Subsequently, we will expand the second sub-question to determine the roles that modelling tools play in these processes, determining how and by whom they are used. The goal is thus to further evaluate the considered system and specifically obtain information on the modelling process.

Based on the results from these two parts, we can then investigate which modelling developments are currently being pursued, and determine their area of applicability in the policy process.

Finally, we will then take a step back and place the postulated changes in the larger governance context to evaluate and forecast the effect, if any, they might have on the performance of air quality policy in municipalities. The results of this question will immediately lead us back to our main research question. To answer this main question we will then combine all the conclusions from the previous sub-questions.

When considering these sub-questions' goals together, we can conclude that our research approach is of an exploratory nature in which we attempt to create a conceptual framework of the current policy process and the use and role of models within it to determine the changes in performance that might occur through their improvement. The focus of the research was thus on using qualitative methods to induce conclusions about the policy process system at hand.

Because of the limited scope of this project, we had to limit ourselves to a case study of one municipality, the conclusions from which we tested in other municipalities. To obtain information about the structure of the process in this case study, we could then narrow down our focus and attempt at creating a qualitative outcome. More details on the selected case study will be discussed in the next section, as well as the sources of data which were drawn upon.

## 2.3. Research Methods and Data Requirements

Based on the aforementioned approach, we can now discuss our methodology in further detail. Relevant aspects like the course of action that we took to perform our research as well as the rationale behind the chosen case study and interviews are discussed below.

### 2.3.1. Methods and Data

Similarly to our previous approach, we can now go through the methods that we selected to perform our research on a per sub-question basis. In general, we relied on three main sources of data: interviews, scientific literature and grey literature in the form of government publications and websites. With respect to this literature, please consult section 2.4, where the specific fields of literature are further introduced.

For the first sub-question, where our goal was to gain an understanding of the municipal air quality policy process and the larger governance perspective surrounding it (in the form of the legal framework). To achieve this, we made use of an iterative approach, where we attempted to apply a theoretical framework of policy processes (as presented by Enserink et al. (2022) ) which was then tested against reality through a series of interviews with individuals involved in it. Similarly to the approach described by Polk (2015) ), we used a co-production methodology, where the stakeholders themselves aided in discerning the structure of the policy process. This was then complemented by drawing upon desk research of grey literature, including sources like the official InfoMil website, which houses a large repository of information on Dutch environmental regulations (Kenniscentrum InfoMil, n.d.-k). The added value of interviews in this sub-question was both from identifying the key parties involved in the municipal policy process but also on the similarities and differences with respect to the theory.

This also returned in the second sub-question, where the same methodology was adopted to determine which models were in use currently and by whom, as well as for which purposes these were used. Once again, we built our conceptual understanding of the relevant models piecemeal, by comparing what was mentioned in the literature (in the form of grey literature, which concerns items like government publications and websites like InfoMil described above) with the processes described in the interviews with relevant individuals. Particular emphasis should thus be once again placed on the iterative nature of this process, as each interview added another piece to the larger puzzle. Following from this approach, we aimed to develop an understanding of the key characteristics of the models used, the role of the users and the purposes for which they were used. This was connected back to the legal framework in order to once again contribute to the comprehensive picture of the municipal air quality policy process mentioned above.

It should be noted, as will be discussed in subsection 2.3.3, that due to the significant interlinking between the subjects covered in them, the first two sub-questions were written in a parallel rather than in succession. This returns in the interview data that was drawn upon, as many of the interviewees that were asked questions on the structure of the policy process, were also given the opportunity to discuss the relevant models and their purposes.

For the third sub-question, we returned to a more theoretical approach, where we performed a literature review of the different development avenues of air quality models in scientific research. However, to determine in which directions to look for these developments, we drew once again upon the expertise given by the interviewees, this time from the model development side, as once again will be discussed in further detail in subsection 2.3.3. We combined this with a more general conceptual overview of areas of modelling development to determine the 5 key avenues which we investigated in this work. For each of these avenues, the main aspects could then be determined from scientific literature on the air quality modelling field. These improvements could then be applied to the municipal air quality policy process to determine the improvements they could bring about.

Finally, in the fourth sub-questions, we returned to the conceptual representation of the policy process developed previously, to identify the key bottlenecks currently hindering it. The basis for the bottlenecks was developed based on the interview questions with all of the interviewees, which is described in more detail in the next section. These bottlenecks were then analysed to apply a tentative multi-level governance approach, discussed in further detail in section 2.4. Based on the results of these last two sub-questions, we could then answer our main research question, and move on to our conclusions.

### 2.3.2. The Case Study of Eindhoven

As discussed previously, we had to be careful with the scoping of our project, as we only had a limited time available to perform it. Therefore in this work, we will only go into depth for one municipality . The chosen municipality is Eindhoven, a city in the south of the country with a population of around 200,000 people. The rationale behind this decision is three-fold.

Firstly, and most importantly, easy access to the network of actors in the air quality policy process. This thesis was performed during an internship with the Dutch research organisation TNO, which is currently working together with a large consortium of knowledge institutions and public agencies to set up a high resolution air quality sensor network in the city (ODZOB, n.d.-b). This means that a lot of the groundwork had already been laid out with respects to establishing contacts. This facilitated the interviewing process and allowed us to get a head start when compared to focusing on other cities.

The second reason flows forth from the previous one insofar that these efforts by TNO and its partners underline the importance and value the municipality places on performing thorough air quality improvements in the city. Setting up this large sensor network is a significant undertaking, and it shows that the local governments' decision makers are involved in the air quality subject, leading us to believe that there was high potential for interviewees to have relevant and useful knowledge for this research project.

Finally, the city also has a significant challenge ahead of them in the form of the construction of thousands of new homes, the expansion of a highway around the city, and a lingering dependence on natural gas for heating (Gemeente Eindhoven, 2022). All of this lead to the city indicating in its environmental vision publication that it will have to create an integrated and sustainable development plan if it wishes to succeed in its goals (Gemeente Eindhoven, 2022). These challenges are universal in other cities in the Netherlands, allowing for solutions that work in Eindhoven to have potential applicability in the rest of the country.

Therefore, as discussed in the previous subsection 2.3.1, for our research case study we focused on the municipality of Eindhoven. This had a few key implications on the outcomes, which we discuss at the end of this work.

### 2.3.3. Interviews

Before we get into our discussion of the details surrounding the interviews, let us take back a step and review the rationale behind choosing interviews as one of our main research tools. As we discussed in section 2.2, we narrowed our scope to a case study in recognition of the time constraints posed upon our research. This meant that we could limit our analysis of the specifics of the municipality of Eindhoven, rather than on the aggregate patterns of air quality regulation at the municipal level in the Netherlands. For the reader interested in this topic, we recommend Bondarouk and Liefferink (2017) and Bondarouk et al. (2020).

In recognition of this focus of our research however, this meant that we were specifically interested in the details of the municipal air quality policy process in Eindhoven, rather than the larger picture. To investigate this structure however, we needed in-depth information which unfortunately could not be found solely in official government publications, not even those of the municipality. With this in mind, we chose to opt for an interview-based research methodology. As also discussed in the methods section, we developed our conceptual representation of the air quality policy process in an iterative manner which was only feasible with the chosen approach, thus further reinforcing our decision to opt for interviews.

The selection of the interviewees was iterative, where we started by reaching out to individuals involved with air quality in the municipality, and based on their recommendations and the development in our understanding of the municipal air quality policy process we looked for interviewees with other expertise. This led us to interviewing three different officials within the municipality, based on the different phases of the policy process as will be described in the next sections. We also included interviews with organisations that were not initially in our scope, namely the National Public Health Institute and the DCMR (the environmental service of the region Rijnmond), because of recommendations following from earlier interviews.

Moving onto the more specific details of the interviews, we should commence by first briefly touching upon the general setup of each discussion with interviewees. The interviews were performed in a semi-structured manner. The questions were shared with the interviewee beforehand, and the interview was conducted in an open-ended way. This meant that we prepared a set of questions beforehand (discussed in more detail below) which outlined the key lines along which we were looking to obtain information, and then proceeded from there. The roles of the interviewees, the goal of the interview and how they are cited in the body of this work are presented in Table 2.1.

Table 2.1: Interview Data: Roles, Dates and Citation Numbers.

| Interviewee Role | Date Interview | Goal Interview | Interview Number/Identifier |
|---|---|---|---|
| Health Service | 04/11/2022 | Role health service, structure municipal air quality policy process. | I |
| Municipality, Decision Making | 04/11/2022 | Structure municipal air quality policy process, role decision making. | II |
| Municipality, Policy Advice | 09/11/2022 | Structure municipal air quality policy process, role municipality, role models. | III |
| Environmental Service | 22/11/2022 | Role environmental service, structure municipal air quality policy process, role models. | IV |
| Municipality, Modelling | 14/12/2022 | Role models, structure municipal air quality policy process, role municipality | V |
| Research Institutes | 22/12/2022 | Developments air quality models. | VI |
| National Public Health Institute | 30/01/2023 | Structure municipal air quality policy process, development in air quality models. | VII |
| Other Regions, DCMR | 02/02/2023 | Comparison structure, comparison conclusions and recommendations. | VIII |
| Other Regions, Utrecht | 24/02/2023 | Comparison structure, comparison conclusions and recommendations. | IX |

The complete list of interview questions that were asked can be found in Appendix A. Please note that for anonymization reasons, the complete interview answers are not included.

As was discussed in the previous section, we went into each interview with a specific goal in mind, and we asked specific questions from each interviewee. We will now first introduce which types of questions were asked from the interviewees, and then in the next section we will discuss how this figured into every sub-question.

**General Questions**

The general questions were posed to all of the interviewees in some form or another. The answers for these questions are therefore also used very regularly in this work.

The first general question that was posed to all of the interviewees was on what they perceived to be the main bottlenecks both to the municipal air quality policy process but also to the larger air quality governance in the Netherlands. This allowed us to get many different perspectives on this issue, which was very relevant to the discussion in the fourth sub-question.

The second general question that we asked from everyone interviewed was on what they believed was necessary to improve the air quality in the Netherlands even further. This ties into the previous question on how we can further improve both the policy process and its outputs, but we added this question to explore any potential solutions.

The final general question concerned the legal framework and the multi-level governance structure of the air quality policy process. This question differed depending on who it was asked of, but in general the aim was to determine how each interviewee perceived the structure of governance around them, and what role they believed it played in the regulation of air quality.

**Municipality Specific Questions**

From the interview with the municipality, there were three key areas beyond the general questions that we were looking to investigate.

Firstly, we were looking for input on the structure and organisation of the municipal policy process. This included the organisations involved in the municipality with air quality, as well as the role they played in developing policies to combat air pollution. The interplay between different actors in the process was also touched upon in this question.

Secondly, we wanted specific detail on how the legal framework shaped the municipal air quality policy process beyond the level discussed in the general question above. This included such measures as the ”NIBM” exception, which was only relevant to municipal stakeholders.

Finally, a question (or multiple questions in the case of the modelling policy advisor) was asked about which air quality models were used, and in which capacity and to which end they were used. Once again, this question was focused more on the specific use of models within Eindhoven rather than the more general prescription for using modelling that comes forth from the legal framework.

**Model Developer Specific Questions**

The two interviews that were taken with the model developers, the RIVM and the research institute, were mostly focused on the relevant development in air quality modelling. For the former, the focus laid mostly with the current models that are in use. For the latter, emphasis was placed on the different avenues that models are being developed in and how these enhancements could be applied to the municipal air quality policy process.

**Other Questions**

Of course, beyond the above discussed questions, a few other questions were asked. A complete list of the questions can be found in Appendix A. However, we would also like to pay particular attention to the questions asked during the interviews with the DCMR and Utrecht. During these interviews, two main avenues of questioning were pursued.

Firstly, we investigated the structure of the municipal air quality policy process, similar to the questions we asked in the Municipality Specific Questions, now with the focus on the similarities and differences with respect to Eindhoven.

Secondly, the conclusions that were developed for the municipality of Eindhoven were tested in these other areas, to determine their wider relevancy.

### 2.3.4. Interviews per Sub-Question

The previously discussed questions can also be put in the context of each sub-question, to discuss what the relevancy of each set of questions was.

**Sub-Question 1**

As we discussed earlier in this chapter, the research into the structure of the municipal air quality policy process was performed in an iterative manner, with a combination of policy analysis literature and grey literature being tested against reality in the interviews.

The relevant answers thus concerned those that were obtained during the interviews with all three of the municipality's policy advisors that we talked to, as well as the interviews with the regional health service and the environmental service. Additional input from the interviews with the national public health institute, DCMR and Utrecht were also taken into account after having developing the results for this sub-question.

The most important questions for this chapter thus concerned those with relevancy to the legal framework, structure of the municipal air quality policy process and role of the organisations and individuals involved. These characteristics were tested against the legal framework found in the official government publications as well analysed against the standard model of the policy cycle. In addition, the input from these interviews was used for the stakeholder scan performed in this chapter as well.

**Sub-Question 2**

For the second sub-question, the focus laid primarily on the models used, and the modelling actors involved. This included the legally models and their features.

The interviews that were pertinent for this sub-question were once again all of those that were performed with individuals involved in the policy process, that is the municipal policy advisors, regional health service and environmental service. Additionally, answers from the national public health institute (which was one of the modelling stakeholders) were also included in this chapter as well as input from the DCMR, which is also an environmental service for a different region.

For this chapter, three main areas of information were required. Firstly, the models used, which was based on a combination of the grey literature described previously as well as the interviews. Secondly, the modelling procedures and purposes were also key, especially with respect to the MGRI model. Finally, information on the legally mandated methods was also drawn from the interview answers.

**Sub-Question 3**

For the third sub-question, the focus was mostly on scientific literature on modelling developments, which will be described in more detail in the next section. However, use was made of the answers from the interviewees involved in the policy process to determine in which directions model developments could prove useful to their purposes.

Furthermore we drew on the interviews with model developers and the national public health institute to apply these model development to the municipal air quality policy process.

**Sub-Question 4**

The final sub-question (under which we include the comparison with other municipalities) drew on all of the interviewees to determine the obstacles currently facing the municipal air quality policy process, as well as the possible solutions to overcome these obstacles.

For the comparison to other municipalities, the focus lie mostly on comparing the conclusions for Eindhoven to their respective region or city.

## 2.4. Literature Overview

In the methods section, we already shortly introduced the methodology behind every research sub-question, and what steps were taken to obtain the answers to them. We will now go into further detail on which sources of literature were drawn upon for each sub-question.

### 2.4.1. Data Sources

For our literature research, we drew on three different sources.

- Google Scholar
- Google
- Infomil.nl

The specific keywords used to perform this research are discussed in each section below.

### 2.4.2. Literature per Sub-Question

Similar to the discussion in the Interview section, we can now consider the different types of literature drawn upon for each sub-question. We will only discuss the types/fields of literature, please refer to the respective sub-questions for the in depth discussions on the literature.

**Sub-Question 1**
For the first sub-question, there are three main areas of scientific literature that we drew upon, which are as follows.

**Scientific Literature**

- Multi-level governance literature: We used multi-level governance literature to evaluate and discuss how environmental problems like air quality are regulated in the European Union, and to connect and illustrate how the municipal air quality policy process is influenced by the other levels of government.
- Stakeholder analysis literature: The stakeholder analysis literature was used to create a stakeholder scan of the municipal air quality policy process in Eindhoven, including the organisations involved as well as their position in the Power-Interest Grid.
- Policy analysis literature: Finally, we used policy analysis literature to introduce the generic structure of the policy process from theory (the phases of the policy process model) which we could then compare to the real situation in Eindhoven.

In addition to this scientific literature, we also drew upon grey literature, which includes sources like government publications and websites.

**Grey Literature**

- Publications on the legal framework of air quality governance in the Netherlands.
- Publications on the organisations involved in air quality governance in the Netherlands.
- Publications on air quality governance in Eindhoven.

**Sub-Question 2**
For the second sub-question, the focus was on the specifics of model usage in the Netherlands, and especially in the municipal air quality policy process of Eindhoven. Therefore, use was made of only grey literature.

**Grey Literature**

- Publications on the different models used in the regulation and monitoring of air quality.
- Publications on the use of air quality models in the Netherlands
- Publications on the legal framework with regards to air quality models.

**Sub-Question 3**
In contrast to the second-sub question, in the third question we drew only on scientific literature namely scientific literature on the different air quality model development avenues.

**Scientific Literature**

- Theory of the different characteristics of a model.
- Literature on improvements in air quality modelling.
- Literature on improvements in the use of air quality modelling in the governance of air quality.

**Sub-Question 4**
The fourth sub-question only drew on one area of literature.

**Scientific Literature**

- Multi-level governance literature for the discussion of a multi-level governance approach.

**General Literature**
Beyond the literature that was used in the sub-questions, we also drew on two more main sources of literature for the introduction. These were primarily scientific literature on the role of models in policy making and the drivers behind model adoption.

## 2.5. Research Flow Diagram

In Figure 2.1, the research flow diagram can be seen. The process for this research project is split into three phases. The first phase is the orientation phase, where the two first sub-questions are answered and a clear picture is painted of the air quality policy process in Dutch municipalities, with a special focus on the use and role of models in that process. This is then followed by a formulation phase, where the takeaways from the first phase are used to evaluate how better modelling tools might bring about changes in the process and of what nature these changes would be. Finally, the results of this are expanded with a more general analysis of the improvements necessary to the air quality policy process. This is then closed out with the conclusions & recommendations. In the figure the preliminary structure of the thesis can already be identified, with chapter numbers and associated sub-questions presented. On the right side of the figure, the methods used are presented per phase.

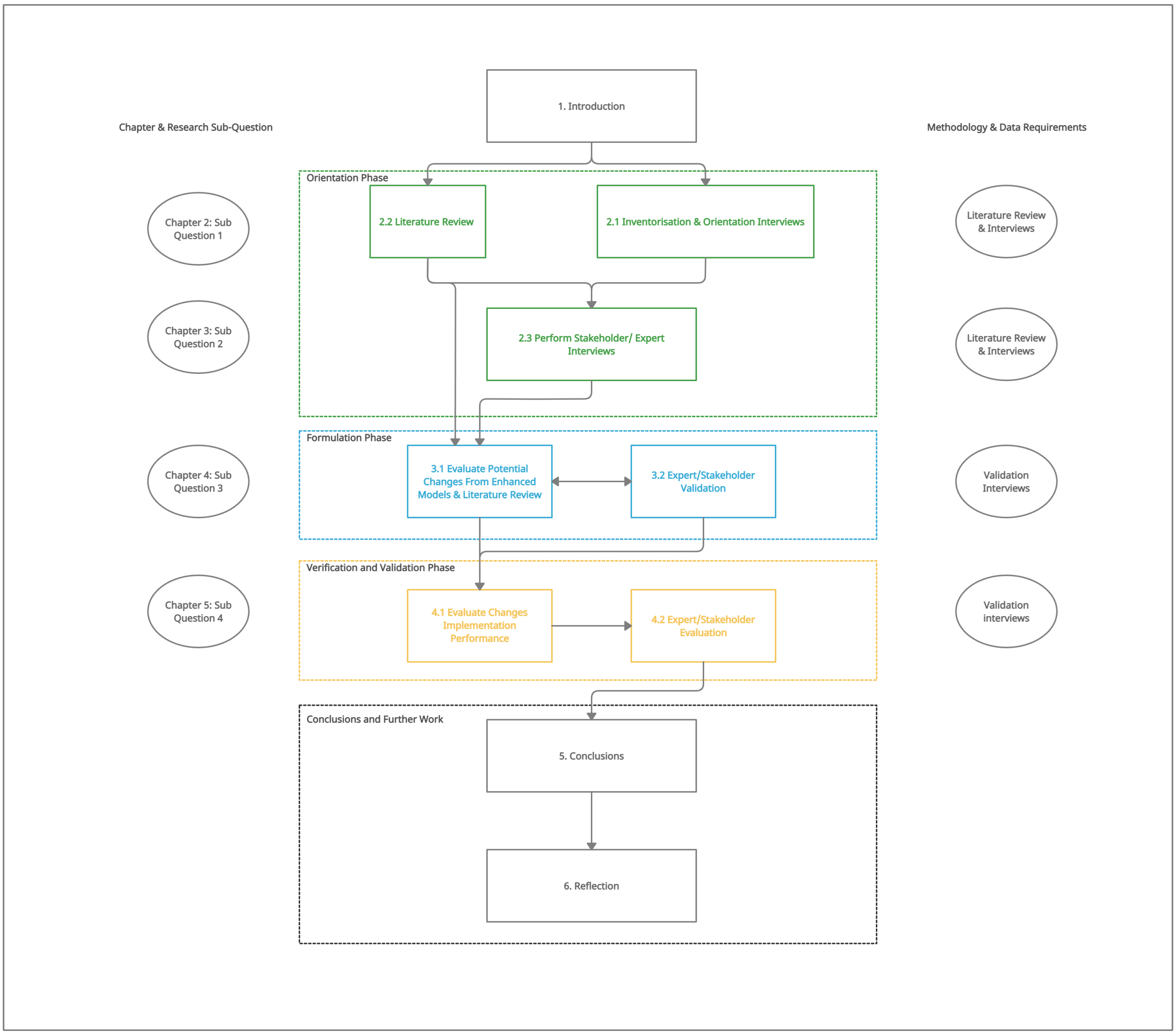


Figure 2.1: Research Flow Diagram

# 3

# Multi-Level Governance Perspective on the Municipal Air Quality Policy Process

As we mentioned in the methodology section, we will commence our research by performing an investigation into the multi-level governance nature of the municipal air quality policy process. At the lowest level of governance, namely the municipal one, we will then apply a standard model of the different phases of the policy process as well as a scan of the relevant stakeholders. The research sub-question that we will be attempting to answer in this chapter is thus as follows: *" What is the current multi-level governance structure of the municipal air quality policy process in Dutch municipalities?".* To answer this question, we will first perform a review of the multi-level governance and the parties involved in the legislation and regulation of air quality. We will subsequently zoom in on the lowest level, the municipality, and describe the legal framework that sets the stage for local air quality governance. we will perform an actor scan to get an understanding of all the parties that are involved in this local governance, and which parties are key players. The policy process that they are involved in then will be evaluated based on the interviews and compared to the structure described in policy analysis theory.

## 3.1. Multi-Level Governance

Due to its complex and interconnected nature, air quality is regulated at all levels of the Dutch government as well as the European Union. We therefore believe an analysis of the municipal air quality policy process would be amiss not to discuss the different responsibilities and jurisdictions that come into play in the regulation of air pollution. This governance approach, where there is a distribution of responsibilities between different levels of government, is critical in ensuring an effective regulatory approach, and has significant influence on the way that parties within the system operate.

### 3.1.1. What is Multi-Level Governance?

Before we discuss the specific characteristics of the multi-level governance structure of air quality regulation, let us first go over what multi-level governance entails, and for which situations it is relevant.

As we mentioned above, multi-level governance is a key theory on the structure and characteristics of government, which Stephenson (2013) describes as "the dispersal and redistribution of powers and competences to different levels of policy making activity, and roles for both existing and newly-created institutions and bodies." (p.828). They also mention how due to "the functional requirements of implementing many policies have demanded massive politico-administrative reorganization at lower levels, and hence the Europeanization [sic] – and to a degree harmonization – of spaces and their units of control." (p. 828). It is clear from this passage that they perceive these two developments, the emergence of both multi-level governance and the growth of the European politic, as deeply intertwined and related. This is underlined by Hooghe et al. (2001), who contrast multi-level governance with another dominant school of thought: the state-centric governance framework. This framework sees the development of the European Union as another level of agreements between sovereign states, which retain and even strengthen their position as the dominant actor in governance. Hooghe et al. (2001) argues against this however, postulating that "European Integration is a polity-creating process in which authority and policy making influence are shared across multiple levels of government -subnational, national and supranational" (p.2). This development is therefore a rejection of state-centric governance and the emergence of a multi-level governance structure in the European Union and its member states, which will continue to evolve over time as it is not a "stable equilibrium" (Hooghe et al., 2001). Saito-Jensen (2015) also underlines that in a multi-level governance structure, lower levels of government have gained increasing importance as they have the ability to "more easily gain the attention and interest of national governing bodies if they can convincingly demonstrate that they have forged strong links with local civil society organizations and are able thereby to claim that they represent the interests of these organizations" (p.5). Understanding the multi-level governance context is therefore relevant even in an analysis of municipal policy processes.

Multi-level governance is also very important in the consideration of environmental issues, especially in those issue like air quality which are not localised to a single specific location. As mentioned by Kauffmann et al. (2020): "Transportation of air pollutants across different countries turns fighting air pollution into a multilevel challenge where domestic intervention need to be supported by IRC [International Regulatory Cooperation] mechanisms that complement local action and resources." (p.19). It is therefore paramount that issues like air quality are dealt with in a fashion which integrates all parties, which Newig and Koontz (2014) calls "mandated participatory planning". They argue that the EU air quality directive are such a form of mandated participatory planning which contain "aspects of multi-level governance, policy implementation and participatory governance" (Newig & Koontz, 2014). More generally, dealing with complex problems that involve many different organisations, jurisdictions, and levels of accountability (such as air quality) requires, as Smith et al. (2006) describes it, "analysis of MLG [multi-level governance ]structures must be accompanied by analysis of MLG processes" (p.18). With this in mind, let us investigate the multi-level governance context for air quality regulation.

### 3.1.2. Application to the Air Quality Policy Process

Now that we have discussed what multi-level governance means, let us consider how it applies to the regulation of air quality. We will start at the top with the highest level of government, and then work our way down to the lowest level of government: the municipality.

**European Union** The first level of government, which significantly influences all of the other levels below it, is the supranational level in the form of the European Union. The EU has set out a combination of policies, tools and instruments to combat air pollution, which are summarised below (European Commission, 2023).

- Policies: air quality standards, reduction commitments, regulations on sources and inter and intra EU cooperation networks.
- Tools: Clean air dialogue, clean air forum, clean air outlook, funding for clean air, zero pollution stakeholder forum, research and monitoring by EU agencies like the EEA and JRC.
- Instruments: Air quality index, Copernicus monitoring service, etc.

As is clear from the above initiatives, the EU is involved in improving air quality in a plethora of ways, but primarily focused on setting standards, regulations and performing monitoring. The implementation of these standards and regulations is then passed down to our next level of government.

**The National Government**

The national government of the Netherlands, the Rijksoverheid, is responsible for incorporating the relevant directives and regulation from the EU into its national legislation, which in the Netherlands is done in the Wet Milieubeheer, which will be described in more detail in the next section. For now, we will briefly describe the initiatives undertaken by the national government and what they are responsible for (Overheid.nl, 2022)

- Coordination of air quality regulation across the different levels of government through funding, coordination and knowledge exchange.
- Monitoring and reporting of the air quality in the Netherlands.
- Development of air quality monitoring tools.

- Regulations on industries, commercial activities and households.
- Air quality standard implementations and/or the adoption of more stringent standards.
- Regulation of emissions from transport.

This is by no means a comprehensive list. What is important to take away from it is that the national government is key in the establishment of the air quality regulation in the country, as long as it fits within the framework set out by the European Union. They explicitly delegate certain responsibilities to lower levels of government who can then use their expertise and local perspectives to better judge optimal implementation of relevant policies.

**The Provincial Government**

The province is one of these lower levels, which is primarily concerned with the regional coordination of air quality regulation. The main aspects that they are responsible for are as follows (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2012).

- Siting of roads, industry, rail, nature, recreation and agricultural areas.
- Coordination and stimulation of cooperation between different municipalities and local organisations concerned with air quality (Provincie Zuid-Holland, n.d.).
- Monitoring of the compliance with environmental laws, including those regarding air quality.
- Supporting citizen engagement networks (IV).
- Coordination of regional public transportation (Provincie Zuid-Holland, n.d.).

From this it is apparent that the province also sets a framework within which municipalities operate, namely the spatial aspect. They also aid in the coordination between different municipalities and help establish regional initiatives. Their role is thus also significant in facilitating the municipal air quality policy process.

**The Local Government: The Municipality**

Finally, we arrive at the subject of our research: the local government. The local government in the form of the municipality is the lowest rung on the ladder of air quality regulation, and the areas they are responsible for follow this line of thinking. We have once again briefly outlined their responsibilities below (I,II,III,IV,V).

- The design, siting and characteristics of local roads, including their construction.
- The evaluation, approval and coordination of construction projects within the municipality.
- Coordination of local public transportation.
- The monitoring of air quality and the enactment of policies to improve it.

As was mentioned by (VIII), the municipality currently mostly focuses on the emissions of air pollution from road traffic and construction, which are their main areas of responsibility.

With a clear view of the multi-level governance structure now, let us go into more detail on the municipality's legal framework, which shapes how the policy process comes about, and what considerations are taken.

## 3.2. Legal framework for Municipalities

Like every public policy and decision making process, the air quality policy process is subject to a legal framework which affords municipalities, like our case study Eindhoven, certain privileges (like setting up air quality policy) and certain responsibilities (ensuring the air quality meets the national standards). They are obliged to properly consider air quality in their decision making, as will become apparent throughout this section. These responsibilities have evolved throughout the past few decades in which the topic of air quality has been at the forefront of public consciousness. We will now present these in chronological order.

### 3.2.1. Wet Milieubeheer

The legal basis for air quality in the Netherlands currently draws forth from the *Wet Milieubeheer* (Environmental Protection Law), as mentioned in the introduction. This law is the basis upon which the majority of Dutch environmental protection legislation is based. Air quality has its own specific provisions in the law with regards to standards, procedures and legal obligations, due to the unique features of air pollution (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, n.d.). These features are primarily related to its transnational diffusion, as air pollutants easily cross borders leading to a strong need for cross-country legislation (European Environment Agency, 2016). It is therefore that the standards adopted for the law are based upon European guidelines, which have been transposed by almost all European countries into their national legislation (Kenniscentrum InfoMil, n.d.-r; Publications Office of the European Union, 2008). The standards, summarised in Table 3.1, are not all applicable to local governments. The $NO_2$ hourly average only applies to roads that are used by at least 40.000 motor vehicles per 24 hour period (highways) and the exposure concentration (which is the concentration relevant to urban populations) is only required for the national government, with municipalities being exempt from having to test for this value (Kenniscentrum InfoMil, n.d.-j).

Table 3.1: Air Quality Standards, bold faced ones do not apply to the municipality.(Kenniscentrum InfoMil, n.d.-j).

| **Pollutant** | **Type of Standard** | **Concentration ($g/m^3$)** | **Type of Standard** |
|---|---|---|---|
| NO2 | Yearly Average | 40 | Limit Value |
| **NO2** | Hourly Average (Max. # Exceedance = 18/Year) | 200 | Limit Value |
| PM10 | Yearly Average | 40 | Limit Value |
| PM10 | Daily Average (Max. # Exceedance = 35/Year) | 50 | Limit Value |
| PM2,5 | Yearly Average | 25 | Limit Value |
| PM2,5 | Yearly Average Exposure Concentration | 20 | Limit Value |
| Benzene | Yearly Average | 5 | Limit Value |

These standards are the minimal levels that all municipalities have to meet, and which offer judicial standing for citizens to initiate litigation in cases of insufficient efforts by their municipalities. However, there are a few key considerations concerning the Milieuwet that significantly detract from the bite of the legislation. Primarily, the standards are so lenient that municipalities will meet them regardless of which projects they feasibly approve. According to a policy officer at the municipality, the standards are lenient enough that "as long as we add a short paragraph about how a project will not be limited by air quality standards to a destination plan [in a destination plan, municipalities must indicate the environmental impact of a project], we are legally covered" (III). Furthermore, the policy officer also mentioned that the structure of the standards, namely in the form of yearly averages, facilitates easy compliance as the effect of construction work and other peak emission moments will be smoothed out over the whole year (III).

With respect to the aforementioned project planning, the Wet Milieubeheer has specific clauses outlining the aspects upon which projects need to be evaluated to determine if they are permitted. Projects should fall under at least one of the following categories (Kenniscentrum InfoMil, n.d.-t).

1. There is clearly no actual or imminent exceedance of a limit value.
2. On balance, the project does not lead to a deterioration in air quality.
3. A project does not contribute to air pollution in a significant degree (Niet in betekenende mate - NIBM).
4. A project is, or fits within, the Nationaal Samenwerkingsprogramma Luchtkwaliteit (NSL) or a regional program of air quality measures.

The first category, constitutes a project that can be clearly shown to not negatively affect the air quality. The second one concerns a project whose impact on the air quality is compensated by a remediating measure which would cause a net positive in air quality (not net zero). The third aspect is a special clause added by the NSL, discussed in more detail in subsection 3.2.2 where the contribution is sufficiently minor to be negligible. Finally, the fourth category is mainly meant for large projects like highway construction or polluting commercial activities deemed critical, which are similar to the second clause but compensated for by more comprehensive and overarching measures by for example the national government or provinces (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, n.d.).

Finally, as mentioned in the introduction of this section, authorities should consider air quality in their decision making processes for spatial and urban planning. This is outlined in a responsibility for governing bodies to enact a ”good” spatial planning, which for the measure of air quality mostly concerns the exposure aspect, which should be taken into account when considering the location of projects that would otherwise fall within the aforementioned categories. For example, projects that fall under the NIBM exemption, might have to be scrutinized more closely if they are to be located in areas where the air quality is already lacking (Kenniscentrum InfoMil, n.d.-i). This is because the effects of air pollution are not binary, but rather linear, as discussed in chapter 1. This leads us towards the next legal framework we will discuss: the consideration of not only air pollution concentrations but also health impacts.

### 3.2.2. Nationaal Samenwerkingsprogramma Luchtkwaliteit

The Nationaal Samenwerkingsprogramma Luchtkwaliteit (National Cooperation Program Air Quality - NSL) came into being after the Netherlands failed to initially meet the European guidelines for $PM_{10}$ in 2005 and for $NO_2$ in 2010 (Kenniscentrum InfoMil, n.d.-w). It was first enacted in 2009 and extended to 2016. After this it was extended one last time until the *Omgevingswet* would come into effect (currently slated for 2023). It added a few new specific clauses and provisions and edited the existing setup to streamline the air quality permitting process and ensure that the right measures were put in place to meet the

To achieve compliance the standards were temporarily relaxed. The yearly average for $PM_{10}$ was raised to 48 $g/m^3$ and for $NO_2$ to 60 $g/m^3$. These heightened concentrations were allowed until the end of the derogation period in 2015. In addition, an escape clause was added to the legislation in which projects that would cause a negligible decrease in air quality do not need to be tested on their contribution to air pollution (NIBM) (Kenniscentrum InfoMil, n.d.-q). According to a policy officer at the municipality, ”this clause was added to avoid an excessive burden on permitting authorities and to reduce their workload” (III). This exemption is now part of the Wet Milieubeheer, which also received the fourth clause, namely that projects that would significantly contribute to air pollution are allowed if they fit within the measures of the NSL or a similar regional program.

The types of measures and examples of such are summarized in part in Table 3.2. Although these measures are not mandatory, governing bodies were obligated to meet these standards by the 2011 ($PM_{10}$) and 2015 ($NO_2$) deadlines, with these measures being guidelines to achieve these goals. They are also forbidden from taking fewer or less effective measures. This clause is to ensure all governments actually carry out the measures in reality or ensure other similar measures that achieve the same results are adopted.

Table 3.2: Examples of Air Quality Measures in the NSL (Kenniscentrum InfoMil, n.d.-y). It should be noted that immisions are distinct from emissions, where immissions indicate the concentration at ground level, experienced by people.

| **Type of Measure** | **Examples** |
|---|---|
| Limit Mixing | Increase flow on roads. |
| Limit Emissions | Improve public transport. |
| Limit Emissions | Low-emissions zone for cargo traffic. |
| Limit Emissions | Low-emission municipal vehicle fleet. |
| Limit Exposure | Emission demands for tender proposals. |
| Limit Exposure | Barriers around highways. |
| Limit Exposure | Construction highways around urban areas. |
| Limit Exposure | Creation of green barriers around highways. |
| Limit Emissions | Good spatial planning by keeping vulnerable communities away from emission sources. |

For a complete list of the measures currently adopted in the municipality of Eindhoven please refer to Appendix B. Governmental bodies are required, similar to in the Wet Milieubeheer, to substantiate new measures or changes to existing ones based on calculations of the effects on air quality to the Ministry of Infrastructure and Water Management (Kenniscentrum InfoMil, n.d.-l). These calculations are done through the *NSL-Rekentool* (Calculation Tool) which uses model inputs provided by the RIVM. This tool and these inputs will be described in more detail in chapter 4.

Finally, and possibly most importantly, the NSL added a monitoring requirement to ensure timely compliance with the air quality standards. As mentioned above, this monitoring is performed by the RIVM. The brunt of the data used to perform this monitoring derives from the GCN and GDN maps (Large Scale Concentration and Deposition Maps) (RIVM, n.d.-e). These maps use a combination of model calculations and measurements, which will be discussed in further detail in chapter 4. It also uses the following data to achieve even more precise information on the air quality (Kenniscentrum InfoMil, n.d.-m).

1. Traffic data
2. Road characteristics and environment
3. Progress of measures and projects
4. Characteristics of livestock farms

The maps derived from the aforementioned data is used both for monitoring but also for municipalities and similar governing bodies to calculate the impact of policy measures such that they can properly quantify their impact (Kenniscentrum InfoMil, n.d.-o). More detail on this will once again be given in chapter 4.

### 3.2.3. Schone Lucht Akkoord

The two legal frameworks that were discussed up until now have been centrally mandated by the Dutch government, making them obligatory for the municipality of Eindhoven. In contrast to this, the *Schone Lucht Akkoord* (SLA) (Clean Air Accord) is voluntary for municipalities to join, with no legal requirements or commitments to upholding the tenets of the accords (“Het schone lucht akkoord”, n.d.). Participation thus signals a governing body’s willingness to improve their air quality. Eindhoven signed the accord back in 2020, indicating its commitment to go beyond the legally mandated standards to improve air quality under the NSL.

As part of the transition from the NSL to the SLA, the municipality ”has created a ”bidbook” containing the policies that the local government could consider to improve the air quality for residents” (III). An example of such a policy was the scooter arrangement that the municipality recently enacted. In the bidbook, the goal of the policy measure (in this example, reducing the emissions from small scooters) and the approach, including the means used are discussed. In addition, the financial requirements are also included. The effects of these policies are then quantified in order to meet the goals of the SLA.

The fundamental goal behind air quality policies and standards is not better air quality. It is an improvement of the health of residents in the Netherlands, and to stimulate efforts towards a healthier living environment. The SLA reflects this in its central goal: ”to achieve at least a 50 percent gain in health by 2030 with respect to 2016”(“Het schone lucht akkoord”, n.d.). There are two key aspects that make up this ambition. First is the ”gain in health” as the relevant measure, which is in contrast to the goals set out in the NSL, which is to meet EU legislation and standards on air quality. The tonal shift has gone from meeting to exceeding and from air quality standards to health gains. This also ties into the more participatory nature of the accord, which requires a certain political will in a municipality to join. To achieve this political will, the goals must be accessible and understandable to citizens who can then vote according to their preferences. Secondly, the temporal aspect of the goal has gone from solely setting a deadline like in the NSL (2015) (Kenniscentrum InfoMil, n.d.-p), to a comparison of the past and the present, where the 2016 number can be used to show the positive trend. This is similar to climate change ambitions that are currently attempting similar goals with respect to 1990. (Ministerie van Infrastructuur en Waterstaat, 2013)

A third aspect that draws attention in the SLA is the implementation plan, which consists mostly of voluntary policy measures and pilots, which participants can pick and choose for their own situation. Efforts are split into ten categories, ranging from mobility, to monitoring all the way to mobile equipment. All these categories have working groups where knowledge and expertise can be exchanged to improve the implementation of policy measures and pilot projects.

Finally, the monitoring of the SLA should also be considered. Due to the absence of a legal obligation, the monitoring and enforcement of the SLA is structured differently: the RIVM provides health indicators which municipalities and other participants can use to measure and monitor their own efforts and their associated effects (Gerlofs-Nijland et al., 2020). These are also compiled in the health effect maps that will be discussed in more detail in chapter 4.

In conclusion, the SLA is a more open-ended, non-legally binding accord which allows participants to share in a knowledge network, trying out and monitoring policy measures and pilots to improve the air quality in their environment. There is also a significant shift from meeting standards to improving health, which indicates a more people-focused approach which the municipality of Eindhoven reflects in its bidbook, where it presents the policies under consideration for implementation.

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### 3.2.4. Omgevingswet

Although the *Omgevingswet* will not come into effect until 2023, municipalities like Eindhoven have long been preparing for its implementation. The preparation started over a decade ago, and has fundamentally restructured the policy process for municipalities as will be further discussed in this chapter (II). The main difference lies in the aggregation of all environmental zoning plans into the Omgevingsvisie (environmental vision) and an redesigned permitting process. Under the OW, these are the main changes.

1. The Omgevingswet explicitly places health centrally in its goals for air quality improvements (II). An example of this is the MGRI map (Milieu Gezondheidsrisico Indicator -environmental health risk indicator), which has been developed by the RIVM using data from 2016 measurements on air and noise pollution. This allows municipalities to directly determine how much of the health burden is a result of inferior air quality. As mentioned in subsection 3.2.3, prioritizing health ”helps with communicating the environmental message to residents, placing it under the focus of improving the healthy living environment” (I).

2. The Omgevingswet dictates that a municipality must create a policy framework (named a ”programma”) when there is a violation of a norm or standard (III). However, at this moment in time, there are no violations in Eindhoven, which means it does not apply to the municipality. This means that any policy measure the municipality wishes to enact must therefore be part of closing the policy cycle, originating from a monitoring/feedback activity.

3. The environmental service, will also experience a change in its procedures (IV). For a more comprehensive explanation of their procedures, please refer to subsection 3.4.7. In short, the permitting process, which is currently done in a traditional linear fashion, with applications being submitted, reviewed and then approved or rejected, will be turned around. Project developers and initiators will be required to submit their plans to the ”Omgevingstafel” (Environmental Board), which is composed of experts of every relevant organisation (GGD, Municipality, ODZOB, Waterschap (Water board), Province, etc.). This board will evaluate the project according to each of their own disciplines, after which they create an integral advice to the project initiator which aspects of the project need review. The permitting authority will then only review whether the project has been updated to include this advice, severely streamlining the permitting process. This also means that a permit might be rejected outright because it ”allows for the rejection of a project strictly based on for example a health impact basis” (IV).

4. In the new environmental visions, municipalities have room to include different stakeholders in their plans like the ODZOB which has expressed a desire to be part of that process. This would allow them to ”add their own expertise and tailor plans so that they are realistic with respect to their enforcement and the optimal use of resources” (IV)

### 3.2.5. The Importance of the Legal Framework

As will become even more apparent in the next chapter, this legal framework is critical to the operation of the municipal air quality policy process. It sets the structure within which all of the stakeholders involved within the process operate, as well as influence which procedures they are obliged to follow. We believe the key takeaways from this section are therefore:

- The monitoring and reporting of air quality is obligatory under the NSL framework, using tools developed and provided by the national government.

- Municipalities are obliged to adhere to a set of air quality standards, and when there is an exceedance of these standards they must take appropriate measures (as outlined within the NSL) to rectify this.
- Municipalities are responsible for the emissions associated with local traffic, which is their main area of possible reductions.
- The municipality of Eindhoven is a participant in the SLA, which is an accord within which parties commit themselves to reducing the health burden of air pollution. It is also associated with certain monitoring requirements.
- The new *Omgevingswet* will force municipalities to approach air quality and other environmental problems in a more integral fashion, involving other stakeholders in their policy and decision making processes. It also requires municipalities to have a clear vision on their environmental policy approaches.

These key takeaways should be held in mind when considering the upcoming content, as a lot of the choices made by actors involved in the municipal air quality policy process are influenced and shaped by the legal framework.

## 3.3. Stakeholder Scan

To properly understand the dynamics of the considered system of the municipal air quality policy process, a more comprehensive picture of the relevant stakeholder groups and their constituents should be sketched. Included should be those parties that are the most relevant to our analysis and those are involved in the modelling of air quality at the local level. This is normally done in the form of a stakeholder scan, as described by Enserink et al. (2022), but due to our scope we will limit ourselves to a stakeholder scan, where we only investigate the stakeholders on a surface level, and omit most of the detail that would come from an in-depth stakeholder scan.

### 3.3.1. List of stakeholders (including position, actions, type)

The topic of air quality involves many parties who influence the municipal policy and decision making process, from both the public and private sector. In Table 3.3 all of the stakeholders that influence the considered system are presented. The list of stakeholders was developed in an iterative fashion through the interviews, where interviewees suggested which parties they viewed as relevant.

Table 3.3: Stakeholders in the municipal air quality policy process of Eindhoven (I,II,III,IV,V)

| Name | Type | Action | Explanation |
|---|---|---|---|
| Ministry of Infrastructure and Water Management | National Government | Propose National Legislation, Create legal frameworks, Support Initiatives, Network | The Ministry of Infrastructure and Water Management represents the national government in the policy processes at hand.<br>It has the ability to influence national legislation and to create legal frameworks which influence the policy process.<br>It also supports initiatives that fall under its purview as responsible authority for larger projects like Eindhoven Airport and highways.<br>Finally, the Ministry organises networking events similar to the RIVM |
| RIVM | National Government | Support Research, Lobby, Support Initiatives, Network, Model Development | The RIVM is responsible for the monitoring of national standards under the NSL.<br>It is also involved in the development of key modelling tools like Aerius and the MGRI-maps.<br>Furthermore, the RIVM also initiates a lot of research projects and supports local initiatives like the regional monitoring network in Eindhoven.<br>Finally, it also organizes networking events where stakeholders and interested parties can get together and<br>exchange knowledge on their air quality policy measures and so forth.<br>The RIVM also prepares documents for the house of representatives with regards to air quality, giving them significant lobbying influence in national legislation. |
| Provincie Noord-Brabant | Regional Government | Lobby, Support Initiatives, Network, Create legal frameworks (for industry) | The province aids municipalities in creating their air quality policy, and creates networking groups for exchanging knowledge and expertise.<br>It also sets regulations for industry. |
| GGD Brabant Zuidoost | Regional Government | Support Research, Lobby, Support Initiatives, Network, Model Development | The Gemeentelijke Gezondheidsdienst Brabant Zuidoost (GGD Brabant Zuidoost) (Municipal health service) is responsible for protecting and improving the<br>health and healthy environment of local residents. It accomplishes this through performing research ,<br>supporting initiatives like the regional monitoring network and through organising network events.<br>The GGD also develops the GGD rekentool which allows for the calculation of health impacts of air pollution.<br>Finally, the GGD also lobbies the national government through the umbrella organisation GGD-GHOR,<br>which represent the interests of the Dutch GGD's on the national level. |
| ODZOB | Regional Government | Support Research, Lobby, Support Initiatives, Network | The Omgevingsdienst Zuidoost-Brabant (ODZOB) (Environmental service) is responsible for<br>permitting, monitoring and enforcement of environmental policy (VTH) in the region.<br>It supports research and initiatives similar to the GGD.<br>It also has the ability to lobby through the umbrella organisation of environmental services. |
| Municipality of Eindhoven | Local Government | Initiate Policy, Create Policy, Norms, Lobby, Propose Legislation | The municipality of Eindhoven consists of the civil servants that make up the non-elected part of the government.<br>They are responsible for initiating new policy proposals,<br>working on policies that have been mandated by the board and city council,<br>setting norms and standards and proposing new projects and legislation.<br>They also have significant political influence due to their work in implementing and refining policies. |
| Municipal Executive (Mayor, Alder people) | Local Government, Elected | Initiate Policy, Approve Policy, Propose Legislation, Lobby | The Municipal Executive, which consists of the Mayor and the Aldermen and Alderwomen (Wethouders),<br>is responsible for implementing the programs and decisions of the municipal council, the province and the national government.<br>It is also responsible for the finances of the municipality.<br>This means that they can initiate new policies, approve proposals by the municipality and propose and lobby for new legislation for approval by the council. |
| Municipal Council of Eindhoven | Local Government, Elected | Initiate Policy, Propose Legislation, Lobby | The city council are the elected representatives, representing local residents and serving as their link into the local government.<br>From the ranks of the council the municipal executive is formed which creates a coalition agreement outlining<br>the programs and policies that the city will work on during their term.<br>The council has the power to initiate new policies, propose and approve new legislation<br>and lobby the executive for the specific implementation of policies. |
| Interest Groups (e.g. Aireas) | Engaged Citizens | Lobby, Initiate Policy, Support/Oppose Initiatives, Vote | Interest groups like Aireas, which consist of citizens who organise themselves to better lobby for their own interests and preferences.<br>They have the ability to influence the policy process through lobbying and proposing policies in concerted fashion, attending networking events<br>and participation moments that are mandatory for new initiatives and projects.<br>Finally, advocacy groups can, and do, influence voting patterns, both in their constituents and outside of them. |
| Citizens | Residents Eindhoven | Lobby, Support/Oppose Initiatives, Vote | Citizens are the basic building blocks of the policy process of the municipality of Eindhoven.<br>They are both responsible for air pollution and suffer from it.<br>They can influence the policy process both directly and indirectly.<br>Directly, they can lobby city council members by attending participation events and city council meetings.<br>At these events, they have the ability to significantly affect the decision making process by expressing their support or lack thereof.<br>Indirectly, citizens set the policy agenda through their voting preferences,<br>as the set of policy measures and initiatives for discussion at are a direct result of the coalition agreements. |
| Commercial Parties (Touw, DGMR, etc.) | Model Developers | Model Development | Commercial parties like the engineering firm Touw and the ICT-company DGMR develop the software packages<br>which are currently used by the municipality to develop policies, monitor existing ones and report the emissions in the city to the national government. |
| Knowledge Institutes (TNO, University of Utrecht, etc.) | Model Developers | Perform Research, Support Initiatives, Model Development | Knowledge institutes like TNO and the University of Utrecht, assist the municipality by performing research, supporting initiatives like the ILM,<br>and developing models like the GCN and GDN maps that are used by the municipality. |

For each stakeholder, the following characteristics are included. Firstly, the type of stakeholder is discussed, which concerns their position in the legal framework or their responsibility. National government stakeholders are responsible for setting the legal framework in which the municipality operates, as discussed in section 3.2 previously, and monitoring compliance with it. Next we have the province of Noord-Brabant, the Public Health Service Brabant Zuidoost (GGD Brabant Zuidoost), and the Environmental Service Zuidoost Brabant (ODZOB), which are regional organisations, which coordinate their work with many municipalities, and who assist the municipality of Eindhoven with developing and implementing its policies and plans. Moving down one more rung on the ladder, we arrive at the local level, where the municipality (consisting of civil servants), the municipal executive (consisting of the governing parties) and the municipal council (consisting of all the elected officials). It is at this level of government that we see the actual initiation, development, adoption and implementation of policies. This layer of government directly engages with residents and administers national legislation. These residents are the next group, consisting of the namesake group and interest groups that are composed of residents who organise among themselves to drive for improvements in air quality. The last group are those parties who develop the models that are used to simulate air quality, being split between commercial parties like engineering firms and ICT companies like TOUW and DGMR, and knowledge institutes like TNO and the University of Utrecht. These parties are not politically engaged but support the municipality in its policy process.

Next up we have outlined the key actions which stakeholders might take. A brief explanation on the actions can be found in the last column. Relevant to the later analysis is determining which stakeholders actions occur in which part of the process. For example, it can be seen that only the municipality and the city council can initiate new policy initiatives, although it should be noted that many actors can do so indirectly.

### 3.3.2. Demarcating the System Boundary

Due to the scope that is selected for this research, not all of the above stakeholders will be included in the further analysis. Therefore we must now demarcate the system boundary that we will be wielding moving forward, as well as determining the inputs and outputs from this system. In order to do so we have adopted the following two possible conditions a stakeholder must fall under in order to be take further in the analysis of the system at hand, namely the municipal air quality process in Eindhoven.

1. The considered stakeholder has a high level of power and interest in the considered system ("player") as positioned in the Power Interest Grid (PI-Grid) in section 3.3.3. These stakeholders will then be identified as the "players" of this system (actors who are critical in the system) and then subsequently included in the larger policy process analysis.

2. The considered stakeholder develops or uses models relevant to the policy process discussed further below. A discussion on the stakeholders that fall under this category is presented in subsection 3.3.4.

### 3.3.3. Power Interest Grid incl. Player Selection

A power interest grid is a visualisation of the influence and engagement parties have, and allows for an analysis of which stakeholders "*must be taken into account in order to address the problem or issue at hand* (Bryson, 2004). Each of the stakeholders that participates in and affects the policy process has a certain level of sway, expressed as their "Power", and is engaged in it to a certain degree, expressed as their "Interest", which are all plotted in Figure 3.1 to determine those parties with high levels of both who we consider the "Players" for further analysis in this chapter. Please note that the levels of power and interest are relative rather than absolute. This means that even though municipalities have far less power than the national government in absolute terms, respectively when compared to citizens, they are both in the high power area of the grid. One should primarily be focused on the area of the grid, where the top right is of the primary interest. Stakeholders in this area are called "players", indicating their influence and engagement with the system.

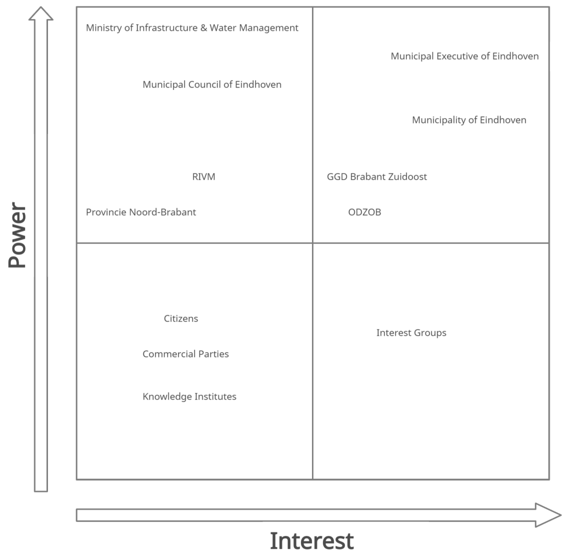


Figure 3.1: Power Interest Grid

From this figure, the four stakeholders will be considered within our system boundary:

- The Municipal Executive of Eindhoven (College van Bestuur)
- The Municipality of Eindhoven
- The GGD Brabant Zuidoost
- The ODZOB

These players will be further discussed in subsection 3.4.2. It is now also important to consider the stakeholders that lie outside of our boundary and how they influence the system. In the table below, we have included a list of the actions that external stakeholders can take to influence the system. These can be seen in the previous Table 3.3 below.

From these actions, it is clear that the players of the system are not wholly independent, and have to answer to a lot of external stakeholders, ranging from citizens and the larger municipal council to the province and the national government. However, the considered players have the most direct influence on the system that we are considering: the air quality policy process in the municipality of Eindhoven, leading to their selection.

### 3.3.4. Modelling Stakeholders

With the subject of this research in mind, extra attention should be given in determining which parties go beyond the political decision making process and who create and make use of computer models to further their agenda. The list of stakeholders that fall under this criteria is relatively similar to the list of players, there are however a few small changes. Firstly, the RIVM is included as it is the main developer of the legally mandated modelling tools that the players have to use, leading to its central location in the modelling framework and policy process. Secondly, the Municipal Executive is omitted, due to their non-technical role in the policy process, leading them to be completely uninvolved in the modelling and development aspect. Their use of models is relegated to adopting the modelling outcomes for the political process, which means they will not be included in the further modelling analysis. The obtained list is then as follows:

- The RIVM
- The Municipality of Eindhoven
- The GGD Brabant-Zuidoost

- The ODZOB

These stakeholders' procedures and the modelling tools they use are described in the next chapter, chapter 4.

## 3.4. The Air Quality Policy Process

With the establishment of the relevant stakeholders, we can now move on to the policy process. The air quality policy process concerns the establishment of new policies, the participatory decision making process, the implementation of these policies and then subsequently the feedback aspect on the efficacy of these existing policies which can all be analysed against theoretical frameworks of policy processes. In this section we will be comparing the municipal air quality policy process in the municipality of Eindhoven to a base structure of a policy cycle from theory, determining where the main similarities and differences lie.

### 3.4.1. A Generic View of The Policy Cycle

Before we discuss the policy process in Eindhoven then, let us first briefly touch on the generic view of what a policy cycle is, what characteristics they contain and what the important aspects are, based on policy analysis literature.

As discussed in the introduction, Howlett and Howlett (2019) recognize in their work on the policy cycle five distinct stages of the policy process. These are as follows.

- Agenda Setting: Where issues or feedback about existing policies first come to the attention of relevant individuals and organisations, and are found to be relevant enough to be targeted by a policy.
- Policy Formulation: Here the policy is developed into more detail, as the issue is researched and possible solutions are formulated. Different policy avenues or options appear here.
- Decision Making: In the Decision Making phase those with the power and responsibility to make decisions evaluate the policy or policies put before them, evaluating the characteristics and features of the different policy options, and then deciding on whether the policy gets passed, and in which form.
- Policy Implementation: The executive branch of the organisation takes the policy option that has been decided upon by the decision making branch and works it out into practice.
- Policy Evaluation: The effects of the policy currently enacted have an effect and are evaluated against their initial purpose as well as the current goals of the organisation, in addition to the evaluation of the situation at hand.

Although it will not always occur in this chronological order, and it should be mentioned that there will be interaction between all the different phases, it is clear to see why the policy process is seen as a cycle, with all the different steps that are taken to get a policy passed in an organisation.

We can then expand this with the work done by Enserink et al. (2022), who have a similar but not completely identical view on the policy process, which can be seen in Figure 3.2.

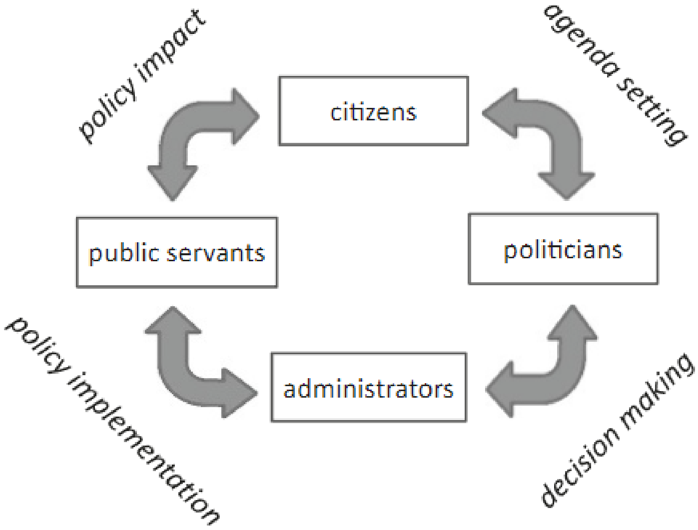


Figure 3.2: Cyclical view of the policy process, taken from Enserink et al., 2022

As can be seen from this figure, the policy process now consists of four phases, where the policy formulation phase is now omitted. It does include a clear view of where the different parties involved in the policy process are involved however.

We will now look at the municipal air quality policy process in the municipality of Eindhoven, to try to determine which structure it has, and how well it aligns with the two theoretical frameworks described here. Before we do that however, we must first discuss which parties are involved in the policy process.

### 3.4.2. The Players and Their Responsibilities

The players that were established in the stakeholder analysis each have their own set of responsibilities and actions, which leads them to all have their own specific procedures and activities.

**Municipal Executive** Firstly, we have the municipal executive of Eindhoven, better known as the ”college van burgemeester en wethouders” or ”college van bestuur”. These are part of the larger municipal council of Eindhoven, and have formed a governing majority, with the appointment of ”wethouders” (aldermen and women) on specific topics. The responsible alderperson for air quality is in charge of ”climate, energy, land and greening”, leading to the possibility of integrating multiple disciplines into one policy initiative. The responsible alderperson has a significant influence on proposed policies, as ”new policy initiatives and changes to existing ones are submitted to the responsible alderman, with whom the specifics are discussed, and who can add their own suggestions to the policy.” (**II**). The importance of this person in the adoption of policies is significant, as in the past it was common that ”policies were stuck in political deadlock because they were not tested [sic] against the wishes of the alderman” (**III**). The influence that the municipal executive has on the process is therefore especially significant, with their backing leading to an almost guarantee of a policy being adopted. The alderperson also has the ability to instruct the municipality to work on specific policies that they desire, or see room for in the political process (**II**). They are also the ones who lead the discussion on municipal council discussion on new policies, and interact with citizens to determine their opinions on policies. This all brings them together as the key decision maker in the policy process, which will be further discussed in subsection 3.4.6.

**Municipality** Policies that are proposed by the alderperson are developed by the policy advisors of the municipality of Eindhoven. The municipality consists of non-elected civil servants, who have specific expertise on topics like air quality modelling, mobility or creating policy advice. As discussed above, one of the main responsibilities that the municipality has is working on the policies proposed by both the larger municipal executive in their coalition agreements (Gemeente Eindhoven, 2022) and the more specific policies proposed by the responsible alderperson. Working on these policies includes not only tailoring the policy to the exact requirements set out by the national government but also consulting with other government parties, like the GGD and the ODZOB to get their input on the impacts and feasibility of proposals. The municipality also consults with non-government entities, like research institutes and commercial parties. Most importantly, they also source the input of residents of the city to determine their view and opinion on certain policies, to ensure that when they get to the participatory decision making phase, significant political support can be achieved. In addition to the policies proposed by the elected representatives of the municipality, civil servants also have ”budget to create their own policy proposals that can be coordinated with the alderman and then proposed to the larger council” (II). The municipality therefore is one of the main actors responsible for new policies, both in proposing them and working them out. This will be discussed in further detail in subsection 3.4.3. Finally, the municipality is also responsible for monitoring the air quality in the city, reporting the concentrations of pollutants both to the council and to the Ministry of I and W under the NSL. This is one of the main areas where the municipality uses the mandatory modelling tools, as will be seen in chapter 4.

**GGD Brabant Zuidoost** Next up we have the GGD Brabant Zuidoost (GGD) which, as mentioned before, is the public health agency responsible for the region in which Eindhoven is situated. Their core task with respect to air quality is quantifying and translating the health effect of air pollution in the region Zuidoost Brabant. In their 2022 report, they indicated that there are still significant health impacts in the region, which can be adressed by improving the air quality (Denissen, 2022). They are also involved in the public policy process, wherein they “advise on the health effect of air quality for both existing and new policy initiatives” (I). They are also one of the founding members of the regional measurement system, which they use to both assist citizens by informing them about the quality of the air around them and to more generally determine the quality of the living environment in the region. The organisation also tries to think about “why people desire measurements, what the driving factor or concern is that is leading to people feeling the need for more information about air quality.” This can then be used in policy advice to the municipality to address the actual issues citizens are concerned about, rather than the symptoms thereof. As mentioned before, their main niche surrounds their core task of improving the health of people living in Zuidoost Brabant, which also means that they are at the forefront of interacting and measuring the impact that air pollution has on the population. This means they regularly interact with citizens on the topic. For now, it should be considered that the GGD is an indirect conduit through which citizens can voice their concerns to policy and decision makers alike. The GGD, just like the Veiligheidsregio and the ODZOB are part of a larger umbrella organisation composed of all of the public health agencies in the Netherlands, which directly cooperates and advises the ministry of public health and welfare (I). This allows them to influence both national and local level legislation, giving them significant power in our analysis.

**Omgevingsdienst Zuidoost Brabant** Finally, we have the ODZOB, this organisation is an environmental service which is responsible for the permitting and enforcement of air quality policies. This provides them with an excellent perspective on what the current situation on the ground is, whilst they also have a foot in both the local and regional level, as their area of responsibility is significantly larger than the municipality of Eindhoven, covering the Southeastern part of the province Brabant. They posses the ability to both initiate and influence policy initiatives as will be discussed in more detail in subsection 3.4.3 and subsection 3.4.7. Their main responsibility lies in evaluating and permitting projects and monitoring those permits throughout their region. They also cooperate in the management of the regional measurement system and cooperate in an advisory manner with the municipality in the development of the Omgevingsvisie.

### 3.4.3. The Creation of New Policies in the Municipality

Practically every party in the air quality policy process has a direct or indirect avenue to propose and initiate new policies to be worked on and to be evaluated and decided upon in the decision making process, with some having more direct approaches whilst others have to cooperate with other parties to get their proposals submitted. The push factor behind a new policy initiative might come from many directions. The lion’s share of policies find their origins at the beginning of electoral cycles, when political parties have to come together to form a coalition and transform their visions into concrete actions. These policy measures are then giving their start in the *bestuursakkoord* (Governance Agreement), in which the ambitions of citizens are reflected both directly and indirectly (III). The direct influence might come from such sources as public participation meetings, which “place the resident in the center of the discussion, which has led to a focus on issues like wood burning and sustainable mobility on the neighbourhood level"(Gemeente Eindhoven, 2020). Indirectly, citizens express their support for policy initiatives through their voting patterns, which allows political parties to directly connect citizens with policy initiatives. An example of this was "the participation of the municipality in the SLA, which was only possible as a result of the political makeup of the municipal council" (II).

The set of policies that the local government then wishes to enact in their term in office are all compiled in the "bidbook", which contains a comprehensive list of the plans the municipality has to work on for the upcoming term. The goal of the municipality is to fit as many of its initiatives into this book, to avoid having to excessively budget for additional policy measures. This compilation is not a policy framework however, but rather a set of goals and actions that are still abstract. These frameworks are only created in those situations in which "the municipality believes it to be useful and necessary, preferring to make use of already existing policies and legal frameworks wherever possible."(Gemeente Eindhoven, 2020). New policy measures are therefore heavily scrutinized not only on their usefulness and cost, but also on their uniqueness and whether the goal can not be accomplished within an already existing framework.

Like the other players in this analysis, the GGD has the ability to signal new policy initiatives and lobby for legislation. For the latter they are able to do so on the national level through the GGD umbrella organisation, which closely coordinates with the ministry of Health, Welfare and Sport. The effect of this may be noticed in the new Omgevingwet, for which "the national GGD's have lobbied in the past few years to better incorporate health standards into the environmental legislation of the Netherlands, and giving municipalities the freedom to implement more ambitious air quality goals" (I). On the local level, the GGD assists in the development of policy initiatives through "on request of a municipality providing a health advice on the considered policy" (I). However, it was underlined by the interviewee that the GGD "does not participate or lobby in the political decision making processes and plays its main role with policy makers and citizens." In general, it can be said that the main goal of the GGD with respect to new policies is to "not advise directly on the specifics of policy initiatives but rather to stimulate more ambitious standards in order to gain larger health gains".

As mentioned before, the ODZOB also has the ability to signal new policy initiatives on both a local and national level through the knowledge network similar to the GGD (IV). They directly advise both policy and decision makers and provide templates for environmental plans for smaller municipalities. They cooperate with the municipality to ensure policies are enforceable and achievable and translate specific policy goals to indicators which may be used to monitor compliance.

### 3.4.4. Policy Development

Once a policy gap or problem is identified, the municipality will start working on a set of policy measures necessary to overcome the issue or address the policy gap. During this part of the process, input from the ODZOB and the GGD is taken, on both the specifics and the implementation of the policy. The effects of these policies are then calculated, and the policy options are developed to a point ready for implementation. In addition, input is taken from citizens directly, as will be discussed below. Once the polices are ready, they are then passed on to decision makers for approval.

### 3.4.5. The Participatory Aspect

Due to the nature of air quality, where it directly affects the health and well-being of citizens, there is a lot of public attention and involvement in the creation and monitoring of air quality policies, which leads to the process being set up in a participatory fashion, where other parties have the ability to provide their input in almost every phase.

To communicate the wishes and desires of citizens however, they must first trust the organisation or entity that they are talking to. And as mentioned by multiple interview subjects, "residents trust the GGD the most, and the decision makers the least", leading to an unique position for the health services to act as both an advisory body and a conduit for citizen input and concerns (I,II). This is in no small part because according to the citizen "the GGD always takes up their plight and fights for the health of the community and the people within it" (II). Therefore they value the inclusion of this organisation in the policy processes, such that they feel like their health is given appropriate weight.In this capacity, the GGD "advises residents on where, when and why you need to measure to obtain useful advice."(I). This is further enhanced by the comprehensibility of the topic of health which , unlike the municipality, ODZOB and RIVM, the GGD communicates in primarily.

Under the new Omgevingwet, there is supposed to be a shift in this however. According to one interviewee "the new environmental vision places health centrally in its goals." (II). This shift away from the technical jargon was also reflected in the SLA in subsection 3.2.3 wording of the ambitions which focus on gains in public health rather than specific norms or pollutants. Through the adoption of this framing, combined with a focus on a healthy living environment, multiple issues come together like "the initiatives for more green space by water management boards for flood management provides an opportunity to improve the health of residents by positively influencing their environment" (I), which can lead to increased acceptability and political will for policy avenues.

This aspect of "maatschappelijk draagvlak" (societal acceptance) returned in multiple interviews (I, II,III), which indicates the importance of involving citizens in the policy and decision making process. For example, it was mentioned how "the proper framing of initiatives to increase societal acceptance in the context of increases in green space is critical to getting them passed through the decision making process". This also means that sometimes policies, which would be highly beneficial for multiple aspects like health, might not get passed because they are controversial among a large part of the population. An example of this would be the removal of the car in the center of Eindhoven. The route that currently goes through Eindhoven, "has been made as unattractive as possible, but it cannot be closed as there is no political will for this measure".

### 3.4.6. The decision Making

Even if air quality policies are not always disruptive and a financial burden on municipalities, they are still politically sensitive leading to decision makers thoroughly evaluating and weighing all the available options when deciding on the adoption of air quality legislation with the political composition of the decision making bodies having a strong influence on the efficiency and throughput of air quality policy making. Under the category of decsion-makers, we understand it to be the that group of elected officials who are responsible for implementing the formation accords.

The first step in the decision making process depends on the nature of the policy iniative. If a policy measure falls within the responisibilities allocated to the municipal government by the municipal council, it can develop a new policy iniative on its authority. Policies that fall under these responsibilities would be those that are proposed under "the space and budget allocated to the policy advisors in the municipality which they only have to coordinate with the wethouder" (II) . The alternative is as follows: "for "measures that fall outside of the purview of the municipality the municipal council has to initiate the project or policy, which is something that occurs regularly in Eindhoven, where decision makers already ordered an investigation into the progress that had been made since the 2015 NSL goals" (II).

In this case, the wethouder meets with the responsible policy advisors within the municipal government and from external organisations like the GGD and the ODZOB, to draw up a plan which can be worked on by each party individually. As mentioned in chapter 1, Eindhoven is the second to last city in the Netherlands with regards to air quality, which gives a significant political incentive for decision makers to focus on this issue, leading to the latter alternative being very common in the municipality. As discussed in subsection 3.4.3, the drive for new policy initiatives might come from many directions, but the brunt of them are decided upon during the coalition forming process.

### 3.4.7. The Implementation and Evaluation of Policies: Permitting, Monitoring and Enforcement

The implementation of policies into reality is one of the key responsibilities of the municipality, which ensures the proper performance of policies and also monitors them throughout their operations. However, if a policy creates new requirements for projects, or commercial activities, they will need to receive permits and be monitored by the ODZOB.

To ensure the proper implementation of policies and the achievement of standards, it is paramount that initiatives are evaluated such that feedback can be given to policy and decision makers who can then use the information to monitor if the municipality is on track to meet both its own ambitions and the legal requirements outlined in section 3.2.

Once the council agrees on a certain measure, and it is passed into the local legislation, the iniative can move to the last player in our process: the ODZOB. The ODZOB is the regional environmental service, of which there are 29 throughout the Netherlands. These organisation are regional entities that are tasked with both core and request activities (IV). Core activities are structured into a system with three main areas, Permitting, Monitoring and Enforcement. It should also be noted that environmental services are "obligated by law to have experts for every one of the main environmental areas (air, water, noise, soil, traffic and so forth) which is checked through a peer-review process where fellow environmental services audit each other"(IV). These peer activities extend into a national cooperation network where knowledge, sensors and tools can be shared to aid in situations where some aspect might be missing in one organisation.

The first core area, Permitting, is rather straightforward. Any activity of a commercial scale, which is associated with a certain environmental risk, has to possess or apply for a permit with the ODZOB. Under the current legal system (pre-*Omgevingswet*) the process is as follows: "A permit application by an entity is evaluated according to national, provincial and local rules on such factors like noise, soil and air pollution and the environmental impact is modelled according to simple calculation models and generic standards. If the impact is deemed sufficiently small or appropriately mitigated, the permit is then passed and the activity may be implemented or executed." (IV). At this point, the role of the permitting authority is finished, and the monitoring officials take up the flag, with no further involvement from the former in the ensuing process.

Once an iniative is implemented, the Monitoring phase commences. In this part of the process there is a wide application of both modelling tools and sensors. It is also here that the biggest issue in the last phase of the policy process arises. Namely that "norms and standards are based upon emissions, which are then used in the permitting process, however for the monitoring area, the immission and mixing lead to the final concentration that are both measured by experts and perceived by citizens. This disconnection between the source of the pollution and the way those pollutants finally deposit after a while causes situations similar to the one occurring recently where "individual companies and farms all are within the limits of their permits, but the mixing between their emissions still lead to local exceedances and contribution to the nitrogen issue". Especially with respect to nitrogen, where accumulation is the main concern currently, there seems to be a strong lack of cooperation and integration between the Permitting and Enforcement groups. In the interview it was mentioned that there is "a strong need for a framework that does not solely evaluate based on individual entities and emissions but rather takes a collective view, determines the available budget for more emissions and extends permits based on this" (IV). It was also indicated how there is "a lack of appropriate modelling tools which aid environmental services by allowing for the simulation and calculation of the interaction between the emissions of different companies and how they result in depositions." (IV).

When a permit is exceeded, depending on the size of the violation, an enforcement officer will award an appropriate punishment, ranging from a fine and recommendations for resolving the violation to the extreme case where law enforcement is used to ensure the immediate halt to the activities that are leading to the violation.

Finally, as mentioned in subsection 3.4.3 the ODZOB also has the ability to signal areas for new policy initiatives and contributes more generally in developing policy to ensure its feasibility in the enforcement phase. The above mentioned network with other environmental services also allows the ODZOB to influence and contribute to national policy development and the implementation of new laws and standards. In the interview it was even mentioned how the ODZOB had a "specific board of experts named the "environmental quality team" which provides specific policy advice and policy pieces to municipalities on subjects that they have a lot of expertise with" (IV). However, it is important to note that "the environmental service legally speaking only has an advisory role, with municipalities having the final say in decisions but practically municipalities adopt policy advice in the majority of cases and there is intense cooperation between the organisations" (IV). This all fits into the more "integral" approach that the ODZOB is aiming for with the new *Omgevingswet*, which was discussed in subsection 3.2.4.

The ODZOB is also a big contributor to the regional measuring system in the region, which it hopes can obtain a legal backing in the near future, allowing for a finer level of monitoring and enforcement of air quality policy. In the vision of the interview subjects, "through the use of cheaper and accessible sensors and a legal framework for their use, monitoring can become very tailored allowing for well-informed permitting process" similar to the one mentioned above. They also mentioned how "models could be used in combination with reference points with validated measurements to validate the regional measuring system and providing a high resolution map of emissions and air quality which is not only composed of a reality based on paper but rather one on the basis of empirical measurements." (IV) If this is coupled to the aforementioned legal framework, air pollution could not only be connected to more general activities like livestock farming or the morning rush on roads but specifically be tied to an activity like the filling of a feeding through, or the startup of car engines on cold days (IV).

### 3.4.8. Visualising the Policy Process

Now that we have gone through the different phases of the policy process, we can visualise the different steps, and the players involved in every step. In Figure 3.3 this is presented, with five distinct phases included. It can be seen that we are now only considering the system, and have not included the system boundary.

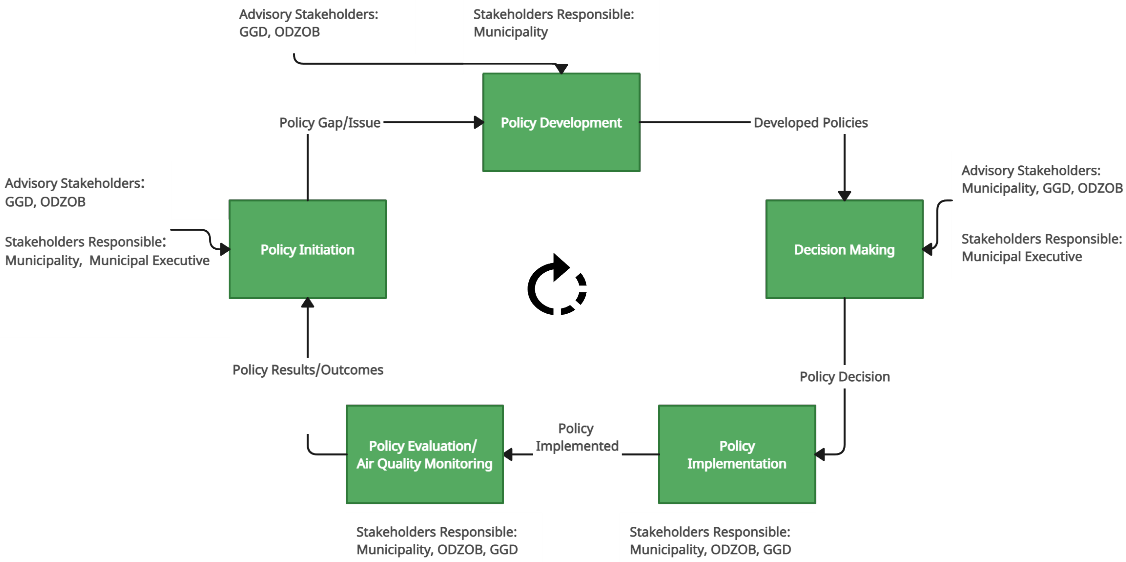


Figure 3.3: Visualisation of the municipal air quality policy process.

It should be noted that the policy process is not actually cyclical in nature, and can take on many different patterns depending on the policy and topic (Enserink et al., 2022). However, for a clear visual representation of the system, that would allow the reader to quickly comprehend the relations between the phases, this structure was adopted. It should be noted that every box represents a distinct step and activity of the policy process, whilst every arrow indicates an input/output.

If we were to go beyond the system boundary now, and include the critical inputs into the municipal air quality policy process, we arrive at Figure 3.4 presented below.

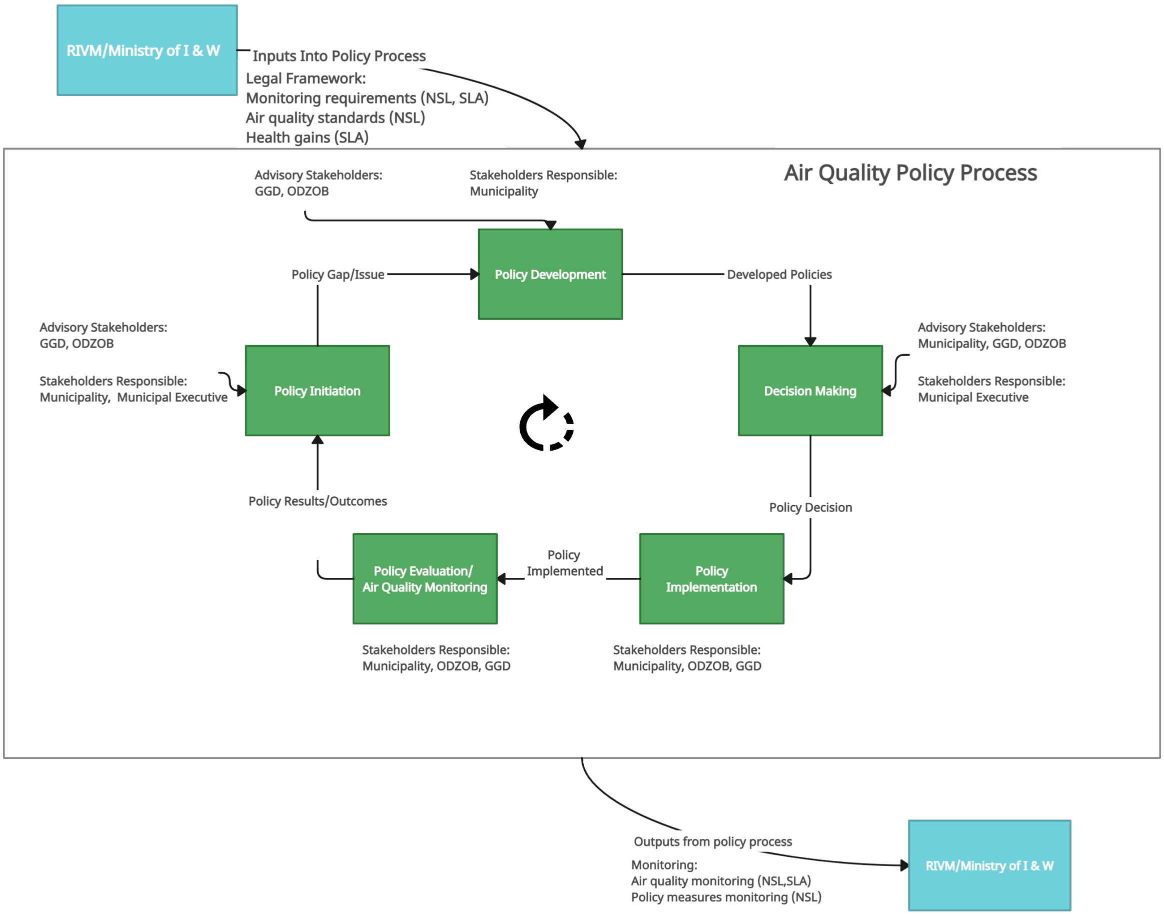


Figure 3.4: Visualisation of the municipal air quality policy process including external inputs and outputs.

This figure thus gives an overview of the structure of the policy process, and we will be basing our further analysis of the process on it.

As can be seen from the figure, there is a lot of interaction between the key stakeholders identified in this chapter. Cooperation between the different parties is therefore paramount to achieving successful policy development and implementation. Furthermore, aligning the expectations and analysing the goals of each stakeholder is therefore critical to improving the policy process, which we will investigate in further detail in chapter 6.

# 4

# The Use of Air Quality Modelling Tools

With a better understanding of the municipal air quality policy process developed in the previous chapter, we can now move on to evaluating how the specific stakeholders each incorporate and use models in their respective procedures.The relevant research question for this chapter is as follows. **”By whom and in which manner are air quality modelling tools used in these policy processes?”**. To answer this question, we must therefore identify which actors are involved with modelling, which models they use and how they use them in their respective procedures.

We have classified models used for simulating air quality models into two main categories: air quality models, and health models that translate air quality into health impacts. A third category of ”Other” models will also be included, containing those models that are significantly relevant to the discussion but which do not fall under the moniker of the aforementioned two categories. Examples of this include the NSL Monitoringstool, in which municipalities must report their policy initiatives. In section 4.1 we will describe these models in more detail, including a discussion of the new CIMLK model which was introduced in 2023. After this, we will introduce and go over all the stakeholders who are involved in the policy process in a modelling capacity in section 4.2. Finally, we will discuss the relevant conclusions in section 4.3.

## 4.1. Modelling Tools

We can now describe these models (both air quality and health models) and their features, determine the legally mandated models and identify the gaps for improvement that we might be able to fill in the next chapter.

### 4.1.1. Overview of Models Methodology

To get a clear understanding of how the different modelling tools are used, let us put them in their proper context. As we mentioned in the previous chapter, there are three main modelling related activities that the municipality of Eindhoven is involved: the modelling of traffic emissions, surface/point source emissions and the monitoring and improvement of air quality within the framework of the NSL and SLA. For each of these we can briefly present which models are relevant and what inputs and outputs are associated with them. All of the models are described in further detail in this chapter.

**Modelling of Traffic Emissions**

In Figure 4.1 below the basic structure of the modelling process is presented. At the beginning we have the Emissie Registratie, which outputs maps of the Netherlands with the distribution of emission sources. This is then used as an input in the OPS (Operationeel Prioritair Stoffen) model, which calculates the GCN/GDN maps (maps of the deposition and concentration of air pollutants in the Netherlands), which are an input for the CIMLK (Centraal Instrument Monitoring Luchtkwaliteit) calculation tool which calculates the emissions resulting from traffic. This is then fed back into the Emissie Registratie, but also into the CIMLK Monitoring tool as inputs.

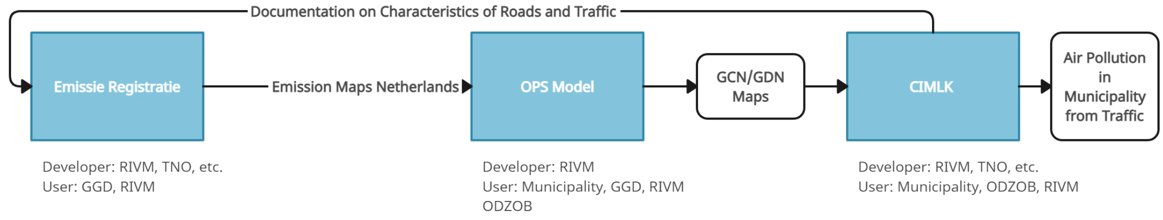


Figure 4.1: An overview of the interaction between the different models used for modelling traffic related emissions.

### Modelling of Surface/Point Source Emissions

For the surface and point source emissions, presented in Figure 4.2, the setup is very similar, with the main difference being that the Nieuw Nationaal Model (which calculates emissions for the surface and point sources) does the final calculations and that there is no feedback into the Emissie Registratie.

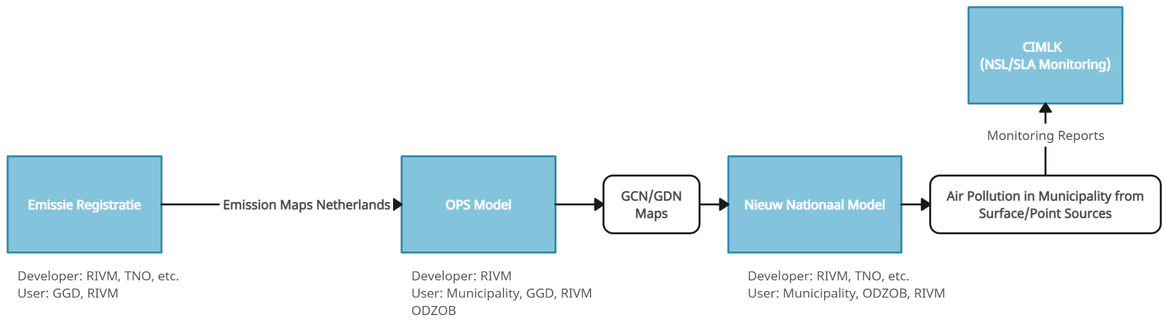


Figure 4.2: An overview of the interaction between the different models used for modelling surface and point source related emissions.

### Monitoring of Air Quality Within Legal Framework

Finally, in Figure 4.3 the interaction with the legal framework and the policy process is outlined. It should be noted that "Outputs from ..." refers to the two modelling processes described above.

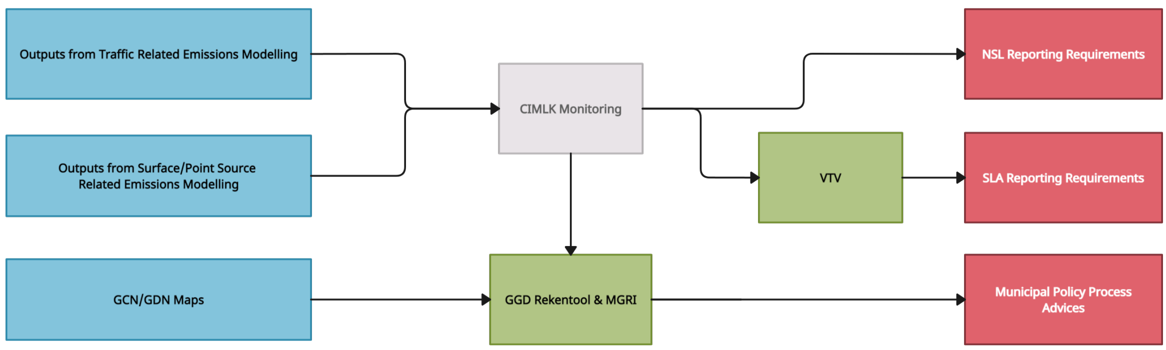


Figure 4.3: An overview of the interaction between the different models and their purposes.

The GGD Rekentool (named after the municipal health service, which develops it) calculates the exposure and health effects of air pollution on the citizens. The MGRI (Milieu Gezondheids Risico Indicator) does the same but includes other sources of environmental pollution like noise. Finally, the VTV (Volksgezondheids Toekomst Verkenning) measures the more general long term health of the Dutch population, which is used as an input into the reporting requirements of the Schone Lucht Akkoord.

With this discussion of the basic structure of the modelling process, we can now go into further detail on each specific model.

### 4.1.2. Models Currently In Use

In this section, we will describe the key characteristics of all of the modelling tools identified previously. The description includes the nature of the model (air quality, health or other), the calculation method, the users and the developers of the model, as well as other relevant information.

**NSL-Rekentool**

The NSL-Rekentool was the original air quality calculation tool, developed and brought into service after the introduction of the NSL program in 2009 (Kenniscentrum InfoMil, n.d.-w). It was created to allow all governmental organisation to calculate the air quality in their territories, and to determine the impacts of certain policies. It is based upon the SRM1 and 2 calculation methods, which are described in further detail in subsection 4.1.4. It was replaced by the Aerius Lucht Rekentool in 2019. It was used by the Municipality of Eindhoven and the ODZOB until recently (IV,V). It is developed by the RIVM and its use is legally mandated under the NSL. It uses the GCN and GDN maps for background concentrations, the Emissie Registratie for emission factors, both described below, as inputs, as well as the data on policy measures and concentrations from the NSL Monitoringstool (Wesseling & Beijk, 2010). It allows for ”online and real time calculation of the air quality”. Finally, the NSL Rekentool is primarily concerned with the emissions from traffic and roads.

**Aerius Lucht Rekentool**

Being the successor to the NSL Rekentool, the Aerius Lucht Rekentool was brought into service in 2019 (Kenniscentrum InfoMil, n.d.-e). It is a model that is part of the larger Aerius modelling suite, which is primarily used to calculate nitrogen emissions, transport and deposition in the Netherlands (RIVM, n.d.-a). The functions of the model remain identical to the NSL Rekentool, with only minor differences in functionality (Kenniscentrum InfoMil, n.d.-e). It too is based upon the SRM1 and 2 calculation methods as described in subsection 4.1.4. It is currently in use with the municipality and the ODZOB. The municipality did continue to use the NSL Rekentool until recently due to the loss of certain features in the Aerius Lucht Rekentool (Kenniscentrum InfoMil, n.d.-e). Development of the Aerius tool is also once again done by the RIVM, with its use being mandatory under the calculation requirements under the NSL. Similarly, the GCN and GDN maps are used for background concentrations, the Emissie Registratie for emission factors, and the NSL Monitoringstool for policy measures currently underway (RIVM, n.d.-m).

**Centraal Instrument Monitoring Luchtkwaliteit (CIMLK)** The final successor of the two models described above, the CIMLK came into use starting January 1st, 2023. It replaced both the Aerius Lucht Rekentool and the NSL Monitoringstool (RIVM, n.d.-c). This means that is able to calculate both the traffic emissions that Aerius previously did, as well as keeping track of the air quality measures and levels throughout the country like the NSL-Monitoringstool did. This is part of the larger transition under the *Omgevingswet*, which tries to bring together the different tools and streamline the process, including the SLA reporting requirements (Rijkswaterstaat, n.d.-c). The CIMLK is built on the Aerius Lucht Rekentool, which is described as the ”calculation heart of the CIMLK” (RIVM, n.d.-c). This means that the CIMLK still uses the same standard calculation methods as the previous two models (SRM1 and 2). It is be used by the Municipality of Eindhoven and the ODZOB, developed by the RIVM and legally required to be used for calculating the air quality and policy measures under the NSL and SLA (RIVM, n.d.-c).

**Nieuw Nationaal Model (NNM)** The NNM is the standard model for the calculation method SRM3. Its main purposes are evaluating permit requests and determining the effects of certain policy measures (Kenniscentrum InfoMil, n.d.-x). This method is used to calculate the spread of air pollution from point and area sources using a Gaussian plume model (Kenniscentrum InfoMil, n.d.-a). It was introduced in 1998 and falls under the Regeling *Beoordeling Luchtkwaliteit 2007* (Air Quality Assessment Scheme 2007) which sets out the specifics on how and when the air quality should be measured (Kenniscentrum InfoMil, n.d.-s; Rijkswaterstaat, n.d.-d). It is in use with the ODZOB, but is currently in the process of being replaced by STACKS+ (GeoMilieu) (V). It is developed by the Werkgroep LuchtkwaliteitsModellen (WLM) which the RIVM plays a prominent role in (Kenniscentrum InfoMil, n.d.-f).

**STACKS+ (GeoMilieu)** STACKS+ (Short Term Air-Pollutant Concentrations KEMA modelling System), as part of the GeoMilieu modelling suite, is a model package developed by DGMR software, that allow for the calculation of air quality according to all three of the standard calculation methods (SRM1, 2 and 3). It is the ONLY commercial model that is certified by the by the Ministry of Infrastructure and Water Management, and also the only one that is certified for all three standard calculation methods (Ministerie van Infrastructuur en Waterstaat, 2021). It is currently being put into service by the ODZOB, supplanting the NNM for permitting calculations (V). It can also be used by the municipality for calculating the air quality if they wish to do so. Insofar, it can be a substitute for the CIMLK tool, although the official reporting still has to be done in CIMLK.

**NSL-Monitoringstool** The second main leg of the NSL, the NSL-Monitoringstool is the tool used by the RIVM to monitor compliance with the NSL and the database in which the policy measures are filled in by local governments. The exact relation between the Monitoringstool and the Rekentool can be seen in Figure 4.4, where the ”calculation tool” was first the NSL Rekentool, which was then replaced by the Aerius Lucht Rekentool. The important distinction is that the Monitoringstool monitors emisisons and policies, whilst the Rekentool calculates emissions.

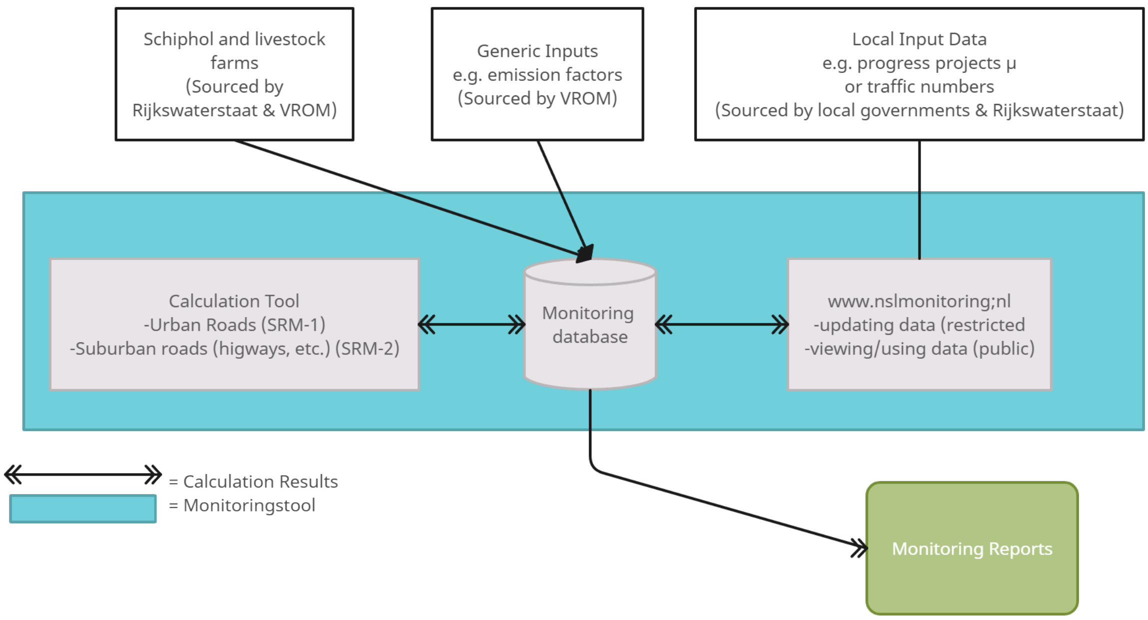


Figure 4.4: A schematic overview of the NSL Monitoringstool and the NSL Rekentool based on (Wesseling & Beijk, 2010).

The whole setup will be replaced by the CIMLK, but a similar structure will be maintained, with a calculation tool and a monitoring tool with an attached database. The NSL-Monitoringstool is, arguably, the most important element of the larger set of models described in this chapter. It, and its successor the CIMLK, are key to the two most important stakeholders: the RIVM and the municipality. They both use it to complete their mandatory reporting requirements to the European Union and the national government respectively (Kenniscentrum InfoMil, n.d.-g, n.d.-n). It is developed by the RIVM and will be replaced in service by the CIMLK starting from the 2023 monitoring round.

**Emissieregistratie (ER)** The *Emissieregistratie* (Emissions Inventory, ER) is a program by a consortium of five government organisations, with the RIVM being the responsible organisation, which ”annually records emissions from all relevant Dutch sources. The ER calculates most of the emissions itself and checks the company emissions supplied each year. The emission data are spatially distributed so that it is known where emissions are released. Reports are also produced annually in accordance with international agreements.” (Emissieregistratie, n.d.-a). One of the outputs of the ER are emission factors which are then used in the Operationele Prioritaire Stoffen (OPS) model described below to obtain the GCN/GDN maps(Emissieregistratie, n.d.-c; RIVM, n.d.-k). These maps are then used in the NSL Monitoringstool and Rekentool (and Aerius Lucht Rekentool, CIMLK) to determine the background concentrations of air pollution (Kenniscentrum InfoMil, n.d.-g)(V). The ER is therefore only directly used by the RIVM, and the GGD uses the output emission factors for their calculations in the GGD Rekentool.

**OPS/GCN/GDN Maps** As mentioned above, the OPS (Operationele Prioritaire Stoffen) model uses multiple inputs to calculate the emission, dispersion, transport, conversion and deposition of air pollutants (RIVM, n.d.-i). One of the inputs is the ER mentioned above. The outputs of the model are then concentration and deposition fields, which can then be distributed using a GIS-tool (RIVM, n.d.-f). In Figure 4.5, a schematic representation of the functioning of the OPS model can be seen, where the upper box, "Data geleverd door RIVM" indicates the data from the ER.

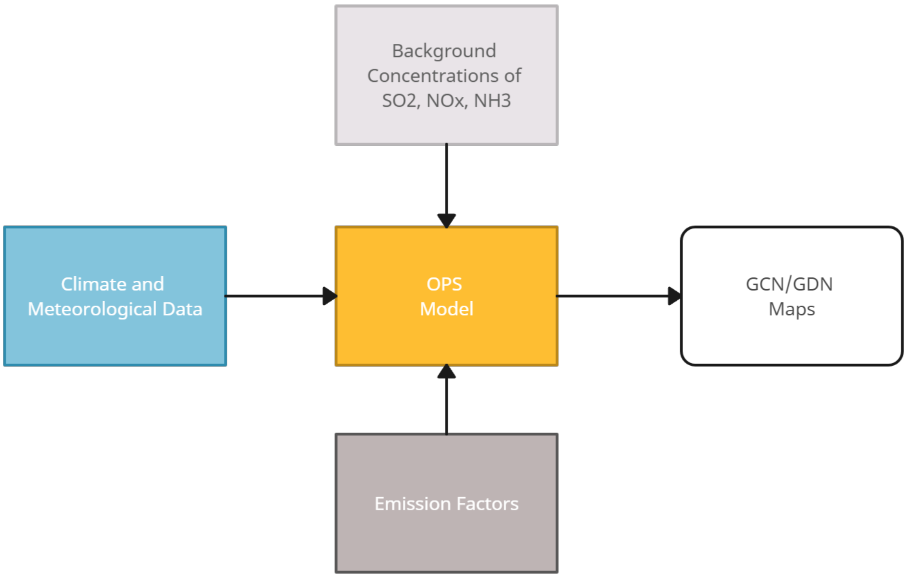


Figure 4.5: Schematic view of the OPS model, its inputs and outputs based on (RIVM, n.d.-f).

The model itself is used by the RIVM, but the output, the GCN/GDN (Grootschalige Concentratie/Depositie Nederland) maps are then used by the the municipality, the GGD, the ODZOB and the RIVM as inputs for background concentrations in their respective modelling tools (NSL Rekentool,Aerius Lucht Rekentool, GGD Rekentool, STACKS+, NSL Monitoring)(ODZOB, n.d.-a)(I)(Rijkswaterstaat, n.d.-b).

**GGD Rekentool** The GGD Rekentool is a modelling tool developed by the different municipal health services in the Netherlands, and which can be used to "translate exposure to air pollution into expected health effects such as premature mortality and disease burden within a population."(Academische werkplaats gezonde leefomgeving, n.d.). It is the most up-to-date and recent model, being most recently updated in 2021, and allows for the calculation of health effects for three major pollutants:$PM_{10}$, $PM_{2.5}$ and $NO_2$ (Academische werkplaats gezonde leefomgeving, n.d.). It is used by the GGD Brabant Zuidoost to perform research like the one recently published on the health impacts of air pollution in the province Noord-Brabant (Denissen, 2022). It uses the yearly averages and emission factors from the GCN/GDN maps and the ER as inputs and returns estimates for disease burden and premature mortality (Denissen, 2022).

**Volksgezondheid Toekomst Verkenning (VTV)** The VTV (Public Health Future Outlook), named after the quadrennial report it was originally developed for (RIVM, n.d.-l), is a modelling tool developed by the RIVM that allows for the calculation of health effects of a variety of factors, like air quality. The methodology of the model can be seen in Figure 4.6, where the exposure is a result of the combination of the GCN/GDN maps with the distribution of population across the Netherlands at the street level. This is then combined with statistical information on relative risk of health effects to achieve a Population Attributable Fraction (PAF), which is the measure of how much of the chosen "disease burden" (e.g.

morbidity, mortality or health expenses) can be attributed to air pollution exposure (Gerlofs-Nijland et al., 2020).

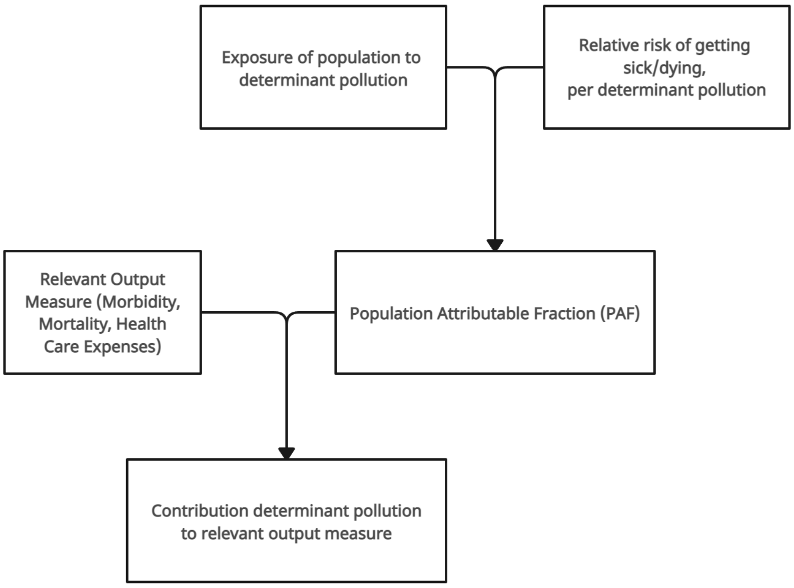


Figure 4.6: A schematic view of the VTV model based on (Gerlofs-Nijland et al., 2020)

The model is relevant because of its position as the chosen tool for measuring the progress of the SLA. The results of the reporting requirements of the SLA are run through the VTV model by the RIVM to determine the relative health gain with respect to the base year of 2016 (Fischer et al., 2015). This is the main difference between the VTV and other health models, namely the Milieu Gezondheids Risico Indicator (MGRI) and GGD Rekentool. Where the VTV is used to monitor the health impacts under the SLA, the other two are tools used to quantify these health impacts and to simulate the effects of certain policies.

**Milieu Gezondheids Risico Indicator(MGRI)** The final model in the list, the MGRI (Environmental Health Risk Indicator, sometimes abbreviated as MGR) is a model that allows for a "health assessment of environmental quality. With this tool, you can identify locations where (future) residents, based on the cumulative environmental impact, are at high risk of health effects."(Informatie- en Kennispunt Gezonde Leefomgeving, n.d.). It was developed by the RIVM in 2016 and further detailed in a pilot project in the Municipality of Eindhoven (RIVM, n.d.-h, 2019). It is used by the municipality and the GGD as the primary tool to assess health effects of policies (II). It differs from the GGD Rekentool in its higher accuracy, but it lacks the discerning power between pollutants.

### 4.1.3. Table of Models Used in Air Quality Policy Process Eindhoven

The key characteristics of these models are listed in Table 4.1, where the following categories are included. Model type describes the nature of the model, be it air quality, health or other. The calculation method is the calculation method that the model is based on, which is primarily relevant for the air quality modelling tools. The extra information category includes information on the status of the modelling tools, like for example the NSL-Rekentool which is currently in the process of being replaced. The next two categories describe the users and developers of the model, followed by the legal requirement to use certain models. Finally, the Legally Mandated category indicates whether the model use is obligatory in the current legal framework.

Table 4.1: Models Currently In Use

| Model | Model Type | Calculation Method | Extra Information | Used by | Developed by | Legally Mandated |
|---|---|---|---|---|---|---|
| NSL-Rekentool | Air Quality | SRM 1 & 2 | Succeeded by Aerius Lucht Rekentool | Municipality, ODZOB | RIVM | Yes |
| Aerius Lucht Rekentool | Air Quality | SRM 1 & 2 | Will be succeeded by CIMLK | Municipality, ODZOB | RIVM | Yes |
| CIMLK | Air Quality | SRM 1 & 2 | Introduced in 2023 | n.a. | RIVM | Yes |
| Nieuw Nationaal Model | Air Quality | SRM 3 | Will be succeeded by STACKS+ (with ODZOB) | ODZOB | WLM | Yes |
| STACKS+ | Air Quality | SRM 1 & 2 & 3 | Currently being taken into service by ODZOB | ODZOB | DGMR | No |
| NSL-Monitoringstool | Other | SRM 1 & 2 | Will be succeeded by CIMLK | Municipality, RIVM | RIVM | Yes |
| Nationale Emissie Registratie | Other | n.a. | Outputs emission factors | GGD | RIVM | No |
| OPS/GCN/GDN Maps | Other | Background concentrations of air pollution | Grootschalige Concentratie/ Depositie Nederland, Output of OPS | Municipality, GGD, RIVM ODZOB | RIVM/TNO | Yes |
| GGD Rekentool | Health | n.a. | Based on (Maas et al., 2015) | GGD | GGD GHOR | No |
| VTV | Health | Dynamo Health Impact Assessment (den Broeder et al., 2022) | Volksgezondheid Toekomst Verkenning, used to quantify health effects for SLA | RIVM | RIVM | Only for SLA |
| Milieu Gezondheids Risico Indicator | Health | Milieugerelateerd gezondheidsrisico | Pilot Project in Municipality Eindhoven in 2016 (van Heeswijk, 2016) | Municipality, GGD | RIVM | No |

### 4.1.4. Legally Mandated Methods

As can be seen from Table 4.1 in the previous section, there are a certain number of legally mandated models or calculation methods. These are worth exploring in more detail, as these are the ones which set the context in which the air quality policy process takes place. This does not only apply to the Municipality of Eindhoven, but other government bodies in the Netherlands as well with reporting requirements. They will all have to use these same legally mandated methods.

These legally mandated methods were originally developed with two goals in mind. Firstly, the methods, first outlined in the Regeling Beoordeling Luchtkwaliteit 2007 (Rbl 2007) follow the framework set out by the European Union for determining air quality, which allows them to be used for the monitoring requirements set out by these EU rules (Kenniscentrum InfoMil, n.d.-s). Secondly, and perhaps more importantly, it was found that, "measurements and calculations of air quality in the past few years have always returned different concentrations of pollutants" (Visser & Wesseling, 2020). To ensure that all parties to the air quality policy process would be working with the same information, it was agreed that under the NSL, everyone would use the same calculation methods (Visser & Wesseling, 2020).

**SRM1** Firstly, we have the *Standaardrekenmethode 1* (Standard Calculation Method 1), SRM1 for short. This method, which is used in the NSL Reken/Monitoringstool, Aerius Lucht Rekentool, CIMLK and STACKS+ models to calculate traffic emissions, is focused on roads of the type 0 through 4, as can be seen in Figure 4.7. These roads are classified as "inner city roads", and thus very relevant for the municipality in its calculations. For an exact technical description, please refer to the technical documentation (RIVM, 2015).

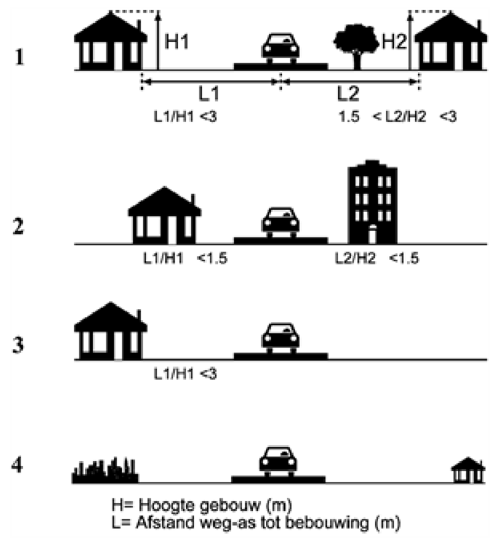


Figure 4.7: Road types 0 through 4, where H is the height of the building (m) and L is the distance between the middle of the road and the building (Kenniscentrum InfoMil, n.d.-v).

Any policy measure, permit or change in local regulation that thus applies to the inner city will therefore have to have its effects calculated through the use of a model that uses this calculation method (Kenniscentrum InfoMil, n.d.-v). In this environment, "a road segment and its associated calculation point have a direct relationship" (Kenniscentrum InfoMil, n.d.-v).

**SRM2** Being very similar in purpose as the SRM1 method, SRM2 is used in the NSL Reken/Monitoringstool, Aerius Lucht Rekentool, CIMLK and STACKS+ models to once again calculate traffic emissions. This method applies to suburban roads, provincial roads and highways, the exact specifications as visualized in Figure 4.8.

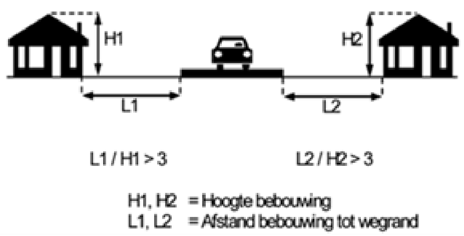


Figure 4.8: A road falls under SRM2 if the ratio between the distance from the road edge to buildings is larger than three times the height of the buildings (Kenniscentrum InfoMil, n.d.-v)

Although the responsibility for highways (Rijkswaterstaat) and provincial roads (Provincie Noord-Brabant) within the territory of Eindhoven are not administered by the municipality, they are still of relevance to it due to the air pollution that is spread over the municipality (Ministerie van Infrastructuur en Waterstaat, n.d.). The main difference in calculation method concerns the effect of the environment that is taken into the calculations, especially with regards to highways (Kenniscentrum InfoMil, n.d.-v). When measuring the concentrations near these roads, or calculating the effect of policy measures in surrounding neighbourhoods, the SRM2 method is used in their models.

**SRM3** The third and final of the standard calculation methods, the SRM3, is used for the calculation of air pollution from point and surface sources. It is used in the Nieuw Nationaal Model (NNM) and the STACKS+ model, the latter of which the ODZOB is putting into service currently to replace the former. Alternative modelling tools that use this method are the PLUIM-PLUS model by TNO and ISL3a by the former Ministry of Infrastructure and Environment (Kenniscentrum InfoMil, n.d.-b). It is especially relevant to the permitting activities of the ODZOB, where it is legally required.

**NSL Monitoringstool** The NSL monitoringstool is used to perform the mandatory yearly reporting of air quality levels in Dutch municipalities (this will be become a biennial requirement under the new *Omgevingswet* (V)) which are then monitored by the Ministry of infrastructure and water management to ensure the compliance with standards under the NSL. Policy measures that the municipality implements are also reported in these tools, which are then included in the calculations of air quality (Kenniscentrum InfoMil, n.d.-n). The inclusion of these policy measures allows for the Ministry and users of the model to have a better understanding of the true state of air quality in the different regions. The yearly reporting of air quality to the European Union is also performed through this tool (Kenniscentrum InfoMil, n.d.-n).

**CIMLK** Being the successor of the Aerius Lucht Rekentool and the NSL Monitoringstool, the CIMLK will also become an obligatory tool for calculating the air quality under the new *Omgevingswet*, following the same SRM1 and 2 calculation methods.

**SLA Commitments** Under the Schone Lucht Akkoord, which the Municipality of Eindhoven has signed, the participants commit to a reduction of health effects related to air pollution of 50% (“Het schone lucht akkoord”, n.d.). To monitor this health impact, municipalities report the same information that they are legally obligated to report under the NSL. This was previously done in the NSL Monitoringstool, and will from 2023 on be done in the CIMLK. The RIVM then uses this data as an input to the *Volksgezondheid Toekomst Verkenning* (Public Health Futures Exploration) model, VTV for short. This model then calculates the reduction in YLL (Years of life lost from mortality. (World Health Organization, n.d.)). Based on this, the progress of the undersigned parties is monitored.

### 4.1.5. Model Timeline

In addition to the users of the models and in which parts of the policy process they are involved, we have also investigated when the models currently in use were first developed. Figure 4.9 presents these dates, as well as the chronological order of model development. An arrow indicates the super-session by one model by another.

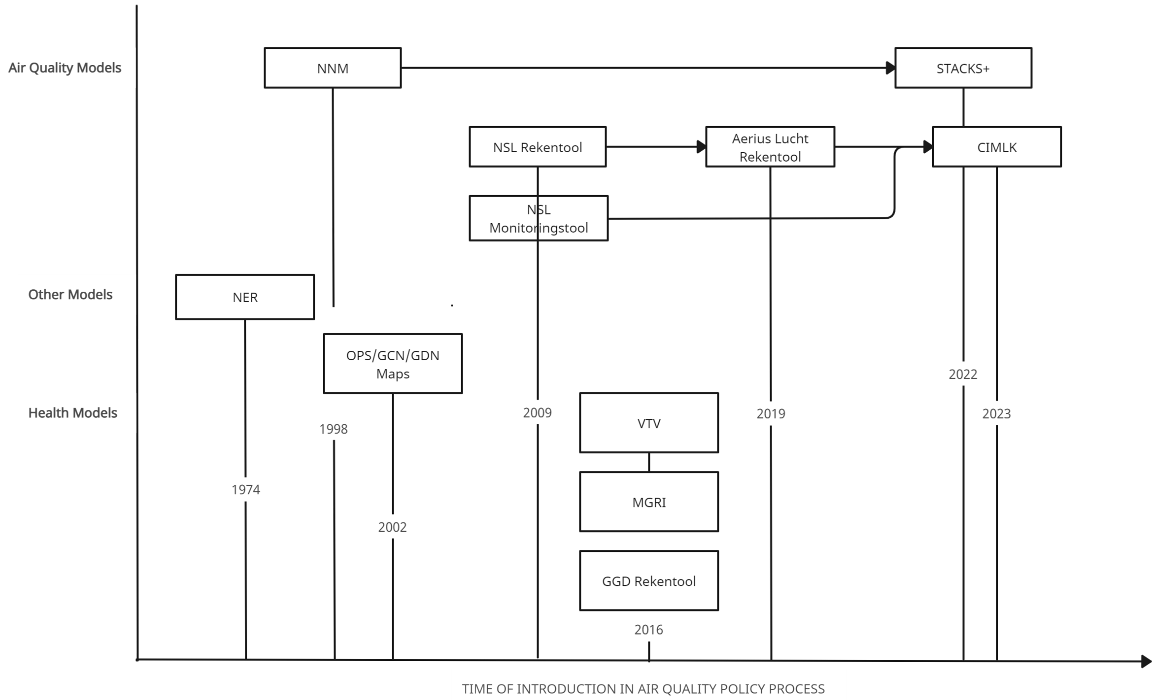


Figure 4.9: Model timeline(Academische werkplaats gezonde leefomgeving, n.d.; Emissieregistratie, n.d.-b; Kenniscentrum InfoMil, n.d.-d, n.d.-u; Rijkswaterstaat, n.d.-d; RIVM, n.d.-e)

As can be seen in the figure, some of the modelling efforts have been underway for almost 5 decades, whilst other models were only introduced in this very year. There is thus a clear signal that model developments can and do get incorporated in the municipal air quality policy process, which is promising for the improvements that we will discuss in the next chapter.

## 4.2. Modelling Actors

In the previous chapter, chapter 3, we already determined the relevant actors which will be discussed in this section. We will now expand upon this by considering which models they use or develop and for which purposes. For each actor we will mention which models they are involved with, in which capacity (user/developer) and the type of models.

### 4.2.1. Municipality of Eindhoven

The municipality is the nexus where all the information comes together to form policies and to support the decision making process. They are both responsible for modelling air quality as well as interpreting and translating the modelling results of other parties into policy.

**NSL Monitoringstool/CIMLK** Firstly, the municipality is legally required, as discussed in section 3.2, to report yearly on the current air quality situation within their city. These concentrations are calculated through the use of the NSL Monitoringstool. The tool is also used to report on the progress of air quality policies for the NSL like for example the low-emissions zone in the city center. The air quality information is also used for the calculation of the health gains under the SLA.

**NSL Rekentool/Aerius Lucht Rekentool, CIMLK** As will be further discussed in section 4.1, these three models serve the same function, being successive versions of the same fundamental calculation tool. The municipality uses these tools to calculate the air quality throughout the city, and to calculate the effects of policy initiatives and measures (V). It is obliged to do this under the legal framework of the NSL, as was discussed in section 3.2

**Nieuw Nationaal Model(NNM)** The municipality uses the NNM- tool to determine the air pollution results from point and surface sources, which is also obligatory under the NSL.

**Milieu Gezondheids Risico Indicator (MGRI)** The municipality uses the MGRI tool to calculate and communicate the health effects of the current default situation and the hypothesized situation with potential policy measures. At this point in time however, only the MGRI tool is used in the municipal air quality policy process. This is also done in a semi-voluntary manner, as under the NSL this is not obligatory. The model was developed in a pilot project between the RIVM and the Municipality of Eindhoven however, leading it to be well known with policymakers who had a clear picture of the value of the health outputs that the model provides.

Table 4.2: Models used by the municipality.

| Model Type | Role | Models |
|---|---|---|
| Air Quality Models | User | NSL Rekentool, Aerius Lucht Rekentool, NNM, CIMLK |
| Health Models | User | MGRI |
| Other Models | User | NSL Monitoringstool, CIMLK |

### 4.2.2. Gemeentelijke Gezondheidsdienst Brabant-Zuidoost (GGD Brabant-Zuidoost)

The GGD Brabant-Zuidoost, the public health service agency for Eindhoven, advises the municipality, the council and citizens on the health of residents of the city. To this end, the agency makes use of both air quality and health models, and contributing in the development of one model (GGD Rekentool). The main focus of their modelling efforts, as will become apparent below, is on assisting other organisations by translating air pollution to health effects and what these health effects mean.

Firstly, the GGD GHOR (the umbrella organisation of GGD's) develops the **GGD Rekentool**, which is a rather straightforward tool that can be used to calculate the health effects of air pollution and nitrogen. It is used by the GGD Brabant Zuidoost to advise and aid municipalities in their decision making through policy advice. A more extensive description of the modelling tool can be found in section 4.1.

Their policy advice can take many forms, ranging from direct consulting on projects, to independent reporting on the health quality as a result of air pollution (I)(Denissen, 2022). For the former, this will become even more regular under the new *Omgevingswet*, where every non-NIBM project is evaluated at the "Omgevingstafel" (Environment Panel), which contains experts from, among others, the municipality, the ODZOB and the GGD. Projects that do not fall under the NIBM-rule and fall outside the purview of standard templates as in the SRM's (see subsection 4.1.4 for an explanation on calculation methods) can then be modelled using the GGD Rekentool, to determine their impact on health through air pollution.

For the latter, the GGD performs its own research on areas that it believes deserve increased attention. For example, the GGD Brabant-Zuidoost recently delivered, in cooperation with two other GGD's a report on the connection between air quality and health in the larger area of Noord-Brabant, which includes the municipality of Eindhoven. To perform this research, use is made of the GGD Rekentool, the results of which were then made more accessible through the *"Meerookmethode"* (van der Zee et al., 2016).

Due to the nature of the organisation, which is primarily focused on the health aspect and less on the air quality modelling aspect, model usage by the GGD is of a different nature than the other players in this analysis. The focus shifts towards a health based approach, which is also reflected in the policy advice that the GGD provides to municipalities. The recommendations are structured in a more integrated approach, where "policy advice is connected to other challenges municipalities face, like the energy transition, housing crisis and the new *Omgevingswet*" (I). To quantify these health impacts through the GGD Rekentool however, data on the air quality is necessary. Currently, the GGD obtains most of this data through the official national emission registration (**Emissieregistratie, GCN/GDN maps**). More detail on these maps is given in the next section. The emission information that the GGD then uses are "yearly average concentrations which connect well with the scientific insights and knowledge from literature on the health effects of air pollution, which uses these same yearly concentrations" (I). The emissions data which is situated geographically then also allows the GGD to determine the specific contributions of each emission source to the health burden that residents experience. Because peak concentrations also contribute significantly to the health effects, especially for people that suffer from ailments like asthma, the GGD also calculates the health effects of these occurrences throughout the year (I). These peak moments are calculated from the yearly average concentrations that are then “calculated through scientific insights and relations to determine the health effects of the peak moments without measurements or data for these moments” (I). It is clear therefore that the GGD mostly uses air quality modelling tools in a limited manner, in order to obtain the data required to translate air quality levels into health impacts to be calculated with the health models.

Table 4.3: Models used/developed by the GGD.

| Model Type | Role | Models |
|---|---|---|
| Air Quality Models | User | n.a. |
| Health Models | User/Developer (GGD Rekentool) | MGRI, GGD Rekentool, GES |
| Other Models | User | Nationale Emissie Registratie, GCN/GDN |

### 4.2.3. Omgevingsdienst Zuidoost Brabant (ODZOB)

The environmental service, the ODZOB, is responsible for ensuring that firms and other business-like activities (activities above a certain scale of impact) comply with the range of laws and rules concerning the environment, including those concerning air quality. This concerns the permitting process and ensuring new projects adhere to both the national and local legislation. The monitoring and enforcement of compliance with these permits also falls under its purview. To do all of this, the ODZOB uses a combination of models, which allow it to perform both its own activities and advise the municipality on its programs, initiatives and policies.

For its permitting process, the ODZOB uses **Aerius Luchtrekentool/NSL-Rekentool/CIMLK** to calculate the air pollution from traffic, but it is in the process of taking into service the STACKS+ model, developed by DGMR. This module will also replace the NNM that was used to model surface and point sources, which are the most relevant for the permitting process (IV).

In addition to the on-site inspections the ODZOB performs to monitor compliance with these permits, modelling tools are also used. The DGMR+ Stacks model will be used for this as well, in order to monitor the air quality and ensure compliance (V).

Table 4.4: Models used by the ODZOB.

| Model Type | Role | Models |
|---|---|---|
| Air Quality Models | User | Aerius Rekentool/NSL Rekentool, DGMR Stacks+ |
| Health Models | User | n.a. |
| Other Models | User | Nationale Emissie Registratie, GCN/GDN |

### 4.2.4. RIVM

The RIVM is the main model developer in the air quality governance arena, being directly or indirectly involved in the development off all of the models that are described in this chapter. Therefore, in this section we will describe their actions in a more generalized manner, in recognition of their more general responsibilities.

**NSL Monitoringstool/CIMLK** As described in section 3.2, the RIVM are the organisation to whom municipalities and other lower government bodies report with their air quality policy measures and the air quality levels. This information is collected in the NSL Monitoringstool, where it is used by the RIVM to monitor compliance with the NSL and to calculate the ”concentrations of air pollutants for the previous calendar year (...). The results of these calculations for the previous calendar year form the basis of the yearly air quality report to the European Union” (Kenniscentrum InfoMil, n.d.-o). The NSL Monitoringstool will however be supplanted by the *Centraal Instrument Monitoring Luchtkwaliteit* (Central Instrument Monitoring Air Quality, CIMLK) from 2023, which means that municipalities will have to report environmental concentrations and their policy measures in this tool, which will be used in an identical fashion by the RIVM as its predecessor.

**Aerius Lucht/NSL Rekentool/CIMLK/SRM1&2** The primary, and most important modelling suite that the RIVM develops are based on the SRM 1 and SRM2 calculation methods for traffic emissions. An explanation on these methods, which were first introduced under the Nationaal Samenwerkingsprogramma Luchtkwaliteit can be found in subsection 4.1.4. The first model that was built upon these calculation methods was the NSL Rekentool, after the program that drove its creation. The NSL Rekentool was the original air quality calculation tool, first adopted in 2009, but was succeeded by the Aerius Lucht Rekentool in 2019 (Kenniscentrum InfoMil, n.d.-p; RIVM, n.d.-a). This successor, the Aerius Lucht Rekentool, is part of a larger modelling suite named Aerius, which is primarily used to calculate nitrogen emission and deposition in the Netherlands (RIVM, 2017). The NSL rekentool was thus absorbed into this broader modelling suite, leading to a reduction of the number of systems that had to be maintained by the RIVM (RIVM, 2017). This merging lead to a few limitations however, which should be resolved in the new model currently being implemented, the CIMLK which was also developed by the RIVM. The ”computing heart of the CIMLK is still based on the Aerius Lucht Rekentool however, with the main difference being a new web-based interface” (Rijkswaterstaat, n.d.-a).

The RIVM does not only develop these tools however. It uses them as part of its responsibilities under the NSL to perform the national calculations of the yearly monitoring of air quality (RIVM, n.d.-a). The same air quality calculation requirements are required under the SLA and the new *Omgevingswet*. As input for these calculations the RIVM uses the information on policy measures stored in the NSL Monitoringtool/CIMLK described above (RIVM, n.d.-a). Finally, the RIVM also certifies other calculation methods that may be used to model air quality, like the DGMR Geomilieu/Stacks+ model that the ODZOB uses (Ministerie van Infrastructuur en Waterstaat, 2021). It is certified for SRM1, 2 and 3 calculations, and it is the only commercial models that is currently certified.

**Nieuw Nationaal Model/SRM3** The Nieuw Nationaal Model (NMM) is an implementation of the SRM3 method. It is developed by the Werkgroep LuchtkwaliteitsModellen (WLM), of which the RIVM is part. This specific model (and the associated SRM) is also discussed in further detail in subsection 4.1.4. This method is meant for the calculation of point and surface sources, which is especially relevant for permitting authorities like the ODZOB. The RIVM develops this model and certifies other models like STACKS+ for their use by governments.

**Nationale Emissie Registratie (NER)** The Nationale Emissie Registratie (National Emissions Registration) is a program by a consortium of Dutch government organisations which registers the emission sources in the Netherlands, and calculates the distribution of emissions across the country. For traffic for example, the emissions are calculated based on average emissions per vehicle type, which is then connected to statistical data on the traffic density on road. The RIVM is the end-developer of these maps, and performs the majority of the modelling involved (RIVM, n.d.-g). The data from these calculations is then used as an input for the background concentrations for the SRM1, 2 and 3 calculation methods.

**OPS** The OPS model is used by the RIVM to calculate the transport of emissions through the air. Based on this model the contribution of surrounding countries on the background concentration for the Netherlands is calculated by the RIVM. This data can then be combined with the background concentration from the GCN/GDN maps as an input to model calculations like the NSL Rekentool and its successors. As an output of the OPS model, the GCN/GDN maps are developed, which are used to calculate the health impact of emissions under the SLA (Gerlofs-Nijland et al., 2020).

**MGRI** Finally, the RIVM also develops the MGRI model (Environmental Health Risk Indicator), which allows for municipalities and other government bodies to ”compare the different MGR-scores of different policy measures. This allows them to choose the ”most positive variant” for the health of its citizens” (RIVM, 2014). The RIVM originally developed this model in a pilot project with the municipality of Eindhoven to calculate different scenarios for urban development, leading to the model being well known with local policymakers and seeing frequent use (II,III).

**VTV Model** Under the SLA, the health effect of air pollution is calculated by the RIVM every year, using the VTV model. This is then used to determine the eventual long term gains that air quality policy measures have achieved, or the potential health gains that can still be made.

**Other models** In addition to all of the models described above, the RIVM develops or uses other air quality models. Firstly, the RIVM uses EMEP4NL, to determine the inflow of air pollution from other countries (leading to increases in background concentration relevant for the Aerius Lucht Rekentool) (RIVM, n.d.-j). Next, the RIVM uses the LOTOS-EUROS model to make day-ahead predictions for air quality and smog. Finally, TREDM is used to verify the proper functioning of models built on the basis of SRM1 and 2.

Table 4.5: Models used/developed by the RIVM.

| Model Type | Role | Models |
|---|---|---|
| Air Quality Models | User/Developer | NSL Monitoringtool, CIMLK, Nieuw Nationaal Model<br>OPS, EMEP4NL, LOTOS-EUROS, TREDM<br>Aerius Rekentool/NSL Rekentool, DGMR Stacks+ |
| Health Models | User/Developer | MGRI, VTV |
| Other Models | User/Developer | Nationale Emissie Registratie, GCN/GDN, |

### 4.2.5. Visualising the Policy Process

Returning to the figure of the municipal air quality policy process that was presented in the previous chapter, Figure 3.3, we can now add on the models that were discussed in this chapter.

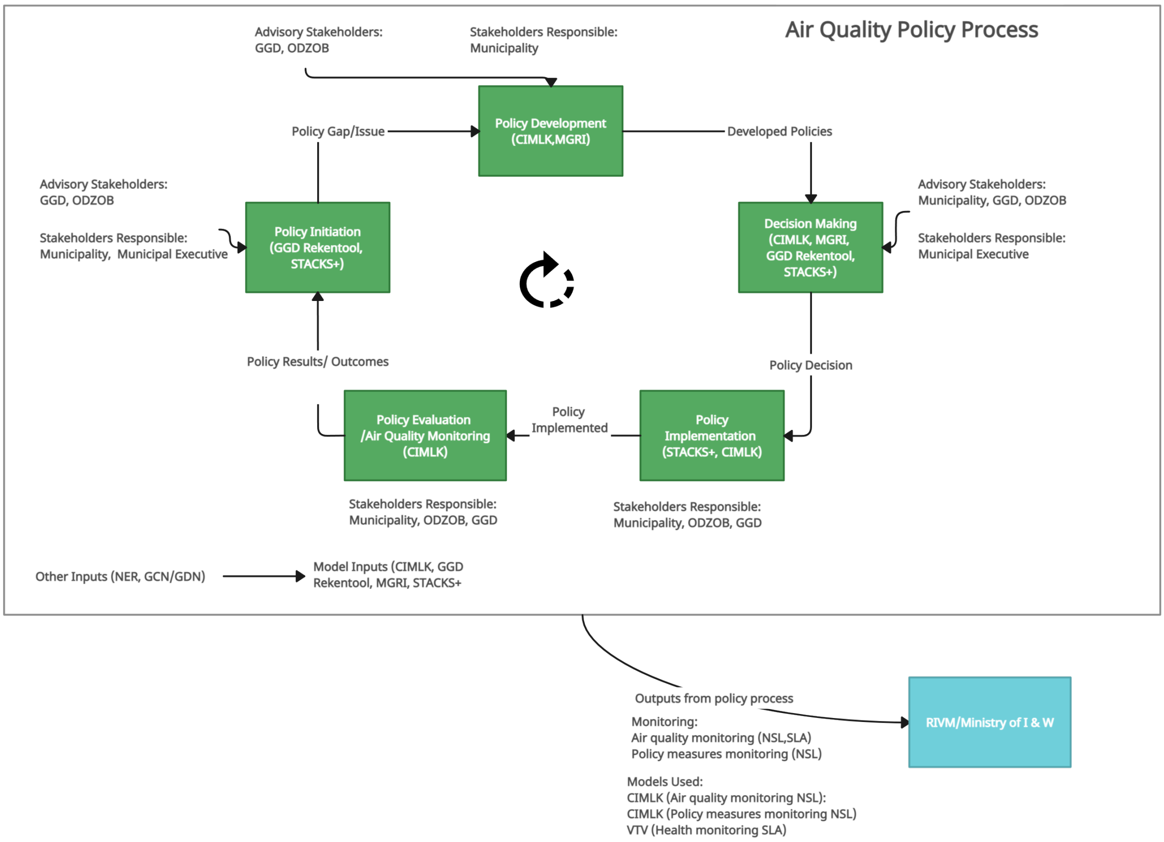


Figure 4.10: Visualisation of Policy Process

## 4.3. Conclusions

In concluding this chapter, it is valuable to revisit the research question that we were looking to answer in it: **"By whom and in which manner are air quality modelling tools used in these policy processes?"**.

We identified three key aspects to answer this question. Firstly, we had to identify the main actors involved with modelling. These were determined to be the Municipality of Eindhoven itself, the municipal health service GGD Brabant Zuidoost, the environmental service ODZOB and the RIVM. Secondly, we needed to determine the models used and their characteristics. We found that these stakeholders used a range of models, all of which are listed in Table 4.1. We divided these models into three main categories: air quality models, health models and other (which were models which did not fit cleanly into these previous two categories). It was determined that there were multiple air quality models, which all took their input data from the "Other" category models, but that these were all related through the standard calculation methods SRM1, 2 and 3. The NSL Rekentool was succeeded by the Aerius Lucht Rekentool in 2019 and the CIMLK tool will succeed Aerius for the purposes of air quality calculation starting from 2023.

In addition to these models, there was the NNM-tool for SRM3 calculations (related to point and surface sources), which the ODZOB is currently replacing in their service with the DGMR STACKS+ model which is the only model certified for calculations for SRM1, 2 and 3.

For the health models, three main tools were identified. The GGD Rekentool was a lower resolution health quality model with the ability to discern the impacts of different pollutants, used only by the GGD. The MGRI model which was used by the municipality and the GGD, to calculate the health effects of different policy options, presented on a clear map. Finally, there was the VTV model, which is used by the RIVM to calculate the health gains under the mandatory reporting requirements of the SLA.

Finally, the third and final aspect that we needed to answer this question, was the procedural fashion in which these models are used. It was clear that although significant modelling activity does take place, the majority of it takes place within the legally required framework which has been set out by the NSL, SLA currently, and the *Omgevingswet* in the future. This has its advantages and disadvantages however, as doing so does ensure that everyone is using the same information. On the other hand, this also means that developments in models that could improve the policy process have not been adopted.

Modelling that was not legally required, such as the use of the MGRI model, seemed to be more a result of existing familiarity with the tool and an understanding of the value derived from the outputs rather than a desire to use new tools to better understand the relationship between air quality and health.

The main takeaway from this chapter therefore, is the importance of anchoring modelling activities within the legal framework and the existence of agreements like the Schone Lucht Akkoord (SLA), which drive municipalities to aim higher, and perform more detailed research. Furthermore, it can be argued that the standard calculation methods (SRM1, 2 and 3) are the main determinants of the nature of the modelling activities that take place, which means that changing or updating them would significantly disrupt the air quality modelling process and most likely the policy process at large.

Reflecting on this however, it is not the case that there is no will to be more ambitious: the fact that the municipality uses the MGRI model, and participates in the SLA with its mandatory reporting requirements indicates that there is space and political will for more and better modelling. It is essential to create the right framework and involve the right actors to get it started.

# 5

# Improving the Models

In this chapter, we will further investigate air quality modelling developments, both in the scientific literature and in research institutes identified in the actor scan in section 4.2.

The main question for this chapter will be:

**In which development pathways are air quality models being developed currently, and how can these be applied to improve the air quality policy process?**

To determine these potential gains, we must first identify the developments in air quality modelling, both in the form of new modelling techniques, new models and improvements to existing ones.

## 5.1. Developments in Air Quality Modelling

This section will be trying to bring together a review of current model developments in both scientific literature and in modelling development organisations. Firstly, we will discuss developments related to improvements in resolution in subsection 5.1.1, both of a spatial and temporal nature. Then, in the second section, subsection 5.1.3 we will be reviewing those developments related to translating the outcomes of models to other factors like health and biodiversity losses. Subsequently, in subsection 5.1.4 we will discuss new developments in the ways users can use modelling tools, by using them for example for scenario analyses. Finally, we will conclude with developments in connecting modelling tools to distributed measuring tools like the ILM 2.0 present in Eindhoven in subsection 5.1.5.

### 5.1.1. Improvements in Resolution

The first development in air quality modelling is very straightforward: improvements in the modelling resolution and scope. These improvements can come from different modelling techniques or even better hardware. Developments in model resolution can be split along two main axes: temporal and spatial.

With respect to increases in spatial resolution, both in the scientific field of air quality modelling and within the institutions discussed in chapter 3 there are efforts towards achieving more finely-grained modelling outputs. A first example of this research was done in a study by Wolf et al. (2019), who used a large eddy simulation model (PALM) to simulate air quality in the Norwegian city of Bergen, which has a similar population to Eindhoven . They identified that one of the large benefits of high resolution modelling was the "ability to resolve the local relief features, which control the air flow and the turbulent dispersion" (Wolf et al., 2019). This same PALM model was used to model traffic related air quality in the mega-city of Nanjing, which has more than 8 million residents(Zhang, Ye, et al., 2021). Due to the large computational cost, a representative set of meteorological scenarios was taken and used to simulate the air quality. Even so, this study illustrates that even in large cities, high resolution air quality modelling is still a possibility. The Dutch research institute TNO is also currently working on developing the DALES large eddy simulation model for the purpose of hyper-local (at street level) air quality modelling, which would allow users to perform scenario analyses for different geometrical configurations (TNO, n.d.)(VI). Existing techniques like Gaussian plume models are also being developed to make use of higher resolution inputs from GPS tracking data, therefore increasing their accuracy (Borrego et al., 2016).

On the other hand, there are efforts to go beyond the limited temporal resolution that is currently adopted. Improving the temporal resolution was specifically identified during the interviews, and in scientific literature too. For example, Zhang, Cheng, et al. (2021) mentioned how ”the benefits of such enhanced detail in time include improved source apportionment, similar to the spatial resolution mentioned above, as well as aiding the precision of epidemiological studies and human exposure research”. The example that Zhang, Cheng, et al. (2021) used was the difference in areas of congregation, where during the day the majority of people would be in office and other places of work, whilst at night exposure potential was the highest in residential areas. These are important considerations for research on the health effects of air pollution, thus giving added weight to the value of increased temporal resolution. Furthermore, Hagler et al. (2020) determined that there was ”A high degree of temporal variability was observed for pollutants associated with direct emissions, with highest hourly average coefficient of variation observed for NO (2.65), SO2 (1.45) and BC (1.21)” (BC stands for black carbon, better known as soot, which is a major component of $PM_{2.5}$ pollution (EPA, 2011)). They therefore determined that the use of high temporal resolution could ”increase the likelihood of resolving geographic source emission areas influencing the measurements and gaining insight into the impacts of emission reduction efforts.”(Hagler et al., 2020). Another study even used deep learning techniques to improve the temporal prediction accuracy, by extrapolating the patterns from short periods over longer times (Ma et al., 2019).

When bringing these two developments of spatial and temporal resolution together, we should think about what the fundamental goal is behind the drive to improve them. This question was asked during the interview with model developers, the goal was determined to be ”adding high resolution information for more accurate source apportionment, such that more specific policy measures can be implemented” (VI). We see this reflected in the stance of the policy advisors with the municipality: ”currently, the specific effects of policy measure cannot always be quantified, which means that checking with the legal methods does not always contribute to improvements to the healthy living environment”. Thus, improvements in modelling resolution could adress specific needs that the municipality already recognizes currently.

It should be recognized however, that resolution is not as cut and dry as it might seem on the surface. There are different modelling techniques that serve different purposes. Models are always an approximation of reality. The difference lies in the assumptions that are made to arrive at these models. Consider the comparison between for example a chemical transport model (like LOTOS-EUROS, used by the EU and RIVM (PBL, 2009) or OPS, also used by the RIVM) and a large eddy simulation like DALES. The former models have the ability to model at large scales the emission, transport, dispersion, conversion and deposition of air pollution. They can accomplish this in reasonable time frames. When used for hyper-local air quality modelling however, they make use of a rudimentary Gaussian plume model, as specified in the SRM-3 calculation method. Large Eddy Simulations like DALES on the other hand, allows for accurate hyper-local air quality modelling, taking into account the local geometry, emission sources and real-time tracking (TNO, n.d.). These models are unfit for larger modelling scales however, as the simulation time would become excessively long (VI). The study by Silveira et al. (2019) looked further into the difficulty of assimilating multiple spatial scales in a model, underlining the necessity of using different techniques for different scales. It is therefore important to recognize that there is no one-size fits all modelling solution. Rather, a modelling suite could be adopted which, depending on the scale the user wishes to model, different modelling techniques are adopted.

### 5.1.2. Improvements in Input Data

The developments in resolution discussed in the previous section hold significant potential, however for them to be properly adopted in the policy process, they need sufficiently accurate input data to function properly. Currently, the models used in the air quality policy process use the data from the Nationale Emissie Registratie (NER) and GCN/GDN maps. The former has a spatial resolution of 5x5 kilometers, whilst the latter has a resolution of 1x1 kilometers (Kenniscentrum InfoMil, n.d.-c; RIVM, n.d.-d; Wichink Kruit & van Pul, 2018). Of course, the NER also includes emission factors and data on the emissions of different sources, which can be apportioned in a more accurate fashion than this. However, it remains clear that to run the more accurate models discussed above, the input data must continue improving at the same rate.

The importance of input data was underlined in a study of the Berlin-Brandenburg region, where it was found that the underestimation of concentrations were partly attributable to ”due to deficiencies in the emission input data and their resolution” (Kuik et al., 2016). This was reinforced by the study of Holnicki and Nahorski (2015) who investigated the connection between the uncertainty of air quality forecast and the uncertainty of the underlying emissions data. They found that ”there is a very substantial level of uncertainty in NOx , PM10, and Pb forecasts which strongly depend on the structure of contributing sources”(Holnicki & Nahorski, 2015).

Multiple studies have worked on improving this input data, with (Kuenen et al., 2022) discussing CAMS-REG-v4 a ”state-of-the-art” emissions inventory for aiding air quality modelling. They achieved a resolution of roughly 5x5 kilometers, equal to the the NER performed in the Netherlands. A more promising approach therefore are smaller scale emission inventories, like the one performed by (Jing et al., 2016), who performed a vehicle emission inventory at a city level, reaching a resolution of 1x1 kilometers. Similarly, (Baayoun et al., 2019) used an innovative approach to locate emissions from diesel generators in Lebanon through identifying which parts of the city were prone to blackouts. Of course, blackouts are not a major issue in the Netherlands, but for sources of air pollution like wood stoves, which are a hotly debated item in Eindhoven (I,IV), using alternative approaches like this could hold significant value in mapping the sources of emissions.

Because the emission of greenhouse gases is linked to the emission of air pollutants, efforts to document the former can also improve the latter and vice versa, as was identified by Arioli et al. (2020) in a review of GHG emission inventories, who found that studies in Indian cities were ”highlighted by the use of air quality data from an Indian agency of air pollution and the municipal statistical database”.

It is concluded from the above that, although there are most certainly developments in top-down emission inventories, a bottom-up approach holds more promise for cities like Eindhoven. Using local measurement networks could deliver this information, as will be further discussed in subsection 5.1.5.

### 5.1.3. Integral Modelling

Although for the current legal framework norms and standards of concentration are the preferred methodology, there has recently been a significant shift in all layers of government towards a more comprehensive health approach which takes a wider view of what air quality means. This development can also be recognized in the development pathways of air quality models . Both in scientific literature (Baklanov & Zhang, 2020) and in the more specific case study of Eindhoven and Dutch municipalities this may be observed (RIVM, 2019; van der Gon et al., 2022).

This integral approach in modelling tries to go beyond the mono-disciplinary approach that has been taken with respect to air quality modelling up till now, attempting to connect a variety of issues such as the energy transition, biodiversity losses, public health, climate change and greening of cities and many more. We will only go into a couple of these in this section, but it should be noted that both the WHO and the European Union have been advocating for such an integrated approach, in an effort to improve the healthy living environment for all (World Health Organisation: Regional Office for Europe, 2018).

Firstly, attempts have been made connecting air pollution and climate change, two issues that are very strongly connected. The interplay between them brings both opportunities and risks. For the former, it should be noted that air pollution and climate change are often caused by the same sources, with for example black carbon (soot), a powerful short-lived climate pollutant, being a component of PM that is a critical air pollutant (EPA, 2011). Therefore, modelling approaches that can connect the health benefits from combatting climate change and air pollution, like for example the one developed in a recent assessment by Perera et al. (2019), could allow policy makers to identify compound benefits from eliminating or regulating emission sources that contribute to both problems. These health impact assessments allow for more comprehensive evaluation of policy measures, connecting them directly to the desired outcome of improved health and reduced mortality levels (Khomenko et al., 2021).

Focusing on connecting health to air quality, as was already discussed in chapter 4, is something that is already ongoing in municipalities like Eindhoven, through the use of for example the MGRI and GGD Rekentool. Many pilot projects on connecting these aspects have been performed in the European Union, using a host of different models, like the AirQ+ model in Spain, ADMS-Local model in the UK and the ELAPSE model for cities in Europe (Khomenko et al., 2021; Rovira et al., 2020; Seaton et al., 2022)

The RIVM is also part of this larger undertaking, with their work being currently focused on developing the VTV model and the SLA indicators, which translate the air quality of the NSL monitoring into tangible health impacts (VII).

There is also increasing interest in connecting air quality to the spatial development of cities, where air quality modelling influences the form and structure of development in cities (Marquez & Smith, 1999). Through a nuanced understanding of the effects of different development patterns on air quality, the municipality could then adapt their development plans to achieve their desired results. Another study in Bucharest, Romania, developed a policy framework which used an air quality model to determine potential exposure at certain sites, which they indicated would ”lead to a harmonisation of policies regarding industrial emissions and land use, resulting in a comprehensive strategy that will take into account both atmospheric pollution and land patterns.” (Ajtai et al., 2020). Not only the zoning and construction of buildings, but also the design of the urban environment could be informed by this, to better incorporate greening measures and adopt a more comprehensive approach to creating a healthy living environment (Badach et al., 2020).

Finally, heat stress is another aspect which can be connected to air quality. Heat stress is partly impacted by the same meteorological conditions that lead to poor air quality, and (Fahad et al., 2021) has even connected the two using air quality indices and meteorological measurements. Similarly, Schaefer et al. (2021) determined that certain environmental characteristics in the built environment, like street canyons (streets flanked by high buildings), can contribute both to increased concentrations of air pollution and urban heat island effects (which cause heat stress). The coupling together of urban heat island and air quality was similarly done in a study of Camden, New Jersey, where it was found that vegetation was a large contributor in the model (Sabrin et al., 2020).

The main takeaway of all of the above is that there is significant opportunity in coupling air quality together with other topics. By attempting to find overlap between problem areas for different environmental characteristics, policy makers can attempt to achieve compound gains for multiple issues, overall improving the healthy living environment more significantly.

### 5.1.4. Developments in Functionality

As the technology and knowledge surrounding air quality modelling develops and expands, more and more aspects can be included. However, as can be seen from the previous section, the users of these models and their information outputs are not only searching for higher accuracy and shorter computation times, but also enhancements in functionality. It is exactly these functionality changes that can make the difference between the adoption and lack thereof for a municipality (II, IV). This added functionality allows them to answer specific questions that make modelling tools significantly more valuable to them. This is especially true when compared to the developments in resolution, as these changes are not very likely to cause significant changes to already existing policy processes, but rather enhancing them.

The first main development in functionality, which was also brought up in an interview with the municipality (III), is dynamic traffic management based on air quality modelling. Research on this technique has been widespread, with multiple projects in the Netherlands alone (Gao, 2012; Wismans et al., 2011). The fundamental concept is rather straightforward: using high resolution air quality modelling to determine the real-time air quality and then using traffic management methods to stimulate ”certain routes, modes and speed of traffic” (III). This would allow municipalities to improve the situation near certain air quality ”hot spots”, which chronically exceed peak air quality standards. The effectiveness of these measures can be mixed however, with one study in Dublin even noting an increase in mortality incidence when reducing the speed limit from 50 to 30km/h (Tang et al., 2020). A more general review of the efficacy of traffic management strategies noted that only aggressive strategies like comprehensive low emission zones would achieve the desired improvements in ambient air quality (Bigazzi & Rouleau, 2017). However, it should be noted that only a part of the policies relevant to Eindhoven could be truly classified as ”dynamic”, with the others being more static measures like the creation of high occupancy lanes, transit improvements and the construction of bicycle and pedestrian infrastructure (Gemeente Eindhoven, 2020). The authors also recognized the methodological issues with measuring the air quality improvements, leading us to the conclusion that although dynamic traffic management based on air quality modelling will not be the single solution, it can be part of a more comprehensive approach to reducing the effect traffic has on ambient air quality.

The second improvement in functionality revolves around the communication of air quality to residents of the municipality. The research into this topic has been long ongoing, with efforts from before the widespread proliferation of the internet aiming to publish the air pollution information in newspapers (Johnson, 2003). Since then, many different approaches have been adopted to communicate this message, ranging from email communications, to SMS messages all the way to a ”personalized real-time air quality informatics system” (Che et al., 2020; Karatzas, 2009). Regardless, this improvement in functionality would allow the municipality to better communicate the air quality in the city to its residents, providing a double advantage. Firstly, vulnerable groups could use this information to minimise their exposure to high level of air pollution, reducing the health impact of air pollution in the municipality, with all of its associated benefits. Secondly, it would improve awareness among the general public of the air quality situation in the municipality. Higher awareness of environmental pollutants has been directly linked to increases in ”willingness to pay” and political support for policy measures that combat air pollution (J. Huang & Yang, 2018; Malik et al., 2022). As one study put it: ”Increased awareness at both the domestic and international level of the health risks related to air pollution from industry, particularly resource-based industries, will likely lead to increased pressure to reduce industrial emissions.” (Taylor et al., 2014). Especially for municipalities, where the distance between decision maker and citizen is a lot smaller, giving the public the tools to inform themselves of the situation in their neighbourhood can be the difference between ”adequate” and ”good” local environmental policy (Serrao-Neumann et al., 2015)

### 5.1.5. Connecting Models with Measurements

With the emergence of affordable and accessible measuring devices, significant growth in distributed air quality measuring has occurred. In the Netherlands alone, thousands of citizens participate in the SLA measuring network to better map air quality across the country (Rijkswaterstaat, n.d.-c). It is therefore unsurprising that these citizens have also provided their measurement data to researchers and model developers to use them for innovative research and uses in their models. In Eindhoven as well, the Innovatief Lucht Meetsysteem 2.0 (Innovative Air Measurement System, ILM 2.0) is already in its second round of development, with the new system aiming for over 150 measurement points throughout the city and surrounding region (Close & Schenk, 2019). Unfortunately, there is no clear connection made between this system and the official monitoring instruments of the municipality (Plomp, 2021).

One of the benefits of connecting models with such measurements, is the sidestepping of the trade-off between remote sensing (such as with satellites) and official monitoring networks (such as the one used in the Netherlands for the NSL). The former has the drawback of ”the inverse relationship between spatial and temporal resolution, i.e., a satellite image could have high spatial resolution but low temporal resolution” whilst the latter is limited by the high cost of measuring stations, limiting the amount that can be installed in each city (Sánchez-Balseca & Pérez-Foguet, 2020)(II)

The use of innovative approaches like big data, IoT technologies and the cloud have been used in a large number of studies to attempt to measure air quality in a more accessible manner (Deng et al., 2020; Hasenfratz et al., 2015; Z. Huang et al., 2021). The main benefit from innovations like these is making measuring cheaper and easier, sacrificing the high accuracy and precision of the national measurement networks which are considered more ”top-down” for the abundance and dispersion of citizen science, which is more bottom-up. However, these measurements are not the sole avenue of approach necessary. As Gawuc et al. (2021) discussed in their study of a bottom-up emissions inventory of residential combustion, ”In order to provide comprehensive AQ (Air Quality) assessment, data collected by such observational stations should be supplemented with AQ modelling, which can provide full spatial coverage over vast areas. AQ modelling is dependent on the emission input data, models used, and methodologies applied” (Gawuc et al., 2021). The relation between the models and the measurement should therefore be viewed as symbiotic rather than competitive.

Thus to conclude, we found that developing an interface and framework between official monitoring tools and local measurements could provide benefits to parties throughout the policy process. Potential exists both in the provision of rough data on a high resolution, and an accessible way to get citizens involved with the topic of air quality. As we saw previously, this potential has already been identified in the Netherlands, and efforts to capture it have been underway in the form of the SLA Samenmeet initiative among other things, but there is still significant room for improvement and development. All of this will become even clearer in subsection 5.2.1, where these improvements will be applied in more detail to the policy process.

### 5.1.6. Combining the Model Developments

In conclusion, let us review the major improvements that we identified. Firstly, we found that significant work has been done in improving the resolution of air quality modelling tools. We delineated these improvements across two axes: spatial and temporal resolution. One study of high (spatial) resolution air quality modelling even investigated a city with demographic characteristics similar to Eindhoven, underlining the potential for the city. The developments in temporal modelling was found to be carry significant importance due to the combination of significant variability in exposure locations (work versus residential) and pollutant concentrations throughout the day. An important counterpoint to consider to this drive for higher resolutions is the nature of the model however, as it was discussed how certain modelling techniques like Large Eddy Simulations could indeed go down to the meter level, but were computationally too expensive for larger area simulations. The integration of multiple spatial scales was thus identified as an important point to consider when implementing new modelling efforts in the policy process.

Furthermore, to achieve these gains in resolution and their associated benefits, we also determined that the input data that is used for these modelling measures must be improved along a similar axis. Without these changes, resolution becomes meaningless, as the gains are nullified by the inaccuracy of the input data. We found that to achieve these levels of accuracy, there was a need for bottom-up inventories of emission sources, which could then be combined with top down data for validation. We identified that local measurement networks like the one in Eindhoven could fill this gap.

We then subsequently explored the developments in integral modelling, which expands the scopes of air quality modelling to combine it with challenges like climate change, health, urban planning and heat stress. These connections between multiple policy obstacles can facilitate the decision making by allowing gains in multiple dimensions, as will become clear below.

Another area where we identified potential was the developments in functionality. Such innovations included dynamic traffic management informed by air quality monitoring to reduce traffic emission hot spots, direct communication of the air quality situation to residents for health protection and increased political engagement and scenario analysis tools for air quality which could aid policy makers by allowing them to directly compare policy alternatives for air quality. This would put air quality, as one interviewee said, ”under the same common denominator as other economic measurements, to better evaluate policy alternatives” (II).

Finally, we identified a move towards bottom-up emission inventories and air quality measurements in literature, using a host of new technological advancements like big data, cloud computing and IoT. These measurements and inventories can then be connected to air quality modelling to form a cooperative relationship where each element supports the other, and where citizens are included in the air quality policy process more extensively.

All of these developments can now be applied to the municipal air quality policy process, to identify where it could improve existing processes or create completely new possibilities.

## 5.2. Improving the Policy Processes Through New and Improved Models

Bringing all of these developments together, we can clearly see that there has been a large jump in modelling capabilities since the development of the original modelling tools that are in use in the policy process nowadays

In this section we will be attempting to connect the developments described in the previous section to their potential areas of improvement in the policy process. It should be noted that some of these are improvements are theoretical, whilst others have already seen partial implementation or experimentation in a pilot fashion. The section consists of two parts. In subsection 5.2.1 we will go over the aspects of the policy process previously discussed in chapter 3, identifying for each where the potential areas for improvements would lie. Subsequently, in subsection 5.2.2 we will tackle the individual problems and areas of improvement identified in chapter 4.

### 5.2.1. Process Specific Improvements

Taking in this variety of developments in air quality and health modelling, we can now analyse how these could be used to improve the air quality policy process. Let us revisit the visualisation that we made for the policy process in the previous chapter.

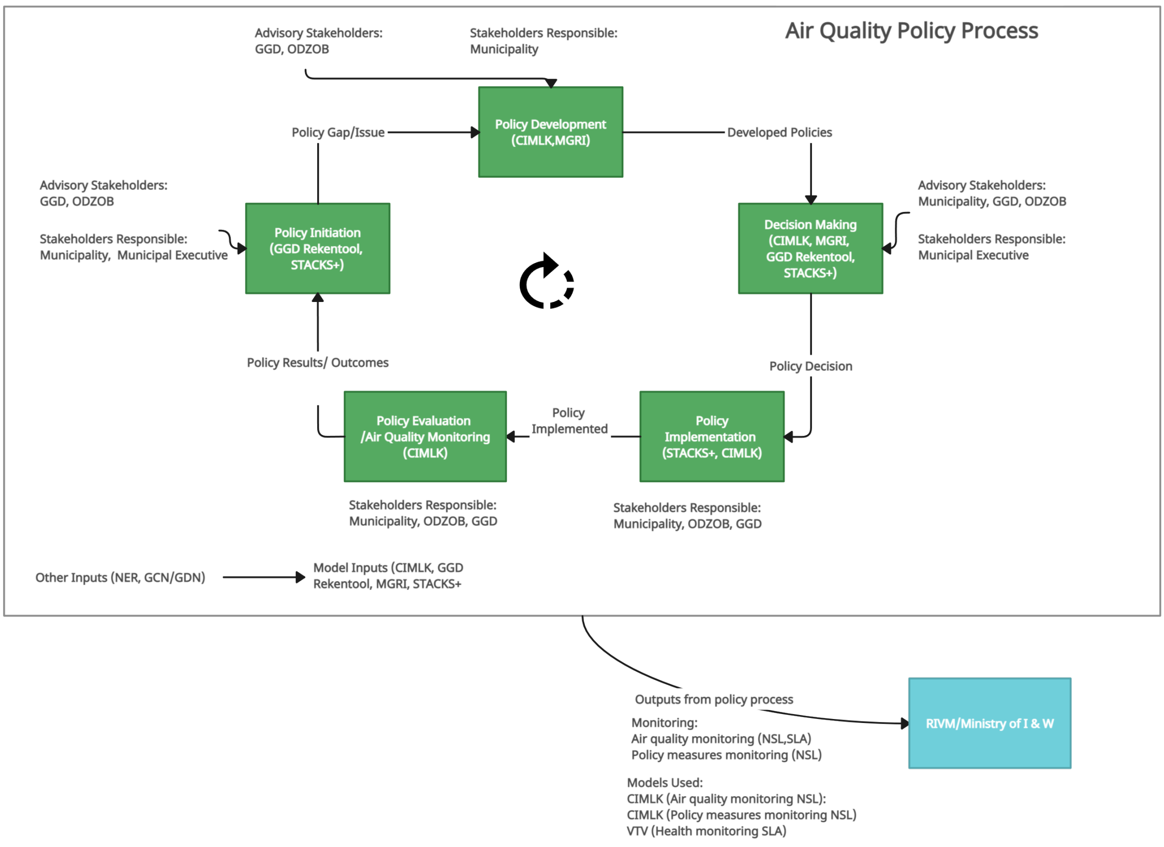


Figure 5.1: Air Quality Policy Process

As can be seen from Figure 5.1, modelling tools are actively used in all phases of the policy process. Let us therefore look into each step of the policy process and determine where there is room for improvement. We will go over every aspect of model development, and discuss the potential for implementation of these improvements on the specific phase of the policy process.

**Policy Initiation**

The policy initiation step, where new policies are created or started, involved the municipality and municipal executive identifying room for improvement in the city, and drawing up new policy proposals. There are two main areas which we identified, that can improve this part of the policy process.

Firstly, newer models allow for the more accurate monitoring of air quality levels in the municipality, to block or even street level, allowing for more tailored and specific solutions. By identifying the specific locations where air quality is lacking, the municipality could then investigate the source of pollution in more detail with higher resolution monitoring tools. The source of the air pollution can then be identified, and potential environmental characteristics that contribute like street design or traffic density. This could also facilitate the creation of new policies by reducing the difficulty in adopting these (because policies will need to be less broad, and will be specifically tailored for a specific source). This fits into the special provision for tailored solutions that the Wet Milieubeheer contains, allowing for tailor-made regulations that are applicable to specific situations.

The second aspect in which these improved modelling tools could aid is by improving the temporal resolution of models. Namely, by moving beyond solely daily averages, and investigating the distribution of air pollution through time, new policy approaches could be identified, relating to for example at which time of day peak concentrations occur. This could aid with determining the source of air pollution and determining appropriate policy responses. The same holds for bottom-up emissions inventories and local measurements: more precise information on where and when air quality is lacking can aid policy makers in determining where there is room in the policy space for new measures.

Finally, both improvements in modelling with respect to functionality and combining with other aspects could aid policy initiation in minor ways. For the former, additional functionality like scenario analyses can help with forecasting the air quality in the municipality in the near future, determining what kinds of reductions will be necessary. For the latter, providing air quality information to citizens can help engage them in the process and lobby for new and improved policy measures.

Thus, to conclude, for the policy initiation step, all of the model development areas contain promise, with especially the improvements in resolution and input data appearing as possible sources of major improvements to this step.

**Policy Development/Participatory Input**

In the policy development phase, the initiatives created in the previous step are worked on and citizens have a chance to voice their thoughts and concerns directly through citizen participation events, or indirectly through their elected representatives or the GGD.

The key aspects of this phase therefore concern developing and quantifying the effect of air quality policies like the low-traffic zones in the centre on one hand and increasing awareness and participation among citizens on the other hand.

With respect to policy development, three key improvements were identified. Firstly, the municipality currently uses both the NSL Monitoringstool (which will be replaced by the CIMLK throughout the course of 2023) and the MGRI tool. Both of these tools are significantly limited in two dimensions: they are limited in space due to their input data being the GCN maps, which have a resolution of 1x1 kilometers, and use yearly averages in their calculations. To aid in targeted policy development (e.g. through the enactment of a through-traffic ban in a specific part of the city for a specific part of the day), a modelling tool that can determine at which points of the day, month or year exceedances are likely, combined with a specific area (it should be noted that the current grid accuracy of 1x1 km means that Eindhoven, with it's area of circa 90 $km_2$ and 116 neighbourhoods can now only be modelled on the neighbourhood level, which means that different source contributions within neighbourhoods can not be determined accurately).

Secondly, by connecting measurements to modelling, the accuracy and effectiveness of the calculations may be improved, leading to better developed policy options.

Finally, by using models that bring together multiple aspects relevant to municipalities like resident's health, climate resilience, and the energy transition, it allows for the combination of multiple positive benefits under the same common denominator (for example, monetary cost), aiding in the possibility for compound gains from policy options.

With regards to the second aspect of citizen participation, we identify two main development areas that could aid and improve it. These are improved resolution, temporally and spatially, and enhanced functionality, in the form of presenting air quality data in an easily accessible manner. Improving the resolution helps primarily with one factor: source apportionment. By providing citizens with information on what causes the air pollution in their environment, they can better represent their interests in the municipality. This ties into the second aspect, namely the ease of access for residents of the municipality to useful air quality data. Currently, the results of local measurements, measurements by the RIVM, the CIMLK results and all the other air quality information are spread throughout the internet on different web pages. Unfortunately, there is a large overlap in the part of the population that is especially vulnerable to air pollution and that part that struggles with accessing this information (Aissaoui, 2021). Therefore, a significant improvement to reaching these groups, could be alternative ways of presenting the information, through for example the weather report on the evening news.

**Decision Making** For the decision making phase, the political aspect of air quality should be considered. This means that any modelling developments should aid either decision makers in their processes or inform citizens to increase their participation and create larger political support for air quality measures. We find that there are two major areas which could contribute here. Firstly, the integral modelling developments, which means that air quality modelling can also incorporate challenges like the energy transition and the healthy living environment can aid decision makers by giving them a more comprehensive view of the benefits and drawbacks of specific policy measures. One interviewee identified it would be useful if there would be a model that could inform municipal councils where there was room for projects in their municipalities in different layers (of pollution) of such a model (VIII). Finally, improvements in functionality, including clearer source apportionment can inform citizens of their own contribution to air pollution, leading to greater potential political support for air quality measures that would reduce their impact (II)

Improvements in coupling measurements with calculations do not aid the decision making process, as the focus here lies on trading off policy options and evaluating their effectiveness.

**Policy Implementation/Evaluation**

The final two phases of the policy process, the policy implementation and evaluation phases, can also gain significant benefits from the improvements in modelling tools. The gains in both temporal and spatial resolution can aid in the monitoring of emissions and keeping track of the progress of policy measures. It is important for the coupling of this phase of the policy process to the next phase (policy initiation) that proper monitoring is performed. The same applies to improvements in input data and measurements, which both aid in ensuring the proper implementation and monitoring of policies.

The improvements in integral modelling and functionality are of reduced value in this phase, as their involvement is more relevant to the earlier phases, where policy initiatives were still under consideration.

All of the improvements identified above are summarised in Table 5.1, with each policy phase's improvements described in each box.

Table 5.1: Improvements in policy process through modelling tools.

| | **Resolution (Temporal/Spatial)** | **Input Data** | **Integral Modelling** | **Functionality** | **Measurements** |
|---|---|---|---|---|---|
| **Policy Initiation** | Identify problem areas | Identify problem areas | Combining policy challenges | Accessible information about air quality for citizens | Identify problem areas |
| **Policy Development/ Participatory Input** | Source apportionment | Source apportionment | Combining policy challenges | Accessible information about air quality for citizens | n.a. |
| **Decision Making** | Source apportionment for political support | Source apportionment for political support | Combining policy challenges | Accessible information about air quality for citizens | n.a. |
| **Policy Implementation/Evaluation** | Determine compliance | Determine compliance | n.a. | n.a. | Determine compliance |

### 5.2.2. Improving the Existing Models

Now that we have discussed how developments in modelling tools can be used to improve the specific aspects of the policy process, let us review the potential areas for improvement to existing models identified by the air quality policy process experts involved with modelling that were interviewed for this work. These were as follows:

1. Models should capture and represent the temporal aspect of air quality (IV).
2. Models should capture the interaction between emissions of different sources (e.g. road and industry emissions) (IV).

3. The air quality model should indicate to permitting authorities what the contribution of existing permits is to the concentration of air pollutants and the impact of more permits (IV).
4. Models should be able to perform scenario analyses (III).
5. Models should be able to incorporate the data from low cost sensors (IV).
6. Models should be able to identify the source of spikes in concentration (II).
7. Models should be able to calculate the peak concentrations of air pollution throughout the day (I).
8. Models should be connected in a modelling suite which can calculate multiple aspects like air pollution, heat stress, smog, health effects, etc in one go (IV).
9. Models should allow for the direct translation and quantification of different policy options in terms of health improvements (IV).

If we check against the five categories that were outlined in Table 5.1, we find that all of the suggested improvements fit into the domains that we identified as promising areas of development. It thus appears that there is no significant disconnect between the direction that modelling development is going and the demand for improvements from the model users. This suggests that if the proper precautions are taken to ensure proper model adoption, as outlined in section 1.2, these new and improved models could be adopted in the policy process.

## 5.3. Conclusions

To conclude this chapter, let us revisit the main question that we aimed to answer with this chapter: **What are the current developments in air quality modelling, and how can these be applied to improve the municipal air quality policy process?**

We determined five main areas where development in air quality modelling and related techniques is underway. These areas were then compared to the areas of improvement for existing models from interviews.

The first area was the improvement in the resolution (and the associated accuracy) of air quality models, which allows them to monitor the concentration and deposition of pollution at block or even street level. We determined that these improvements could primarily aid in the policy initiation and the policy implementation/evaluation phases. For the former, the higher resolution would aid in the identification of problem areas where a new policy measure could ameliorate the situation. For the latter, improvements in the resolution would aid in monitoring compliance and determining the effectiveness of existing policy measures.

The second aspect, which was related to the improvement of input data, which is currently based on the GCN maps with their accuracy of 1x1km. An improvement in input data could aid once again in the policy implementation/evaluation phases, where it could help in determining whether firms and other business-scale activities are compliant with their permits. We also found that this improvement in input data could aid in source apportionment during the policy development phase, where a policy measure could be specifically tailored to the problem that it was trying to adress, rather than being a blanket measure.

Next, there was the growth of integral modelling, which is modelling that allows for municipalities to target and quantify the effects of policies in multiple dimensions like health, noise pollution and air pollution. By bringing all of these aspects into the same model, or modelling suite, the benefits of policies could be better represented. This advancement might find use in both the policy development and decision making phase, as it could make policy measures more attractive, and allow for municipal policy makers to target compound benefits that would be hard to identify otherwise.

Another significant area of development was the growth in functionality of air quality modelling. This could be in the form of detailed scenario analyses which could allow policymakers in the policy development phase to evaluate multiple policy scenario's side by side. Another potential gain that was identified was by providing air quality indices to citizens to increase their engagement and political support for air quality measures in the decision making phase.

Finally, we found a significant move towards bottom-up measurement of air quality in literature, through for example connecting models with networks of measuring sensors, to validate with official maps like the GCN maps. These could aid in both the policy initiation and implementation/evaluation phases, to monitor compliance and identify problem areas.

Aside from these potential gains we also discussed the improvements for existing models which came forth from the interviews with experts in the air quality policy process. We found that the areas that the interviewees perceived as currently ripe for improvement matched up well with the modelling development dimensions identified previously, and thus that if proper care was taken by model developers to ensure appropriate model adoption, these models could find a place in the air quality policy process.

# 6

# Improving the Policy Process

In the previous chapter we identified areas of improvement in the policy process for modelling tools. These improvements can now be evaluated to determine if they would lead to a gain in the performance of the municipal air quality policy process. After this we can determine what would be needed to overcome the bottlenecks in the process that are still left behind. The question that we will be looking to answer for this chapter will therefore be: **”What obstacles currently exist in the municipal air quality policy process, and how can these be overcome?”** To answer this question, in section 6.1 we will be revisiting the areas of improvement identified in the previous chapter, and comparing them against the bottlenecks we identify in the policy process. In section 6.2 we will then reflect on the improvements that would be needed to overcome the remaining bottlenecks.

## 6.1. Evaluating the Gains from Models

With the improvements to the models from the previous chapter, which parts of the policy process are actually improved? And where are the actual bottlenecks in the process? If we compare these two against each other, we can then obtain the gaps that are left behind and must therefore be overcome in other ways.

### 6.1.1. Gains From Models

In the previous chapter, we discussed a set of potential improvements to the air quality policy process, summarised in Table 6.1.

Table 6.1: Improvements in policy process through modelling tools.

| | **Resolution (Temporal/Spatial)** | **Input Data** | **Integral Modelling** | **Functionality** | **Measurements** |
|---|---|---|---|---|---|
| **Policy Initiation** | Identify problem areas | Identify problem areas | Combining policy challenges | Accessible information about air quality for citizens | Identify problem areas |
| **Policy Development/ Participatory Input** | Source apportionment | Source apportionment | Combining policy challenges | Accessible information about air quality for citizens | n.a. |
| **Decision Making** | Source apportionment for political support | Source apportionment for political support | Combining policy challenges | Accessible information about air quality for citizens | n.a. |
| **Policy Implementation/Evaluation** | Determine compliance | Determine compliance | n.a. | n.a. | Determine compliance |

These improvements could aid the policy process in a couple of ways, which are illustrated in Figure 6.1, with each red arrow representing a key improvement to the process.

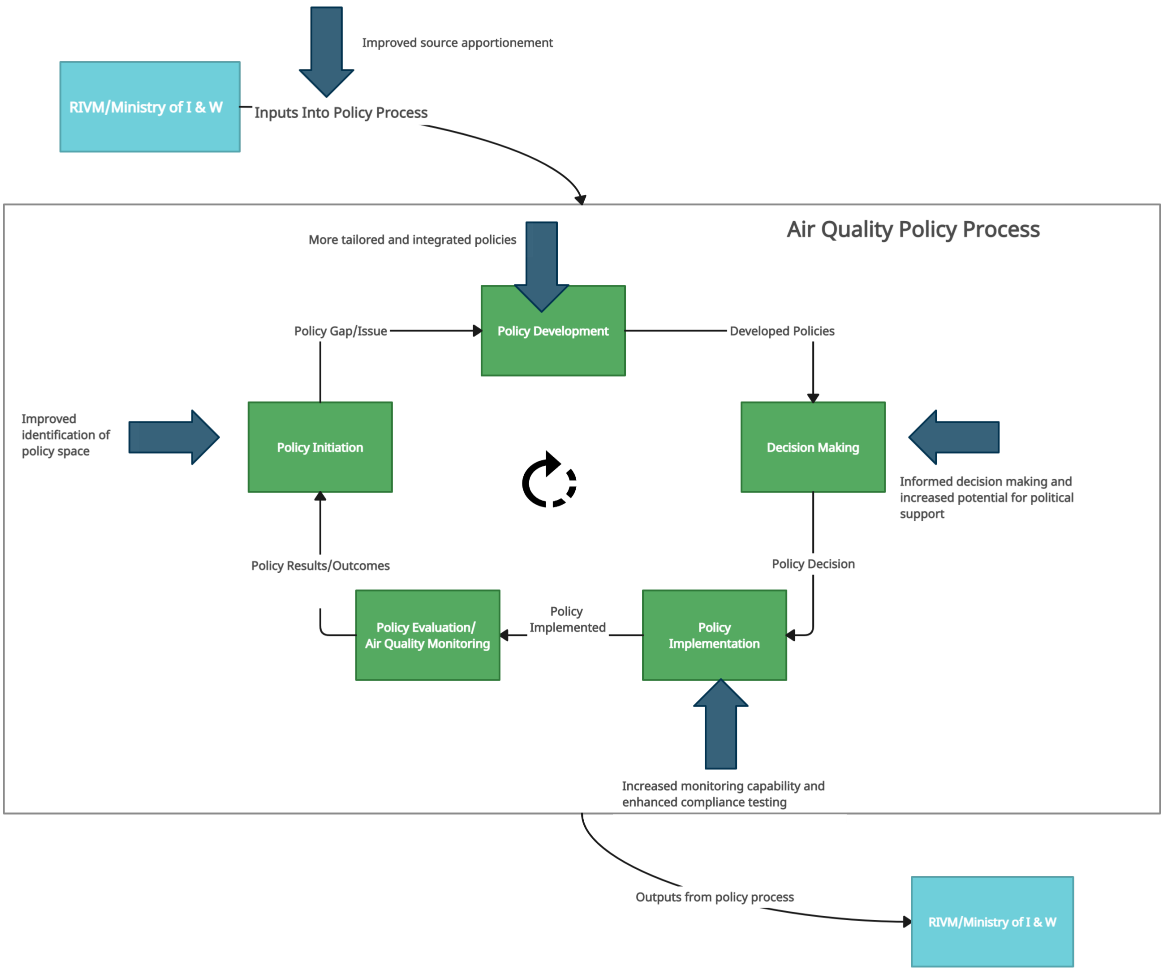


Figure 6.1: Improvements in the policy process through developments in modelling tools.

Outside of the considered system, better input data will allow for improved source apportionment in maps like the GCN that are used to monitor air quality.

Inside the system, the model developments will allow for improved identification of opportunities in the policy space (the space of possible policy measures), and an easier process of identifying problem areas. In the policy development phase, modelling improvements will lead to more tailored (i.e. better suited to the issue it is trying to solve) and integrated policy measures combining aspects such as creating a healthy living environment and the energy transition, which are interconnected with air quality.

The improved tools have the potential to aid informed decision making by combining the aforementioned aspects and putting them all under the same common denominator (for example monetary cost), allowing for a more straightforward quantification of benefits of policies. They can also aid in generating political support through increased citizen engagement with the topic of air quality, which should push their representatives in the city council to support air quality policy measures.

Finally, the policy implementation/evaluation phases receives major improvements in the form of increased monitoring capabilities which allows for enhanced compliance testing and permit enforcement, which should aid in the reduction of exceedances and violations.

Therefore, it can be observed that every part of the policy process is thus improved in some ways. But does it solve the issues that are holding back the policy process?

### 6.1.2. Bottlenecks

To further improve this implementation performance, we had to determine what was holding back the policy process. During the interviews we therefore questioned the interviewees on where they believed the bottlenecks in the municipal air quality policy process were. These bottlenecks are described in detail in Table 6.2 below. To determine the stage of the policy process associated with the bottleneck, please refer to the second column.

Table 6.2: Table of air quality policy process bottlenecks in the order of the process. PI: Policy Initiation, PD: Policy Development, DM: Decision Making, EXEC: Policy Implementation/Evaluation, INP: External Inputs Policy Process System.

| Bottleneck | Stage Policy Process |
|---|---|
| 1. There is a lack of an integral approach when identifying room for improvement. | Policy Initiation |
| 2. Air quality is not leading in the policy process (political consideration take the forefront, unless there is a clear violation of standards) | Policy Initiation/Decision Making |
| 3. Air quality standards are easy to reach, they are an afterthought when considering most projects through the NIBM-exemption. | Policy Development/Inputs Policy Process |
| 4. Lack of awareness surrounding air quality and an associated lack of willingness to adapt behaviour to minimise contribution by citizens | PD/DM |
| 5. A lot of the comprehensive measures that could lead to further significant improvements in the air quality require a cooperation framework between actors on multiple levels and areas of government, and a comprehensive political vision which is currently missing. | PD/DM |
| 6. Air quality is not explicitly coupled to other issues in the municipality like the densification of the city center. | PD/DM |
| 7. There is a need for a more integral approach to air quality policy development and decision making, where multiple decision makers and parties come together to combine their expertise. | PD/DM |
| 8. Permitting is based on emissions, but the standards relate to immissions, leading to a disconnect between the permitting and monitoring side. | Policy Implementation/Evaluation |
| 9. There is a need for more real time monitoring, thus for an increased temporal resolution. | Policy Implementation/Evaluation |
| 10. There is a lack of a legal framework for finely grained monitoring and thus enforcement. | Policy Implementation/Evaluation |
| 11. For some pollutants, background concentrations are dominant in determining local concentrations, which means that municipalities can only influence them in limited amounts. | Policy Implementation/Evaluation/Inputs Policy Proc |
| 12. There are no universal standards with regards to health when considering air quality. | Inputs Policy Process |

This is visualised in Figure 6.2, where the main bottlenecks of each part of the policy process are presented with their respective phase.

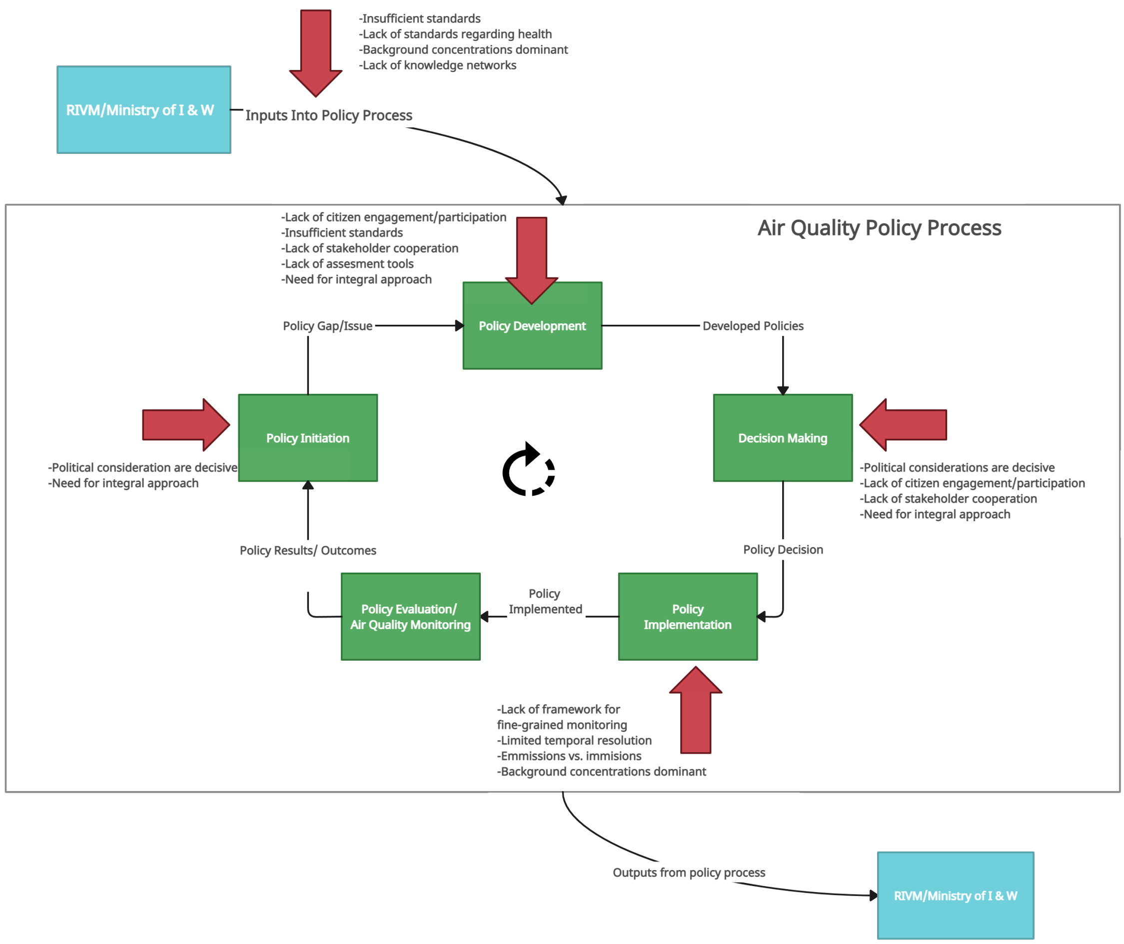


Figure 6.2: Bottlenecks in the air quality policy process.

Now let us review which of these bottlenecks are overcome by the model improvements, and which are left.

### 6.1.3. Gaps

If we review Table 6.2, and compare it to the improvements to the air quality policy process presented in Figure 6.1, we believe that the following bottlenecks could be partially or even completely alleviated by improvements in air quality models discussed in chapter 5. It should be noted however, that improvements in modelling do not guarantee that these bottlenecks would be fully overcome. Rather, they could provide some much needed breathing room and be part of a larger set of solutions aimed at actually fully bypassing the limitations. Each number is associated with the respective number in Table 6.2

- 1. Through integral modelling, air quality could be coupled with other healthy living environment aspects like noise and water pollution to aid in identifying areas with potential compound gains for multiple aspects.
- 4. Improvements in modelling outputs could aid in stimulating citizen awareness and participation.
- 6. Models that allow for more integral simulation of policy scenario's could aid policy and decision makers in coupling air quality to other issues that the municipality faces.
- 7. As mentioned above, multi-disciplinary models could aid in multi-disciplinary policy development and decision making.

- 9. Improvements in temporal resolution could help move policy implementation/evaluation beyond yearly averages.

Therefore, although they are unable to adress of the critical bottlenecks, we postulate that improvements in air quality modelling can actually bring about significant improvements to the policy process, especially through the coupling of air quality to other aspects of the healthy living environment. This is therefore also the area where we believe there to be the most potential room for further improvements.

For our gaps, we are therefore left with bottlenecks 2, 3, 5, 8, 10, 11 and 12. These are mostly related to air quality standards, cooperation frameworks, citizen engagement with air quality and integrated decision making. However, as we mentioned above, the bottlenecks that fall within the model improvements are not guaranteed to be fully overcome by these models. We will therefore also include them in our further investigation into how we could overcome the current obstacles in the air quality policy process.

## 6.2. Improving the Policy Process Further

With the determination of the bottlenecks that hinder the air quality policy process, we can now look into the more general measures that we believe would be necessary to overcome them. We argue for the use of a multi-level governance framework that involves all levels of government and connects a more expansive set of solutions.

### 6.2.1. Multi-level Governance

As mentioned above, to overcome these bottlenecks, we determined that there is a need for a multi-level governance framework which combines decision makers from every layer of government and even parties outside it to achieve a holistic set of solutions. But why do we argue for the need for such a framework instead of attempting to adress the issue at the municipal level? We identified three characteristics related to the nature of the municipal air quality policy process that drive this need.

- Municipalities only have limited authority to regulate sources of air pollution (Characteristic of dutch governance structure) (VIII).
- Air pollution is, due to its nature as an airborne pollutant, a multi-level governance problem, and so is its regulation (characteristic of air pollution and its regulation) (VII).
- The air quality policy process is significantly influenced by political considerations (characteristic of municipal decision making)(II,III).

The three above mentioned aspects in our eyes support the need for a comprehensive cooperation between different levels of government. As mentioned by Enderlein et al. (2010), ”multi- level governance is necessary to internalize spillovers across jurisdictions while tailoring policy to local circumstances.” (p.17). As we already discussed in chapter 3, current air quality governance already occurs in a multi-level structure, with each level of government, from the municipality all the way up to the European Union playing a significant part in regulating air pollution.

We therefore conclude that, to address all of the bottlenecks presented in Table 6.2, there is a need for solutions on all levels of government, and even by those outside of government. We can now discuss for each of these parties, what we determine to be the areas where they can improve the air quality policy process.

In the next sections therefore, we will discuss for each level of government what actions we believe should be taken to further strengthen and enhance air quality governance. These are firstly the ones identified in section 3.3: the national, provincial and municipal government. We also include the supranational level in the form of the European Union, as well as an additional group which includes organisations like model developers and citizen interest groups, because we believe all of these parties play an important role in the municipal air quality policy process.

We also recommend that this approach across multiple levels of government is coordinated at a national level, because of their extensive knowledge networks, and resources available to coordinate the actions that will be discussed below. They have the ability to connect the local and regional levels to the discussions between different countries, as well as the legal jurisdiction to implement the necessary action plans where needed.

### 6.2.2. Local Government

Starting off with the lowest level of government, which is the closest and most involved with citizens. Under local government we understand all the parties discussed in chapter 3, namely the municipality, the municipal council, the GGD Brabant-Zuidoost and the ODZOB.

We recommend the following steps that local governments can take to improve their local air quality policy process.

- **Engage citizens with air quality to increase citizen participation and political support for air quality measures.**
- **Connect air quality with other issues relevant to municipalities like the healthy living environment and climate change.**
- **Focus on reducing air pollution from the sources that municipalities can influence (like local traffic and mobile sources).**

The first initiative is something that the municipality is already undertaking in several different ways, ranging from the ILM 2.0 measuring system which allows residents to couple their own air quality sensor to the network to the use of the Brabantse Omgevingsscan to determine the perception of air quality by residents (Gemeente Eindhoven, 2020)[1]. We recommend that the municipality continues to support and expand these and similar programs, in order to engage citizens young and old with the topic. We recommend that they also continue to work together with the GGD Brabant Zuidoost to cultivate this citizen engagement, drawing on the increased trust that the population has in the GGD when compared to the municipality (II).

Secondly, the municipality should attempt to connect air quality with other relevant issues. This attempt should not be a one-time thing, but should rather become part of the institutionalised air quality policy process, ensuring that it becomes more than a superficial consideration and is taking into account throughout the development of policies. Once again, efforts to achieve this are already underway in the form of the *Omgevingstafel* (Environmental Board) under the new *Omgevingswet* (VNG, n.d.). This board incorporates this integrated policy and decision making approach by involving multiple parties with different expertise like the ODZOB, GGD, Veiligheidsregio and Waterschappen to all give their input on the evaluation of policies and projects in the beginning phases (*Samenwerkingsafspraken ketenproces Omgevingswet Zuidoost-Brabant*, 2021). However, we recommend that the municipality takes this one step further, and incorporates these parties in all phases of the air quality policy process, from policy initiation to Implementation/Evaluation. This could be in the form of an oversight committee (composed of the aforementioned parties) which advises and guides the municipality and the council on their policies.

Finally, the municipality should continue and renew their efforts regarding the emissions that they do have jurisdiction over, like traffic and mobile sources from construction (VIII). Continuing to aim for policies like removing cars from the city center, reducing congestion and implementing deliberate circulation measures which separate sensitive groups like the elderly and the young from traffic. With regards to other areas like mobile sources from construction and generators, we recommend that the municipality implements targets policy measures like the one it is currently considering with regards to making taxis more sustainable. In this example, although the municipality cannot outright ban or regulate these taxis, they can provide strong incentives like only allowing electric taxis to make use of the taxi stop in front of the central station to stimulate drivers to adopt these more sustainable options (Gemeente Eindhoven, 2021). Similar incentives could work for construction, where the municipality could decide to only allow construction firms that adopt more sustainable methods to bid on municipal construction projects. Thus, through creative policy options, the municipality can still indirectly influence emissions like these, and gain the associated reductions in air pollution.

### 6.2.3. Provincial Government

Going one level up, we have the provincial government bodies, the province of Noord-Brabant in Eindhoven's case. The province has a different set of responsibilities that interact with air quality in a different fashion. We therefore recommend the following two approaches for improving the municipal air quality policy process.

[1] Environmental scan of the province, see (Gezonde Leefomgeving, n.d.)

- **Initiate and aid citizen participation initiatives in municipalities.**
- **Work towards increasing the stringency of regulation on industry through permitting.**

The first aspect that the province of Noord-Brabant could make significant gains on is to initiate new, and aid existing, citizen participation initiatives, both in the municipality and the region. According to (VIII), provinces have the ability to financially support municipalities in their efforts to engage citizens on topics like air quality and increasing awareness. The province already participates in initiatives like the ILM 2.0 and the Stookalert (which lets residents know when wood burning could prove noticeably detrimental to air quality). (V) also mentioned how the province was very involved with the municipality during the establishment of the first air quality policies in 2007. Since then, it seems that their prominence in supporting the air quality policy process has subdued to a certain extent. We thus recommend that the province renews efforts like these, and provides funding to engage for example students in high schools and local interest parties with air quality.

Secondly, the province is responsible for, and the main source of, setting the permitting requirements that commercial activities need to adhere to (IV). This means that they have a direct influence on the emissions coming from industrial and commercial activities. We recommend that they continue to implement industry specific requirements for measures like for example filters on smokestacks, or cleaning measures in livestock stables as mentioned by (IV).Secondly, the province is responsible for, and the main source of, setting the permitting requirements that commercial activities need to adhere to (IV). Through direct cooperation with the municipality and the environmental service, they can aid in more sensitively distributing commercial emissions, reducing exposure of vulnerable groups.

### 6.2.4. National Government

Next, we have the National Government. As we will see below, they are the organisation which has the tools and resources available to them to make significant differences in municipal air quality policy process. We have identified these main avenues which we determined to be most fruitful.

- **Create knowledge networks for information sharing about air quality.**
- **Aid municipalities in the establishment of citizen participation initiatives.**
- **Provide and support modelling tools that can be easily used by municipalities to connect air quality to other topics.**
- **Adopt a timeline plan with continuously more strict standards to stimulate actors to work on ambitious air quality regulation.**
- **Incorporate health into the larger national government strategy for air quality.**
- **Create a regulatory framework to reduce emissions from sources like wood burning, the construction sector and traffic.**

Starting at the top, we argue that the national government, and the RIVM in particular, should create knowledge networks for sharing information about both the the modelling/measuring of air quality, as well as the policies designed to improve it. Currently, there is a standard framework under the SLA agreement for knowledge development, but we propose that this framework is expanded even further ("Kennisagenda", n.d.). We believe that a nationally coordinated knowledge development framework, in which municipalities can share information on which policies they have implemented, what the effects of these policies are and for which situations they could be useful in other municipalities. This could all be done (and combined in) the CIMLK tool, which all municipalities will already have access to. By offering such a knowledge base in which every municipality can contribute, policymakers should be able to improve their policies and could use other municipalities' enacted policies to support theirs in the decision making phase. Such a framework has to be coordinated at a national level, to ensure all parties get involved, and the most amount of information can be obtained.

Following this line of thinking, citizen participation initiatives are also a key juncture where the national government can be key in improving air quality. Once again, the RIVM and other national government bodies should play a coordinating role, including parties like regional GGD's[2], environmental

[2] Public Health Agencies

services and other experts in the discussion with citizens who are looking to get engaged with air quality. Like the provinces, they can also provide financial support to municipalities to initiate citizens engagement programs, and through the results of national initiatives like the VTV discussed in chapter 5 they can offer these municipalities the topics to talk about to residents.

Another significant area where the national government, and especially the national government in its capacity as model developer and certification authority, can help is in the provision of easily accessible models which provide further functionality over the standard CIMLK air quality model. By expanding upon, and further developing tools like the MGRI maps, model developers like the RIVM can aid municipalities like Eindhoven in achieving their air quality goals through enhancing the policy process. Especially by incorporating the model developments discussed throughout this work in freely available software, the RIVM can ensure that more integrated assessments are made, and that air quality can be connected in an integrated manner with other topics, which also benefits the goals that the national government sets itself with the new Omgevingswet.

The next recommendation for gap improvements is the creation of a timeline plan with continuously more strict standards to keep drive local government to work on ambitious air quality regulation. As was mentioned by (III), due to the current standards being relatively easy to reach, air quality impact quantification during project development has become nothing more than a superficial assessment of the NIBM framework. We therefore recommend that the national government keeps lobbying both nationally and internationally for more stringent standards. We believe that an effective strategy should consist of making a longer term time plan with deadlines in between, each deadline slightly raising the standards. In the long run, the end goal could be the achievement of the WHO goals, but in the short run the goal should be the continuous attention on the improvement of air quality. By keeping politicians and citizens semi-regularly engaged with the topic, we can attempt to ensure that air quality receives its proper place in the valuation of the healthy living environment.

Following the same line of thought, we advise that the legal framework should be updated to further include health in its standards. This translation of air quality to health is already part of the SLA, but the goal set for this agreement ("50% health gain by 2030 with respect to 2016") remains relatively vague and nonbinding. We recommend that the national government incorporates this health aspect in detail in the larger strategy for improving air quality in the Netherlands, and continues to push for gains in the reduction of exposure to air pollution of sensitive population groups.

Finally, we advocate for the establishment of new, or increasing the stringency of existing, legal frameworks surrounding sources like wood burning, the construction sector and vehicular traffic. Municipalities have, as was mentioned by (VIII), (V) and (VII), only a limited amount of influence on the air quality in their environment. They can only influence the aforementioned sources indirectly, as we discussed in subsection 6.2.2. The responsibility to directly regulate these emissions is the national government's, which also has the knowledge and resources available to properly evaluate and implement such measures. Concrete policy measures in such a framework would differ per source, but as was discussed by (VIII), as the contribution of traffic to air pollution reduces thanks to the electrification of cars and stimulation of alternative transport modes, so will the ability of municipalities to further reduce emissions.

### 6.2.5. European Union

Going beyond the national government level, we have the European Union (EU). The role of this body when considering air quality is of course a little more complicated. However, there are two areas in which the EU can accomplish things that other bodies can not.

- **Work together with member states to agree on air pollution goals.**
- **Coordinate and negotiate transnational air pollution issues.**

The first aspect ties into the aforementioned road map towards more stringent air quality standards at the national government level. As mentioned by (VII), the European Union is currently working on more ambitious air quality standards, which would attempt to strike a middle ground between the current standards and the ones recommended by the WHO for zero health impact. The zero pollution action plan also aims towards similar (but less stringent) goals as the SLA, with a target of 55% reduction in premature deaths by 2030 with respect to 2005 (European Commission, n.d.). This indicates that there are most definitely already efforts underway to raise the standards and to improve air quality even further.

However, we recommend that the Union aims even higher, and follows the same recommendation made for the national government, in establishing a clear road map to follow towards a zero health impact future, which can be periodically updated. The input of all member states is essential for such a road map, in recognition of the cross-border nature of air pollution.

The second aspect ties into this transnational aspect, as air pollution in municipalities can, depending on the meteorological conditions, be very strongly influenced by pollution coming across multiple borders. (VII) mentioned how during days with strong easterly winds, the RIVM could detect the increase in in air pollution resulting from the burning of coal in power plants all the way over in Poland. It is therefore very important that efforts towards improvements in air quality also attempt to overcome the ”tragedy of the commons”, where everyone is negatively impacted by the over-exploitation of the common resource, namely the air above the European continent. To overcome this obstacle, we need a strong cooperation network where countries work together to improve air quality. The European Union is, in our view, an appropriate institution to organize and coordinate this cooperation, and we recommend that it creates an appropriate framework within which member states can come together to coordinate their efforts.

### 6.2.6. Other Parties

Of course, even outside of the different layers of government there is space for improving the air quality policy process. We have identified the following two main groups that we hypothesize could make a difference.

- **Research institutes/ Model developers**
  - **Collaborate with large municipalities that have both the air quality issues (industry, traffic, etc.) as well as the scale and resources to work on them.**
  - **Continue efforts towards more accurate source apportionment in modelling tools.**
  - **Continue developing functionality of modelling tools.**

  The first group of organisations that we believe can play a role in overcoming the bottlenecks in the air quality policy process are the research institutes and model developers. As was mentioned in chapter 5, modelling developments do have significant potential to aid municipalities in better understanding and combatting air pollution. Working together with the municipalities that have both the resources to investigate air quality in their city to a higher level, and the issues to warrant such attention would in our view be the most optimal way to ensure the improvements actually get applied. It is worth mentioning the importance of including these municipalities in the model development process however. As we discussed in chapter 1, model adoption is strongly driven by the familiarity of users with the features and possibilities behind a certain tool. We recognized the same thing with the MGRI-maps, which saw significant use in the municipality of Eindhoven, which was driven in part by the pilot project that was run in the city. We thus recommend model developers to actively engage with potential municipalities to determine areas where the added value of models could be maximised.

  To gain this value however, there are two avenues of model development that we believe that should be focused on. Firstly, there should be a push to achieve higher levels of resolution (temporally, spatially and in the input data) to improve source apportionment. By improving this apportionment, municipalities can reduce the need for blanket measures and focus on tailored policy approaches, which reduce one of the biggest obstacles to the air quality policy process: political support in the decision making phase.

  This ties into the second avenue which we recommend that model developers look into: improving the functionality and flexibility of the models they develop. We identified two main improvements in functionality that are worth looking into. Firstly, allowing for municipalities to perform scenario analyses that would let them, for example, compare the impact on air quality of two different project proposals. An added value would then be if this scenario analysis could then be translated into a difference in health impact (or exposure) which could be taken into the decision making.

Secondly, we recommend the development of functionality in the direction of more integral modelling. The example that was given by (VIII) was the ability to combine multiple layers on a map, each layer representing relevant aspects like heat stress, air pollution, noise, etc. This would provide policy makers with a graphical overview on where in the city the biggest compound benefits could be realised from policy measures, or where there is space for projects like the construction of more homes.

- **Interest Groups/Citizens**
  - **Engage fellow citizens to work with the municipality on improving the air quality in their neighbourhood.**
  - **Increase awareness and political engagement of fellow citizens on air quality.**

  The second group that we believe possess significant ability to influence the municipal air quality policy process are interest groups like Aireas and engaged citizens. As we have mentioned many times throughout this work, political considerations play a very dominant role in determining the nature and ambitiousness of air quality policy in the municipality. Residents can therefore influence both the policy development and decision making phases of the air quality policy process by attending citizen participation events and by voting and contacting their local representatives.

  To improve the air quality policy process, we recommend that interest groups engage their fellow residents to work together with the municipality and other actors like the GGD Brabant Zuidoost to improve the air quality in their neighbourhood. As residents, they are likely to have a good understanding on what drives air pollution exposure in the area which, combined with the expertise from for example the GGD, can result in more tailored and effective policy strategies.

  And of course finally, we recommend that citizens get involved within their community, rallying popular support and voting for politicians who aim to improve the healthy living environment. As was mentioned by (VIII), local representatives are a lot closer to their constituents when compared to the national and provincial governments, and are therefore more inclined to take their wishes to heart.

### 6.2.7. Multi-Level Governance Visualisation

All of the aforementioned gap improvements are now presented in Table 6.3, with the associated bottleneck that the improvement targets. In the table, the gap improvement, the organisation or government level responsible for it are presented in the first two columns. For more information please refer to each respective section. In addition, the bottleneck that the improvement is targeted to overcome is mentioned in the third column, as well as the associated phase of the policy process in the last column.

Table 6.3: Gap improvements for the air quality policy process, the bottleneck targeted and the phase of the policy process. PI: Policy Initiation, PD: Policy Development, DM: Decision Making, EXEC: Policy Implementation/Evaluation, INP: External Inputs Policy Process System.

| **Gap Improvement** | **Organisation** | **Targeted Bottleneck** | **Phase Policy Process** |
|---|---|---|---|
| Engage citizens with air quality to increase citizen participation and political support for air quality measures. | Local Government | 4 | Policy Development/Decision Making |
| Connect air quality with other issues relevant to municipalities like the healthy living environment and climate change. | Local Government | 1, 6, 7 | Policy Initiation/Policy Development/Decision Making |
| Focus on reducing air pollution from sources that municipalities can influence (like local traffic and mobile sources). | Local Government | 3 | Policy Development/Inputs Policy Process |
| Initiate and aid citizen participation initiatives in municipalities. | Provincial Government | 2, 4 | Policy Initiation/Policy Development/Decision Making |
| Work towards increasing the stringency of regulation on industry through permitting. | Provincial Government | 11 | Policy Implementation/Evaluation/Inputs Policy Process |
| Create knowledge networks for information sharing about air quality. | National Government | 2, 4 | Policy Initiation/Policy Development/Decision Making |
| Aid municipalities in the establishment of citizen participation initiatives. | National Government | 2, 4 | Policy Initiation/Policy Development/Decision Making |
| Provide and support modelling tools that can be easily used by municipalities to connect air quality to other topics. | National Government | 6 | Policy Development/Decision Making |
| Adopt a timeline plan with continuously more strict standards to keep driving actors to work on ambitious air quality regulation. | National Government | 2, 3, 8, 10, 11 | Policy Initiation/Policy Development/Decision Making/ Policy Implementation/Evaluation/Inputs Policy Process |
| Incorporate health into the larger national government strategy for air quality. | National Government | 12 | Inputs Policy Process |
| Create a regulatory framework to reduce emissions from sources like wood burning, the construction sector and traffic. | National Government | 10 | Policy Implementation/Evaluation |
| Work together with member states to agree on stricter air quality standards. | European Union | 3 | Policy Development/Inputs Policy Process |
| Coordinate and negotiate transnational air pollution issues. | European Union | 11 | Policy Implementation/Evaluation/Inputs Policy Process |
| Collaborate with large municipalities that have both the air quality issues (industry, traffic, etc.) as well as the scale and resources to work on them. | Other parties | 5 | Policy Development/Decision Making |
| Continue efforts towards more accurate source apportionment in modelling tools. | Other parties | 9, 10 | Policy Implementation/Evaluation |
| Engage fellow citizens to work with the municipality on improving the air quality in their neighbourhood. | Other parties | 2, 4 | Policy Initiation/Policy Development/Decision Making |
| Increase awareness and political engagement of fellow citizens on air quality. | Other parties | 2, 4 | Policy Initiation/Policy Development/Decision Making |

### 6.2.8. Evaluating the Gains from Gap Improvements

To round off this chapter, let us now shortly review the application of these gap improvements to the policy process, similarly to how the modelling improvements were applied in chapter 5.

**Policy Initiation**

The policy initiation process will be supported by two major types of improvements: better identification of problem areas/opportunities and a legal framework that stimulates more ambitious air quality policy.

With respect to the former, increased citizen engagement and awareness will make decision makers more motivated to engage with air quality and invest more time and effort in it. By working together with the municipality, citizens can also aid in identifying the policy space available. This ties into the connection of air quality with other issues, which is also facilitated by increased engagement with the topic in both the political arena as well as among residents.

For the latter, the creation of a more ambitious legal framework will push decision makers to consider more ambitious air quality policies, as well as give them a clear view of the road ahead.

**Policy Development**

With respect to the policy development phase, almost every gap improvement can aid in facilitating it. The improvements could, in theory, lead to a more integrated, participatory policy development process, where the outcomes are well-tailored to the needs of the municipality and adapted to the conditions on the ground.

Stricter standards, the translation of air quality to health and a more integral policy process approach will all aid in stimulating stronger policy measures, which all come together to improve the healthy living environment.

Finally, by coordinating across different levels of government, knowledge can be exchanged, policy responses can be optimized, and emissions gains properly distributed.

**Decision Making**

The decision making phase of the policy process will benefit from increased citizen engagement and awareness, which will ensure that representatives can work for the initiatives that their constituencies support.

Furthermore, by connecting air quality to other issues more integrally, the decision making process can attempt to connect multiple issues together, to achieve compound gains from single policies.

**Policy Implementation/Evaluation**

For policy implementation and evaluation, a stronger regulatory framework will ensure that there is a reduction in the emissions from sources that the municipality does not have jurisdiction over. Improved modelling tools will also aid in source apportionment, and monitoring air quality in the city. Finally, a stricter framework with respect to industry will aid the environmental service in reducing emissions which, combined with the decrease in background concentrations from outside the municipality (both on a national and international level), should lead to overall better air quality in the municipality.

### 6.2.9. Combining the Improvements

Now that we have discussed the changes from both modelling and gap improvements, let us combine them in a visualisation of the different levels of governance, to clearly determine which actors are associated with each action.

The improvements are now incorporated into the visualisation Figure 6.3, to get an overview of the interaction between the different levels. For this visualisation, we have merged all of the improvements into four main categories.

- **Increase air quality standards and cooperate with other countries.** These are the improvements that are related to the standards and the larger legal framework which demarcates the system boundary of the municipal air quality policy process.
- **Improve modelling tools for air quality.** This concerns the development of modelling tools as discussed in chapter 5, now connected to the actors that are responsible for facilitating their use and improvement.

- **Increase citizen engagement and develop political awareness surrounding air quality.** This improvement is about creating political support for air quality measures, both through citizen engagement and awareness campaigns as well as integrated decision making.

- **Improve air quality by reducing emissions and exposure in an integrated fashion.** This improvement concerns those that are targeted at reducing the emissions of the sources that different government levels or citizens have jurisdiction or control over.

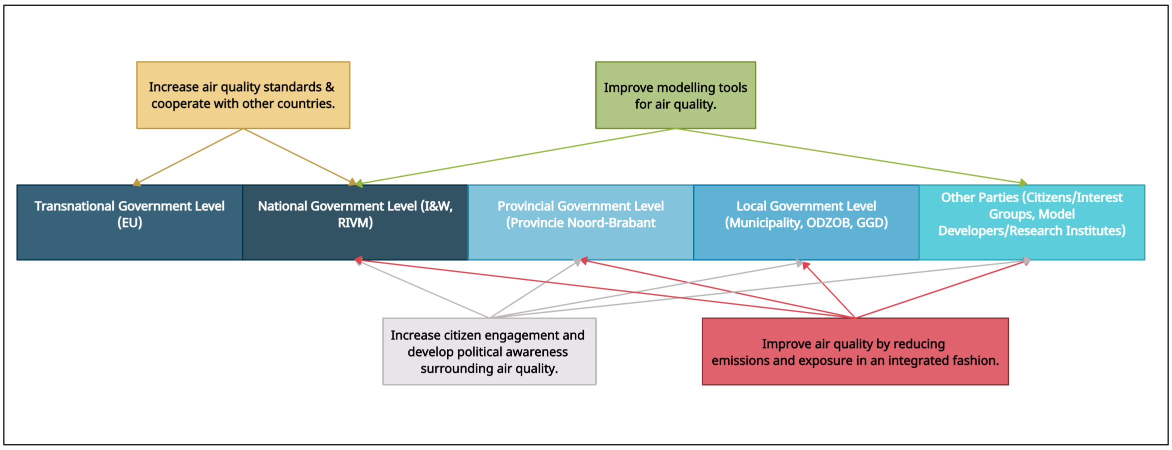


Figure 6.3: A visualisation of the linking of each level of government to the key improvements necessary to improve the municipal air quality policy process.

We thus see that there is possibility at each level, and that cooperation within the different levels of Dutch government is important to improving the municipal air quality policy process. We recommend that decision makers keep this need for multilateral coordination of efforts in mind, and that the municipality of Eindhoven seeks to involve as many of the actors in their efforts as possible. We believe that the end responsibility for coordinating this should still fall on the national government however, which has both the means and connections required to truly coordinate policy responses, something that falls well beyond the possibilities available to a single municipality.

## 6.3. Conclusions

In this chapter, we found that there are a range of bottlenecks that are currently holding back the municipal air quality policy process in Eindhoven, and with it the associated air quality. We identified a list of bottlenecks based on the interviews with experts involved in the policy process, which can be viewed in Table 6.2. To overcome these bottlenecks, we investigated solutions that fall into four main categories, which are as follows.

- **Increase air quality standards and cooperate with other countries.** These are the improvements that are related to the standards and the larger legal framework which demarcates the system boundary of the municipal air quality policy process.
- **Improve modelling tools for air quality.** This concerns the development of modelling tools as discussed in chapter 5, which surrounds five main areas of improvement: improved resolution, input data, functionality and increasing the integrality of modelling as well as connecting models to measurements more intensely.
- **Increase citizen engagement and develop political awareness surrounding air quality.** The second to last improvement is about creating political support for air quality measures, both through citizen engagement and awareness campaigns as well as integrated decision making.
- **Improve air quality by reducing emissions and exposure in an integrated fashion.** The final improvement concerns those that are targeted at reducing the emissions of the sources that different government levels or citizens have jurisdiction or control over.

We then placed these categories of solutions in terms of which organisation or government is responsible for it, in order to illustrate the complexity of the problem, and the need to coordinate policy responses.

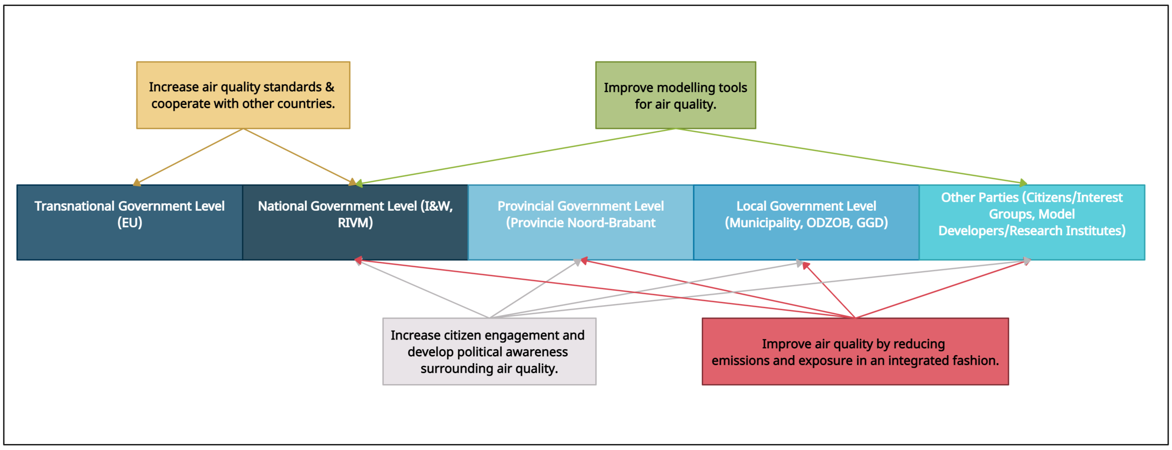


Figure 6.4: A visualisation of the linking of each level of government to the key improvements necessary to improve the municipal air quality policy process.

As can be seen from Figure 6.4, these solutions require the cooperation of many levels of government. We therefore recommended the adoption of an approach across multiple levels of government, where the national government plays a coordinating role, involving relevant parties from all levels of government to aim higher and further. Such an approach could take a similar form as the already existent Schone Lucht Akkoord, but taking a more engaged stance towards involving stakeholders from the whole spectrum, instead of only a limited number of parties. Within this approach across multiple levels of government, we see significant potential for improved modelling tools to play a role in improving the means available to actors across different government organisations, but especially municipalities, which will allow them to perform improved source apportionment as well as coupling air quality to other relevant issues. This will allow them to develop more tailored and effective policy solutions, leading to a long term improvement of both the health and livability of the city. These conclusions have been developed for the municipality of Eindhoven, our case study. To expand our scope, we can now investigate them in other municipalities.

# 7

# Comparison with Other Municipalities

As mentioned in chapter 2, to determine if our conclusions had wider applicability, we interviewed experts from two other cities. In section 7.2 the answers from an air quality policy maker in the municipality of Utrecht are presented. In section 7.3, the results from the DCMR, the environmental service that works in the region of Rijnmond, which includes the large city of Rotterdam, are discussed. For both, the structure of the air quality policy process is first discussed, after which the applicability of the conclusions for Eindhoven are evaluated.

## 7.1. Comparison Methodology

To determine the wider applicability, we investigated two main areas in our comparison interviews with Utrecht and the DCMR.

Firstly, we asked interviewees questions about the structure of the municipal air quality policy process in their respective regions, including which parties were involved in it, how certain policy topics were put on the agenda and how models were used in the development of policies and the wider policy process. This could then be compared against the features identified in Eindhoven, to determine which similarities and differences were present and theorize on potential reasons behind them.

Secondly, we questioned interviewees about the applicability of our findings from Eindhoven, specifically on the need for an approach across multiple levels of government as well as citizen engagement and stimulating political awareness about air quality. This would allow us to determine if our findings indeed had the broader applicability, and if not what led to these issues not being relevant for them.

With this description of our methodology, we can now go into the answers we found for Utrecht and the DCMR.

## 7.2. Utrecht

First, we have the municipality of Utrecht, where the goal was to better understand the structure of the air quality policy process and the bottlenecks associated with it, as well as determining the improvements necessary to overcome them.

With regards to the structure of the municipal air quality policy process, it was found that the structure in Utrecht followed the same patterns as in Eindhoven. The first stage of the policy process commences with the identification of the ambitions of the municipal council ('policy initiation'), which are then further developed by the municipal policy advisors ('policy development'). The policies are then approved by the municipal executive ('decision making'), and then implemented and monitored by the municipality and the environmental service ('policy implementation/evaluation'). The environmental service and the health service (GGD) are also involved in the development of policy measures, and have the ability to signal new policies. There is also a certain level of regional cooperation with other cities like Amersfoort.

The municipality primarily uses the CIMLK tool to calculate the air quality in the city and its surroundings, and also makes uses of the GeoMilieu (STACKS) modelling suite to aid urban development and specific destination plans. In such applications, they manually compare different variants of plans with respect to each other with respect to air quality. In the past, the municipality also used the MGRI-maps, but more recently, the translation of air quality to health has been outsourced to consultancies and the RIVM, due to their higher level of expertise and knowledge about the subject.

The bottlenecks for this municipal air quality policy process do differ significantly for some aspects. Due to the prominence of green parties in the municipal council and the more general left-leaning nature of the municipality, there is a significant amount of political support and ambition for working on air quality, in contrast to Eindhoven where citizen engagement is a significant obstacle.

The limitations of the municipal policy space identified in Eindhoven do apply to Utrecht however, where municipalities only have limited power and ability to influence the air quality in their environment. It was mentioned that in Utrecht, the municipality has the ability to influence about twenty percent of the air pollution, with the other eighty percent coming from sources or areas beyond the municipality's control (e.g. industry, regional and national pollution, etc.). To continue improving air quality in the municipality therefore, there would be a need for an approach across multiple levels of government, with initiatives primarily being coordinated on the national level of government. This is not to say that the municipality of Utrecht was said to be unable to do anything, but rather that their efforts should be part of a large framework of efforts and policies coordinated across the country and the European Union. Thus, this latter bottleneck, and the improvements necessary to overcome it, align rather closely with those identified for Eindhoven.

## 7.3. DCMR

Next up, we have the DCMR, which is the environmental service for the region of Rijnmond, encompassing the region around the city of Rotterdam. Because the comparison was made from the perspective of the environmental service, no comprehensive comparison on the air quality policy process in municipalities like Rotterdam could be made. It was noted that the DCMR, similarly to the ODZOB, advises and works with municipalities in their region. They focus on permitting, monitoring and enforcement of large industry and calculating air quality for municipalities. These calculations can take the form of quantifying the effects of policy measures, such that a properly informed decision can be made by decision makers, which is backed up by calculations. They also advise on the feasibility of policy measures and help in working them out. In addition, the DCMR also monitors the policy measures in their implementation and evaluation phase. Finally, it was mentioned that municipalities are the ones who identify and initiate policy measures, and that the environmental service aids in the development and implementation/evaluation of policy initiatives.

Drawing the comparison to Eindhoven then, we can see that at least the policy implementation/evaluation phase is relatively similar, and that the environmental service plays a relatively comparable role as the ODZOB. With respect to the conclusions from the previous chapters, both on the bottlenecks and the required improvements, the following answers were found. Firstly, for the region of Rijnmond, the value of increasing awareness among citizens was seen as relatively valuable. Especially because of the reduced distance between representative and voter (e.g. smaller constituency) , the wishes of residents were said to be more thoroughly reflected in the municipal council. Stimulating citizen awareness and engagement was therefore mentioned to be a worthwhile investment. An example of an initiative that came up during the interview was bringing together the locations where citizens could find information from for example local measurements. It was discussed how many municipalities, currently operate their own websites whilst there is already an aggregated source for these measurements which could be used. Providing an easily accessible source of information for people that are interested in it could aid in developing citizen awareness.

Furthermore, it was mentioned that, like in Eindhoven, there is a need for a comprehensive approach across multiple levels of government which includes municipalities. The environmental service reported that the contribution that municipalities can influence (i.e. traffic and mobile sources) accounted for less than half of the emissions, with the contribution of traffic being forecasted to continue to reduce with increasing prominence of electric and hybrid vehicles (Gemeente Rotterdam, 2020). A third of all emissions (or even more, determining on the meteorological conditions) was determined to be from outside of the region, and the rest of the emissions fell under the jurisdiction of provincial and national governments (e.g. industry, wood burning, ships). The need to coordinate responses between different governmental bodies and levels was thus identified to be crucial in the interview.

## 7.4. Conclusion

To conclude, we found that the structure of the municipal air quality policy process in both the region of Rijnmond and municipality of Utrecht aligned relatively closely with the structure identified for the municipality of Eindhoven.

Needs for policy and ambitions are identified in the policy initiation stage by the municipal council, with room for the municipality, the environmental service and the health service to signal their own policy initiatives. These are then further developed in the policy development stage by the municipality, where other parties like citizens, the GGD and the environmental service can give their input and advice. The policy are then evaluated and approved by the municipal executive in the decision making phase, which citizens can directly and indirectly influence by voting and contacting their representatives. Finally policy that is approved is then implemented in the policy implementation phase by the municipality and the environmental service, who evaluate the efficiency and efficacy and can then feed this back to the first stage.

It was also found that the modelling tools used were once again mostly the same ones determined in Eindhoven, with the important exception of the MGRI-maps, which were substituted with outsourcing to consultancies and the RIVM in Utrecht, following a lack of expertise on the subject.

With respect to the bottlenecks in this process, it was found that the demographic and political constituency of the city determined if citizen engagement and development of political awareness around the topic of air quality was a bottleneck to the policy process. It was found that it was a bottleneck for Rijnmond, where citizen engagement was still seen as a potential area for improvement. For Utrecht, this limitation did not apply, with a more environmentally engaged constituency that already favoured policies that come forth from the air quality policy process.

The second bottleneck of limited power and ability to influence the air quality applied to both Rijnmond and Utrecht, with both interviewees calling for a more coordinated approach across multiple levels of government, where each level of government could play an important role, which would strengthen air quality standards in the country and aim for more ambitious legislation.

# 8
# Conclusions & Discussion

In this work, we aimed to investigate and develop an understanding of the structure of the Dutch municipal air quality policy process, and the role that models played in it. This research was performed in a case study of the municipality of Eindhoven. We interviewed a range of experts involved in the different stages of the policy process, and attempted to generalise our findings based on interviews with experts from other municipalities. The interview data was combined with information from official publications and literature surrounding air quality modelling. Based on this, we attempted to create an understanding of the policy process and sought to identify recommendations to improve it. We therefore end this work by revisiting and answering the research question.

***What potential improvements in the Dutch municipal air quality policy process can be made, and what role can models play in this?***

The answer to this research question should thus be twofold. Firstly, how can the air quality policy process be improved (and what are the associated obstacles to these improvements). Secondly, how can improved modelling tools aid the policy process and overcome the bottlenecks which are currently present in the municipal air quality policy process.

## 8.1. Revisiting the Research Question

To obtain these answers, we broke down our research question into four distinct sub-questions. The questions, and the methods used are as follows.

- **What is the current multi-level governance structure of the air quality policy process in Dutch municipalities?** To answer this question, we drew upon information from grey literature (in the form of government publications and websites) and interviews with individuals involved in the municipal air quality policy process.

- **By whom and in which manner are air quality modelling tools used to support the policy processes in this structure?** Similarly, in this question we drew upon grey literature and interviews with experts on modelling in the municipality.

- **What are the current developments in air quality modelling, and how can these be applied to improve the municipal air quality policy process?** For this question, a scientific literature scan was performed of the development pathways of air quality models was combined with interviews with model developers from both the public and private sector.

- **What obstacles currently exist in the municipal air quality policy process, and how can these be overcome?** Finally, for the last sub-question we combined information from these same two sources: interviews with individuals involved with the municipal air quality policy process and scientific literature on multi-level governance.

### 8.1.1. What is the current multi-level governance structure of the air quality policy process in Dutch municipalities?

In the first sub-question, we investigated the structure, characteristics and the actors involved in the air quality policy process.

We identified four distinct phases in the municipal air quality policy process. These are as follows.

- **Policy Initiation.** The policy initiation stage concerns the identification and selection of new policies related to air quality. The main actors responsible for this phase are the municipality and the municipal executive [College van Bestuur & Wethouders]. In addition, the health service (GGD Brabant Zuidoost) and the environmental service (Omgevingsdienst Zuidoost Brabant, ODZOB) have the ability to signal the need for policy initiatives to the responsible stakeholders. The majority of new policies are identified and put on the agenda at the beginning of the electoral cycle (i.e. after elections). A list of policies is then composed in a document called a ”bidbook”, which explains the thought process and the requirements (both financial and practical) of each policy measure. Throughout the rest of the electoral cycle there is the possibility of developing new policy initiatives, but this is less common.
- **Policy Development.** The next phase of the policy process concerns the policy development phase, which includes citizen participation as well. During this phase, policy measures are developed in more detail, with regards to aspects like scope (where in the municipality it will apply), duration and definitional details. The responsible stakeholder for this part of the process is the municipality itself, with advice coming in from the GGD and the ODZOB on their own respective expertise. In addition, during this phase the input from engaged citizens and residents affected by the potential policy measure is collected. The main goal of the policy development phase is therefore to develop the specifics of policies, and to calculate the effects on aspects like concentration as well as cost. It is also therefore one of the main phases of the municipal air quality process where models are used, as will be further discussed below. Finally, is also during this phase that different policy alternatives might be developed, which are evaluated in the next stage of the process, the decision making.
- **Decision Making.** The third phase is the decision making phase, where the municipality returns to the municipal executive with the detailed plans for their policy initiatives. At this point, the mayor and the alder-people will evaluate the different policy options, determine the political feasibility of the policy options for the municipality at large and finding the room for it in the budget. During this phase, they also take input from the advisory actors from the previous phase, namely the GGD and the ODZOB. It should be noted that citizens also have an indirect say in this part of the process, as their voting preferences will lead to the political makeup of the municipal executive. Once a policy gets approved in the decision making phase, it can then finally be moved on to the final phase of the policy process: the policy implementation and evaluation.
- **Policy Implementation/Evaluation.** The policy implementation and evaluation phases, as the name implies, are the points where policy measures get implemented into concrete real-world actions. The primary responsible actor for this phase, the municipality, implements the necessary changes or sets up the programs as dictated by the details of the policy. At the same time, the ODZOB and the GGD are also responsible for this phase, depending on the specific policy measure. Policies with regards to commercial activities are coordinated through the ODZOB, whilst policies pertaining to health or citizens directly are usually coordinated in cooperation with, or directly by, the GGD. As a result of this part of the process we have the outputs of the municipal air quality policy process. These are aspects like the air quality in the municipality, the permitting requirements, the citizen engagement and awareness about air quality and so forth. Finally, in this phase we also have the mandatory reporting requirements under the different legal frameworks like the Schone Lucht Akkoord (SLA) and Nationaal Samenwerkingsprogramma Luchtkwaliteit (NSL) which will be discussed below.

The structure of the municipal air quality policy process is visualized in Figure 8.1.

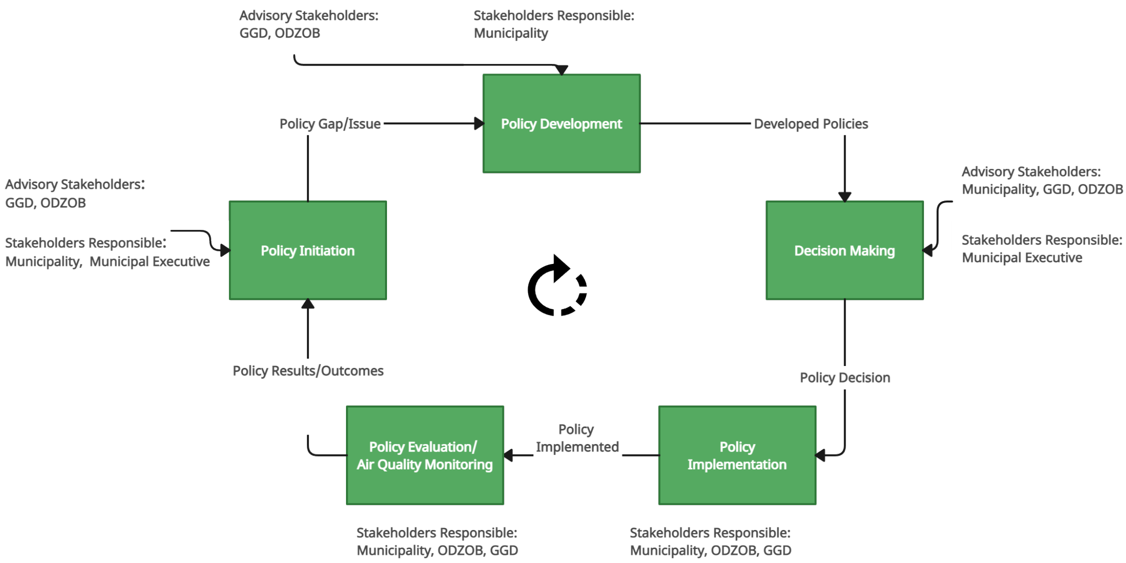


Figure 8.1: Visualisation of the municipal air quality policy process.

Going beyond the system boundary, we also included the key inputs and outputs of the system in Figure 8.2. Outside of the system boundary we have the legal framework which includes three of the most important pieces of legislation. These are as follows: the Nationaal Samenwerkingsprogramma Luchtkwaliteit (NSL), the Schone Lucht Akkoord (SLA) and the Omgevingswet. The first, the NSL, was the original legal framework for improving the air quality in the Netherlands, and imposes specific air quality standards, mandatory reporting requirements and obligatory model uses. The second, the SLA, is a voluntary agreement in which municipalities, provinces and the national government participate to improve the air quality in their respective jurisdictions even further. The agreement also comes with a clear goal (a 50% reduction in negative health effects due to air pollution by 2030 with respect to 2016) and mandatory reporting requirements, using the same tools as used in the NSL. Finally, we have the Omgevingswet, which drives the municipality towards a more integral approach with respect to environmental legislation and policy. This piece of legislation (coming into effect in 2023) will drive the different actors in the municipal air quality policy process to increased cooperation and more integrated decision making, including multiple aspects like air quality, heat stress, noise pollution and many more into the healthy living environment goals.

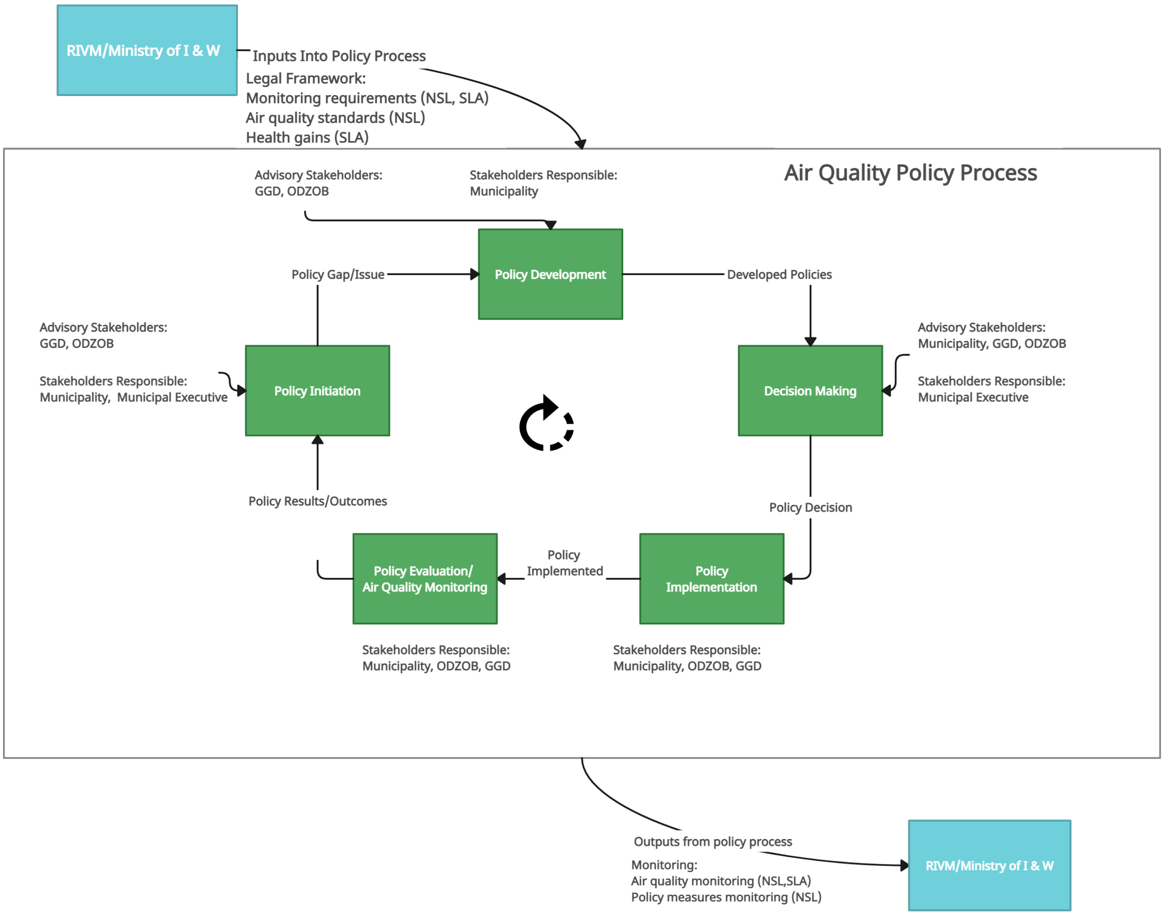


Figure 8.2: Visualisation of the municipal air quality policy process including inputs and outputs.

As can be seen, there is a significant amount of interaction into and out of the system boundary, as a result of the legal framework. But how are models used in this process?

### 8.1.2. By whom and in which manner are air quality modelling tools used to support the policy processes in this structure?

We determined that there are four main modelling players: the municipality of Eindhoven, the ODZOB, the GGD, and the RIVM. The models they use and their respective characteristics are presented in Table 8.1

Table 8.1: Models Currently In Use

| Model | Model Type | Calculation Method | Extra Information | Used by | Developed by | Legally Mandated |
|---|---|---|---|---|---|---|
| NSL-Rekentool | Air Quality | SRM 1 & 2 | Succeeded by Aerius Lucht Rekentool | Municipality, ODZOB | RIVM | Yes |
| Aerius Lucht Rekentool | Air Quality | SRM 1 & 2 | Will be succeeded by CIMLK | Municipality, ODZOB | RIVM | Yes |
| CIMLK | Air Quality | SRM 1 & 2 | Introduced in 2023 | n.a. | RIVM | Yes |
| Nieuw Nationaal Model | Air Quality | SRM 3 | Will be succeeded by STACKS+ (with ODZOB) | ODZOB | WLM | Yes |
| STACKS+ | Air Quality | SRM 1 & 2 & 3 | Currently being taken into service by ODZOB | ODZOB | DGMR | No |
| NSL-Monitoringstool | Other | SRM 1 & 2 | Will be succeeded by CIMLK | Municipality, RIVM | RIVM | Yes |
| Nationale Emissie Registratie | Other | n.a. | Outputs emission factors | GGD | RIVM | No |
| OPS/GCN/GDN Maps | Other | Background concentrations of air pollution | Grootschalige Concentratie/ Depositie Nederland, Output of OPS | Municipality, GGD, RIVM ODZOB | RIVM/TNO | Yes |
| GGD Rekentool | Health | n.a. | Based on (Maas et al., 2015) | GGD | GGD GHOR | No |
| VTV | Health | Dynamo Health Impact Assessment (den Broeder et al., 2022) | Volksgezondheid Toekomst Verkenning, used to quantify health effects for SLA | RIVM | RIVM | Only for SLA |
| Milieu Gezondheids Risico Indicator | Health | Milieugerelateerd gezondheidsrisico | Pilot Project in Municipality Eindhoven in 2016 (van Heeswijk, 2016) | Municipality, GGD | RIVM | No |

We found that next to the air quality models, there are also models that translate the concentration of air pollution to health impacts, which are used by the GGD, municipality and the RIVM.

It was also clear that the main driver behind model usage was the legal obligation to do so, with additional models only being used sporadically. In situations where non-mandatory models were used (the MGRI model), this appeared to be a result of the familiarity of users with the model, which was developed in a case study in the municipality.

Our main takeaway was the importance of models to be anchored in the legal framework, to ensure their proper usage. In addition, we also determined the possibility of using health models to directly translate air pollution to health impacts or even monetary cost.

Revisiting the air quality policy process visualisation, we can now add the relevant models to it.

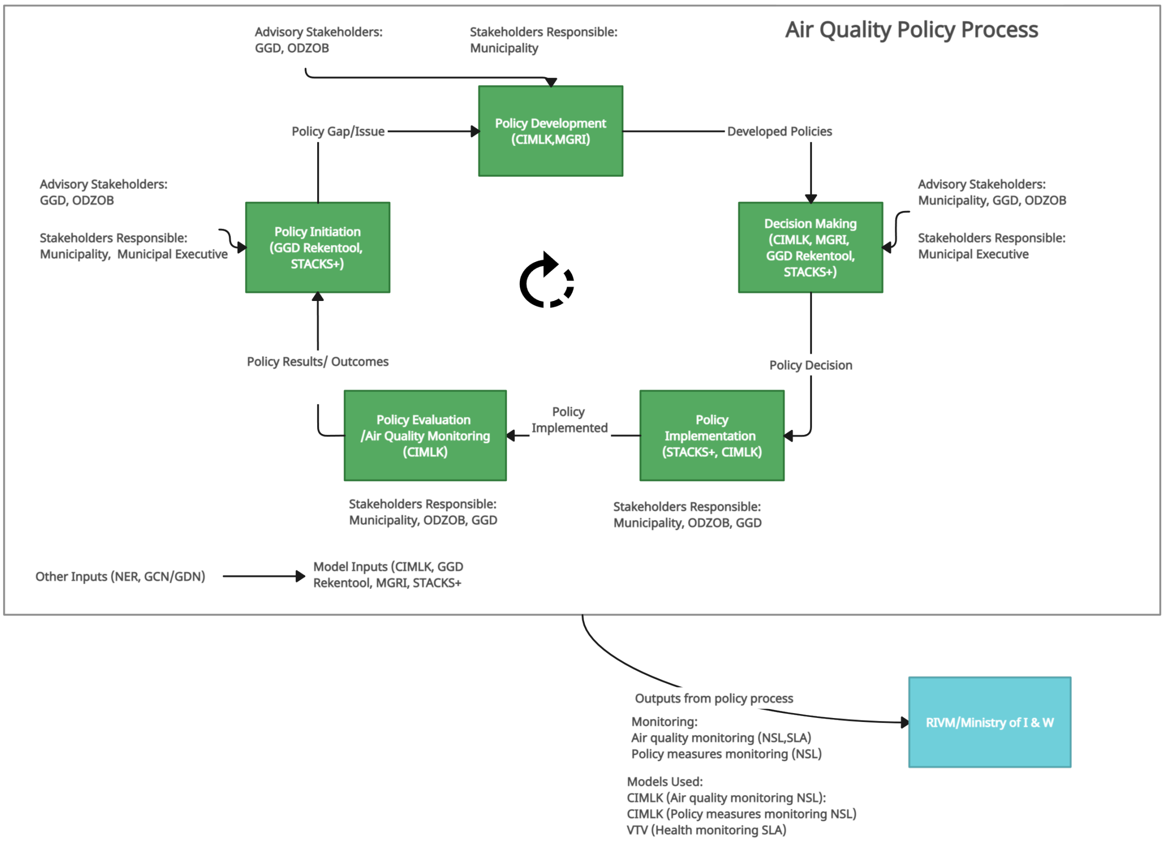


Figure 8.3: Visualisation of the policy process including the models used.

Based on these models, we could then investigate in further detail how these models could be improved.

### 8.1.3. What are the current developments in air quality modelling, and how can these be applied to improve the municipal air quality policy process?

We discussed improvements along five main axes of development, as presented in Table 8.2. In this table, these improvements are then applied to the municipal air quality policy process. The five areas of improvements align with the different aspects of an air quality models. The improvements in input data and measurements are rather straightforward. These improve the model inputs, which should improve the modelling outcomes. The improvements in resolution, both temporally and spatially, concern an enhancement in the model's predictive characteristics. Finally, the improvements in integral modelling and functionality can then be considered an improvement in the outputs of the model.

Table 8.2: Improvements in policy process through modelling tools.

| | Resolution (Temporal/Spatial) | Input Data | Integral Modelling | Functionality | Measurements |
|---|---|---|---|---|---|
| **Policy Initiation** | Identify problem areas | Identify problem areas | Combining policy challenges | Accessible information about air quality for citizens | Identify problem areas |
| **Policy Development/ Participatory Input** | Source apportionment | Source apportionment | Combining policy challenges | Accessible information about air quality for citizens | n.a. |
| **Decision Making** | Source apportionment for political support | Source apportionment for political support | Combining policy challenges | Accessible information about air quality for citizens | n.a. |
| **Policy Implementation/Evaluation** | Determine compliance | Determine compliance | n.a. | n.a. | Determine compliance |

As can be seen in the table, almost every part of the policy process could benefit from these improvements in certain characteristics. Figure 8.4 presents these improvements in the municipal air quality policy process figure that we have used previously.

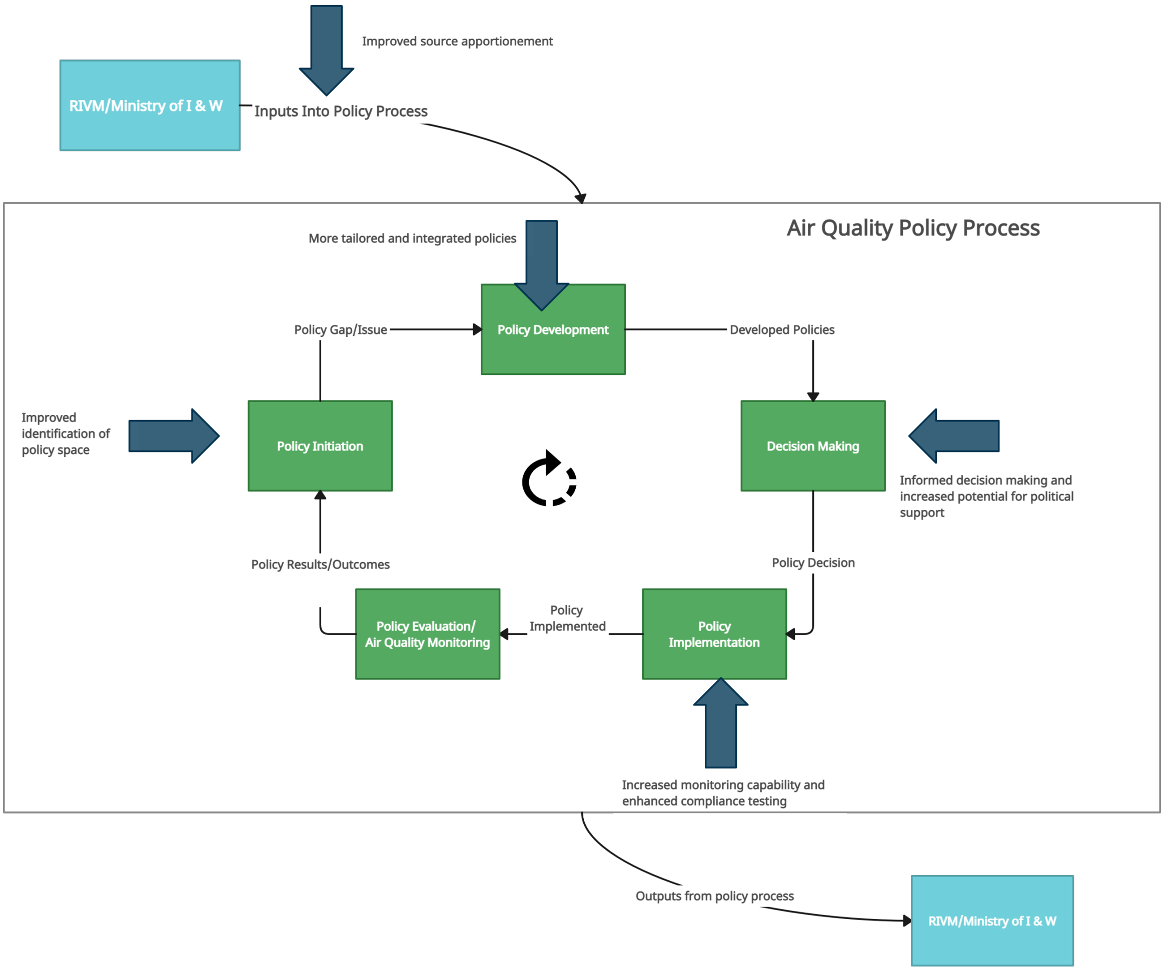


Figure 8.4: Improvements in the policy process through developments in modelling tools.

We therefore arrive at an overview of the developments related to better modelling tools, and can now evaluate what is needed to improve the process even further.

### 8.1.4. What obstacles currently exist in the municipal air quality policy process, and how can these be overcome?

For the final sub-question, we investigated which bottlenecks are present in the municipal air quality policy process, and then compared them against the improvements obtained in the previous sub-question. Based on this comparison, we determined that gaps that were still missing, and the associated ”gap improvements” necessary to overcome them. The bottlenecks are presented in Figure 8.5.

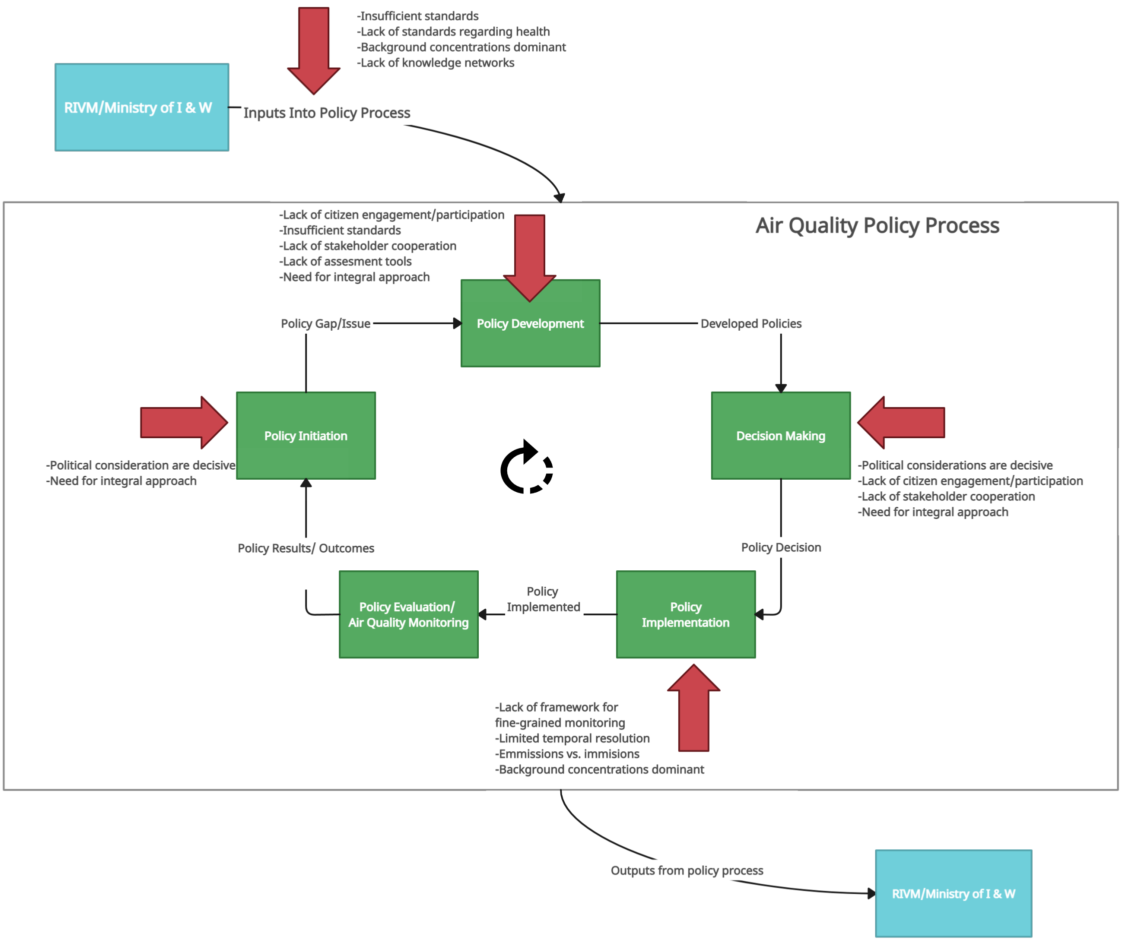


Figure 8.5: Bottlenecks in the air quality policy process.

We determined that the gaps that remained, were distributed all across the policy process, and thus we developed gap improvements for all of the bottlenecks. We summarized these into four main categories, presented in Figure 8.6, and explained in more detail in the next section.

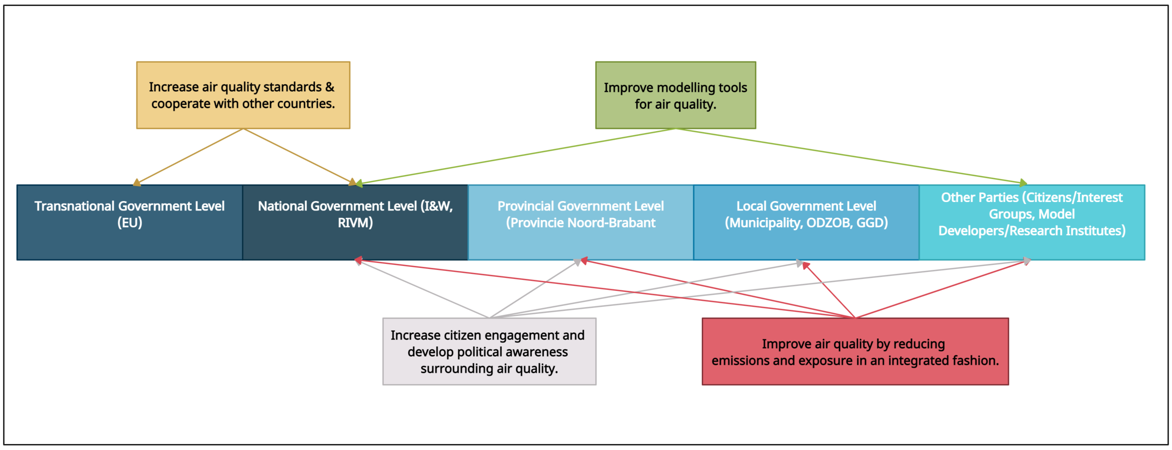


Figure 8.6: A visualisation of the linking of each level of government to the key improvements necessary to improve the municipal air quality policy process.

As can be observed from the figure, these improvements are connected to multiple levels of government and different actors. We recommend an approach on multiple levels of government, described in more detail below.

### 8.1.5. Answering the Research Question

With all of the information from the four sub questions we discussed now, we can once again revisit the research question.

***What potential improvements in the Dutch municipal air quality policy process can be made, and what role can models play in this?***

We found that there are four main areas in which the air quality policy process may be improved. Firstly, the legal framework set out by the national (and supranational with regards to the EU) government should be updated continuously in the form of more ambitious air quality standards, the linking of air quality to health and increased cooperation between different levels of government. Secondly, efforts should be put towards increasing citizen engagement and awareness surrounding the topic of air quality in order to increase political support for policies improving it. Thirdly, air quality and sources of air pollution (emissions) should be targeted and tackled in an integrated fashion. Air quality should be coupled to other relevant issues to municipalities like the housing crisis, climate change and the healthy living environment. Furthermore, integrated policy making also means coordinating and tailoring policy options across multiple levels of government, with active participation from municipalities, provinces and the national government, as well as citizens across the country. The final area for improvement concerns the second part of the research question, namely the improvement of modelling tools for simulating air quality. Let us discuss this in more detail.

With regards to improving modelling tools, we found that there are a few main characteristics which are valuable. These are improved source apportionment, more integral modelling, and a more diverse functionality set. Improved source apportionment will allow for more tailored and specific policy approaches, as well as a facilitated approach across multiple levels of government through a clearer distinction of responsibilities. More integral modelling will allow the combining of policy challenges like noise pollution, heat stress and health with air quality, which will give policy makers to opportunity to identify and target potential compound gains from policies which address multiple issues. Finally, improvements in functionality will allow for better communication of air quality information to citizens, improved emissions management and the comparison of policy alternatives and scenarios. Combining all of these improvements brings us back to the main goal: supporting policy and decision makers in their process and facilitating their efforts.

These conclusions were also touched upon in other areas in the Netherlands, namely the region of Rijnmond and the municipality of Utrecht. It was found that for both of them, there is a demand for a multi-level governance solution to improving air quality. It was also found that if sufficient political support can be rallied, significant policy initiatives can be undertaken, but that all of this will still fall short if policy is not coordinated across multiple jurisdictions and governments.

To conclude then, we found that there is a need for efforts across multiple levels of government to improve the air quality policy process, wherein multiple initiatives like improving air quality modelling tools are combined to structurally overcome the obstacles that are currently holding it back.

## 8.2. Discussion & Limitations

Before we move on to the recommendations that we drew from our conclusions, we should also reflect on our research and its limitations. We will discuss three aspects of our research: the methods used, the results obtained, and the conclusions drawn.

### 8.2.1. Methods

Starting with our reflection of the methods used in our research, we differentiate between the three main data sources: interviews, scientific literature and grey literature. With respect to the interviews, there are a few points we believe are worth discussing. Firstly, we should reflect on the comprehensiveness of our interviews. Although we were able to perform interviews with all of the main parties involved in the municipality (i.e. the different departments in the municipality and the supporting services like the ODZOB), we were unable to speak to individuals involved in citizen action groups or municipal council members in an interview format due to time constraints. Although conversations with people that would fit these specifications were held, we were unable to perform a recorded interview with them, which did limit the extensiveness of our information on the structure of the municipal air quality policy process. In addition, the interviews that were taken were mostly one interview (sometimes with multiple people, but always only one interview) per organisation for all parties except the municipality. This limited the ability to compare information obtained from interviews in the same organisation to determine overlap and differences, which we were able to do for the municipality. Having been able to do this for the other parties would have also been valuable.

Another limitation of these interviews were the difficulties getting in touch with the officials after having performed the interview. A lot of the follow-up questions that arose as we performed the interviews and gained a deeper understanding were left unanswered which unfortunately meant that all of the interview data reflects the limited knowledge of the subject and the structure of this research at that point in time. By performing the interviews in a rounds-manner, where the same experts would have questions put to them multiple times throughout the thesis process, their role could have been strengthened and the discovery process facilitated.

With respect to the scientific literature used and reviewed, we performed our research in a non-structured manner, that is to say, there was no clear methodology behind our methods of collecting information about the subject at hand. As was mentioned in the methodology chapter, the primary focus for the literature scan revolved around investigating the development pathways of air quality models. The primary, and only, preparations that were made before commencing this process were in the form of the interview with the model developers of the research institute. Although this gave a good overview of modelling developments, and a few indicators of key words to pursue, we would argue that it was not a sufficient approach. As will be mentioned in chapter 9, we recommend others authors perform structured research in the direction of air quality modelling development pathways, to create a more comprehensive view of this research, which could then be built upon further by those looking to implement these improvements in practice.

Finally, we also drew upon grey literature, which in our case meant literature in the form of government publications, documents and websites. There were a few aspects here that are worth discussing, especially with respect to the websites. One of the big limitations that our research ran into, was the introduction of the CIMLK model starting from January 1st, 2023. Our research commenced back in September 2022, which meant that right around the time we were finishing the second sub-question of our research, there was suddenly a big overhaul in the models. This had two main implications: firstly our whole story had to be rewritten for this sub-question, which we tried to use as an opportunity to improve rather than an obstacle. But secondly, this also meant that a significant number of websites, including those dedicated to the NSL Rekentool, suddenly became unavailable and redirected to the main page of the CIMLK tool [1]. Because of this, we had to suddenly find new sources for those websites, which was unfortunate.

[1] See for example the website for the NSL Monitoringstool, which now redirects you to the CIMLK page: https://www.nsl-monitoring.nl

With all that said however, we would be amiss not to mention and appreciate the quality of the information available about this topic on government websites. Websites like infomil.nl and iplo.nl were incredibly valuable sources, which went in significant detail whilst still explaining everything in clear and understandable language. The fact that this information is not only publicly available but also well-written and presented is worth mentioning and we are very grateful for it.

Finally, we were unable to generalise our findings as much as we might have liked, only being able to interview two other areas. It would have been valuable if we could have performed interviews with different sizes of municipality, but once again time constraints were limiting.

### 8.2.2. Results

Let us now move on to reflecting on the results that we obtained throughout the different sub-questions that we answered, and think about how they fit into the expectations that were formed at the beginning of this work.

**The structure of the municipal air quality policy process** The municipal air quality policy process structure is conceptually similar to the phases model (Enserink et al., 2022). However, the phases model is a significant oversimplification of how the process occurs in real life. As mentioned in the chapter itself, most of the new policy gaps and associated initiatives are identified at the beginning of the term of a municipal council. In the coalition agreements that are made between the governing parties, most of the policy measures are already mentioned at least in limited detail if not already in a developed manner. For most of the rest of the governing period, the policies are then passed through the other three phases of the policy process, with some taking significantly longer to get passed through the decision making (for example the low emissions zone in Eindhoven).

Furthermore, in our visualisation we only represented the players that were identified in the stakeholder scan section, whilst in reality, a lot more parties are of course involved, both private and public. For example, one of the stakeholders that was identified was the citizen interest group Aireas, which cooperates with the municipality on the ILM 2.0 measurement network and its implementation. This does not fit into our visualisation, whilst it does happen in reality, reflecting the limitations of our abstraction.

Finally, we also made the choice to present our results in a linear fashion, whilst in reality the different phases continuously interact with each other in significant ways. The policy development is informed and influenced by the current implementation of other policies, and the decision making will take current new initiatives into account in their actions. It is therefore once again paramount to underline the simplifications made to make the process understandable.

**The use of air quality modelling tools**

Moving on to the second sub-question, as discussed in the section above, this chapter had to be updated halfway through the process due to the release of the CIMLK model, which meant that a lot of the players suddenly started to use other models.

Another limitation of this chapter is the lack of discussion about traffic models. As was mentioned in the text, the municipality combines the input from the GCN/GDN maps with a traffic model in the CIMLK tool to obtain the concentrations in the municipality. The effect of the choice of traffic models also has a significant influence on the outcome of these air quality models. This means that a discussion of these traffic models could have been valuable in enhancing our analysis.

The last main reflection point we would like to discuss about this chapter is with regards to the lack of understanding on why certain players use certain models. Although we did discuss this briefly in some of the sections, there was no in-depth analysis or questions about this, in neither the interviews nor this work. By digging further into this issue, a deeper understanding on what drives the use of certain models could be obtained, which is especially valuable to model developers.

**The improvements in modelling tools**

The main limitation in our analysis of the improvements in modelling tools is the lack of a structured literature review discussed in the section about the methods adopted above. By performing such a review, a more comprehensive picture could have been drawn, and the analysis could have been deeper.

**The approach across multiple levels of government**

With respect to the approach across multiple levels of government, we believe additional research on the characteristics, use and implementation of such a coordinated approach would have enhanced this work significantly. Currently, this is only done in a superficial manner in chapter 6, which unfortunately detracts from the applicability and usefulness of our analysis outcomes.

### 8.2.3. Conclusions

Reflecting on our conclusions, we see that although we have answered our research question in detail, all of the conclusions (and recommendations made in the next chapter) are rather tentative. Although there is precedence for an approach across multiple levels of government in the form of the NSL, the conditions that led to the establishment of that program are no longer true today. As we mentioned in the legal framework section of chapter 3, at the time, the Netherlands did not meet the legal air quality standards it had set out for itself. To achieve them, policy makers in the national government clearly realized they needed to get all levels of government on board to improve the air quality across the country. We therefore conclude that to establish another such program, the need and conditions for it must once again arise. This is also the reason that we underlined the importance of sharpening the standards at the EU and national level, as this would be most straightforward way to ensure that the pressure to improve the air quality in the Netherlands becomes an important topic again.

We would also like to mention one of the main limitations of our conclusions being only from one municipality: as we already noticed in our interviews with the municipality of Utrecht, not all of the aspects apply everywhere. Depending on both the environmental and political conditions in a municipality, some of the problems and solutions discussed in this work might be more or less applicable. We therefore will also recommend in the next chapter that further research is applied on determining how important this national cooperation and political support making is in other municipalities in the Netherlands.

Finally, we also believe that the conclusions that were obtained for our research questions were significantly influenced by our framing. A large focus of our research laid with the use of air quality models, which although they are clearly of significant importance for this problem, are not actually the key bottlenecks as was discussed in chapter 6. When considering these conclusions therefore, it should be kept in mind that the framing of the research questions has significantly contributed to the answers that were given to it.

# 9 Recommendations

Based on the conclusions discussed above, we have also developed a set of recommendations. We have split these recommendations into two main categories. Firstly, we have the recommendations targeted at the governmental actors directly or indirectly involved in the municipal air quality policy process. Secondly, we have a set of recommendations, specifically for the Dutch research institute of TNO. This work was written during an internship at this organisation. Finally, we have created a set of recommendations for further research associated with this work and the wider air quality policy process.

## 9.1. Recommendations

As mentioned previously in the conclusions, we recommend an approach across multiple levels of government to improve the municipal air quality policy process. Such an approach would involve the coordination of the different levels of government, starting at the municipal level, up through the province and the national government, all the way to the European Union. We recommend an approach that involves all of these actors due to a few key features of the municipal air quality policy process. These are related to the distribution of powers with regards to regulating emissions, with each level of government having jurisdiction over different sources, the nature of air pollution being dynamic in space (i.e. air pollution does not remain at the source but crosses multiple governmental boundaries) and finally the intrinsic interlinking of environmental politics and air quality. Due to these aforementioned reasons, we conclude that a unilateral approach of improving air quality would not suffice and we recommend an approach that is coordinated at the national level where all government levels play their respective parts.

The different policy solutions for every level of government come down to, as discussed in the conclusion, four main areas of improvement. These are as follows. The respective responsibilities for these general areas can be found in Figure 8.6, where a visualisation of the approach across multiple levels of government is presented.

- Increase air quality standards and cooperate with other countries.
- Improve modelling tools for air quality.
- Increase citizen engagement and develop political awareness surrounding air quality.
- Improve air quality by reducing emissions and exposure in an integrated fashion.

The list of recommendations for government have been summarized in Table 9.1. These fit into the larger recommendation for an approach across multiple levels of government as discussed above.

Table 9.1: Table of Recommendations for Government

| Gap Improvement | Organisation |
|---|---|
| Engage citizens with air quality to increase citizen participation and political support for air quality measures. | Local Government |
| Connect air quality with other issues relevant to municipalities like the healthy living environment and climate change. | Local Government |
| Focus on reducing air pollution from sources that municipalities can influence (like local traffic and mobile sources). | Local Government |
| Initiate and aid citizen participation initiatives in municipalities. | Provincial Government |
| Work towards increasing the stringency of regulation on industry through permitting. | Provincial Government |
| Create knowledge networks for information sharing about air quality. | National Government |
| Aid municipalities in the establishment of citizen participation initiatives. | National Government |
| Provide and support modelling tools that can be easily used by municipalities to connect air quality to other topics. | National Government |
| Adopt a timeline plan with continuously more strict standards to keep driving actors to work on ambitious air quality regulation. | National Government |
| Incorporate health into the larger national government strategy for air quality. | National Government |
| Create a regulatory framework to reduce emissions from sources like wood burning, the construction sector and traffic. | National Government |
| Work together with member states to agree on stricter air quality standards. | European Union |
| Coordinate and negotiate transnational air pollution issues. | European Union |

## 9.2. Recommendations for TNO

As was mentioned in chapter 2, this work was performed during an internship with the Dutch research institute TNO. In our research, we obtained a few key recommendations which we believe could help the work they are doing in developing the modelling tools used to simulate air quality. We have split these into two main categories, presented as follows.

- Collaborate with large municipalities that have both the air quality issues (industry,traffic, etc.) as well as the scale and resources to work on them
- Continue efforts towards more accurate source apportionment in modelling tools.

Of course, these recommendations do not solely apply to TNO, but are also relevant to similar organisations like universities and other provides of modelling tools. However, we will focus on the applicability for TNO here due to our experience with them during our internship.

With regards to the first recommendation we found in our conversations with the regional health and environmental services that for smaller municipalities, there is a distinct lack of resources and personnel to tackle these issues comprehensively (which ties into our call for an approach across multiple levels of government). This means that if research institutes wish to work directly with municipalities, they should evaluate which role they wish to play, ranging from direct consulting all the way to indirectly developing the modelling tools that are mandatory through the legal framework like in the SLA. Furthermore, as we mentioned in the introduction of this work, cooperating and coordinating with municipalities in their air quality governance and in the development of modelling tools is essential for their proper use. It is therefore clear that there is significant potential for research institutes like TNO to contribute to improving the municipal air quality policy process, in whatever form they see fit, as long as proper consideration is given to the ends that they wish to achieve.

On the second point, we would like to underline the importance that accurate source apportionment has to municipalities. One of the main themes that came back repeatedly was the importance of developing policies and plans which are well-tailored and narrow, in order to ensure they step on as few toes as possible, and thus do not suffer from the ever present political considerations at the municipal level. It is therefore absolutely essential that municipalities have a clear picture on what the origin is of the air quality affecting its citizens, which can be significantly aided by the provision of improved source apportionment in tools like the GCN/GDN maps.

Furthermore, this improved ability to discern to which extent different sources of pollution contribute to the air quality in the municipality is incredibly important in order to give the municipality the information necessary to lobby decision makers at the provincial and national level to take additional steps in order to reduce the exogenous pollution coming into the city. This information is exactly the type of thing that a research institute like TNO could offer with improved modelling tools, which could also be coupled to enhanced measuring networks, all coming together to form possibilities for mutually beneficial partnerships. We therefore recommend this avenue as the second main recommendation for TNO: continue driving for better and more accurate models, which improve resolution both spatially and temporally, and allow municipalities to develop better and more effective policy solutions.

## 9.3. Recommendations for further research

Below, a few key recommendations for further research have been formulated.

- **Investigate air quality modelling pathways.** Our review of air quality modelling developments was unfortunately not structured in a comprehensive manner, which means that there might still be gaps in the model developments discussed in this work. We recommend a comprehensive review of these developments in order to determine what other gains could be made by applying better modelling to the municipal air quality policy process.

- **Investigate wider applicability in other municipalities.** As mentioned in the conclusions, we already tried to investigate the wider societal relevance of our conclusions by comparing them in two other areas, namely the region of Rijnmond and the municipality of Utrecht. Although some of our conclusions still applied there, not all of them did. We recommend a more comprehensive analysis of these similarities and differences, and the drivers thereof.

- **Investigate the effects of the Omgevingswet.** As discussed in chapter 3, the new Omgevingswet will fundamentally overhaul a lot of the municipal air quality policy process, especially with regards to the implementation and evaluation of policies. Research into the effects thereof would be valuable.

- **Investigate the municipal air quality policy process in other countries.** The Netherlands has a rather unique governance structure, which means that some of the conclusions that were drawn in this work could be investigated for other European countries, to determine what causes the differences and how the process could be improved there.

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# A

# Interview Questions

All of the interview questions that were asked during the research for this work are presented below, per specific group that was interviewed. It should be noted that these questions were asked, and thus reported here, in Dutch.

## A.1. Municipality of Eindhoven

Three interviews were performed, with individuals involved in the decision making, policy advice and modelling parts of the air quality policy process.

### A.1.1. Decision Making

1. In het nieuwe bestuursakkoord worden beleidsplannen zoals een slooppregeling voor brommers en snorfietsen opgebracht. Hoe komt zo een regeling van A tot Z tot stand?
2. Wie is er allemaal betrokken in het ontwikkelen van beleidsadviezen en welke rol spelen zij later tijdens de besluitvorming? Wie kan er nieuwe initiatieven signaleren of op de agenda zetten?
3. Worden resultaten uit onderzoek en modellen ook meegenomen in het beleid en besluitvormingsproces?
4. Organisaties zoals de GGD en Omgevingsdienst spelen een grote rol in het creëren en uitvoeren van luchtkwaliteitsbeleid. Hoe worden zij betrokken in het besluitvormingsproces en wat voor een invloed hebben zij in het vormgeven van nieuw beleid?
5. Vraag 5: Wat zijn in jouw ogen de voornaamste veranderingen die de nieuwe omgevingswet gaat brengen voor jullie eigen beleidsproces?
6. Er zijn meerdere theorieën over hoe beleid tot stand komt. Ik heb hieronder de drie voornaamste even opgesomd. Welke van deze drie sluit volgens jouw het beste aan bij het beleidsproces in de gemeente Eindhoven?

### A.1.2. Policy Advice

1. Wie is er allemaal betrokken in het ontwikkelen van beleidsadviezen en welke rol spelen zij later tijdens de besluitvorming? Wie kan er nieuwe initiatieven signaleren of op de agenda zetten?
2. Hoe worden resultaten uit onderzoek en modellen ook meegenomen in het beleid en besluitvormingsproces?
3. In verschillende publicaties van de gemeente kwam ik de term "postzegel plannetjes" tegen, wat dan zou gaan over kleinschalige bestemmingsplannen. Kunnen in jouw ogen dit soort kleinschalige ontwikkelingen doelbewust worden ingezet om de luchtkwaliteit te verbeteren of in ieder geval de negatieve effecten van projecten te verlichten?

4. Hoe bepalen jullie of een project valt onder "Niet in betekende mate" bij te dragen aan luchtverontreiniging?
5. De jaargemiddelde concentraties die leidend zijn in de huidige wetgeving kunnen niet altijd de volledige gezondheidsimpact van piekmomenten weergeven, noch het effect van ultrafijn stof. Hoe denk jij dat de gemeente in kan zetten op het beter bepalen (zoals bijvoorbeeld met het luchtmeetnet) en verbeteren van dit soort aspecten?
6. Waar zie jij de grootste obstakels voor het verbeteren van luchtkwaliteit in de gemeente liggen? En hoe denk jij dat deze obstakels overkomen zouden kunnen worden?

### A.1.3. Modelling

1. Luchtkwaliteitsbeleid zoals de milieuzone komt natuurlijk niet van de ene dag op de andere tot stand, maar welke rol spelen modellen en simulatie tools in het ondersteunen en soms leiden van de discussies rondom dit soort onderwerpen?
2. Wat voor een modellen worden er nu gebruikt om luchtkwaliteit te voorspellen? En hoe worden deze modellen gebruikt in het ontwikkelen van beleidsadvies?
3. Op welke basis worden modellen gebruikt? Wordt er buiten de wettelijk vereiste toetsing (bv. NSL Monitoring Tool) ook nog aanvullende modellering gedaan?
4. Wat voor een data gebruiken jullie om je model te runnen? Kunnen regelingen zoals het luchtmeetnet bijdragen om de voorspellingen te verbeteren?
5. Wat voor een obstakels komen jullie tegen in het gebruik van jullie modellen? Zijn dit gebruikersgerelateerde obstakels (gebrek aan data, tijdsrestricties etc.) of zijn ze gerelateerd aan de toepassing en vertaling naar de praktijk (resolutie, vertaling naar beleid, etc.)?
6. Waar ligt er volgens jouw ruimte voor verbetering in het proces? Welke leemtes zouden betere modellen kunnen vullen om de gemeentelijke beleidsprocessen te verbeteren?

## A.2. Environmental Service

1. Hoe zit het vergunningsproces voor bijvoorbeeld een groot nieuwbouwproject in elkaar? Hoe ondersteunen jullie projectontwikkelaars en burgers hier in?
2. Welke regels en leidraden volgt de omgevingsdienst in het waarborgen van de luchtkwaliteit?
3. Wanneer een nieuw beleid wordt aangenomen door gemeenten, betekent dit ook nieuwe werkzaamheden voor jullie. Hoe vertalen jullie deze regelingen zoals de nieuwe slooppregeling voor brommers en snorfietsen naar concrete processen binnen de omgevingsdienst?
4. Wat voor een rol spelen luchtkwaliteitsmodellen in jullie werk? En welke informatie halen jullie uit deze modellen?
5. Welke rol en ruimte hebben jullie om nieuwe beleidsinitiatieven op de agenda te zetten bij gemeenten?
6. Waar zie jij de grootste obstakels voor het verbeteren van luchtkwaliteit in de gemeenten liggen? En hoe denk jij dat deze obstakels overkomen zouden kunnen worden?

## A.3. Health Service

1. In de conferentie over het luchtmeetnet rond Eindhoven kwam naar boven dat de GGD de resultaten van het luchtmeetnet kan gebruiken om beleidsadvies te geven aan gemeenten. Wat voor een vorm zou zo een beleidsadvies nemen?
2. Hoe ondersteunt de GGD meer algemeen gemeenten in het ontwikkelen van luchtkwaliteitsbeleid? Speelt de GGD ook een ondersteunende rol in besluitvorming?

3. Welke informatie wordt hiervoor uit methoden zoals modellering en simulatie gehaald? Hoe vertaal je deze informatie naar concrete lijnen die gemeentelijke beleidsadviseurs kunnen meenemen in hun eigen processen?

4. In literatuur ligt er een grote nadruk op het belang van “framing” voor de succesvolle uitvoering van effectief luchtkwaliteitsbeleid. Is dit een kwestie waar er bij de GGD uitdrukkelijk aandacht wordt besteed? Hoe beinvloedt dat de opzet en uitkomst van analyses die worden uitgevoerd?

5. Hoe balanceert de GGD vereisten die door nationale regelgeving opgelegd worden (bijvoorbeeld door het RIVM) met de wensen en doelen van gemeenten?

6. In een gesprek met experts van de GGD Rotterdam-Rijnmond werd er aangegeven dat veel van hun werk reactief is, wat inhield dat ze zich voornamelijk bezighielden met vragen van wethouders en burgers. Speelt de GGD soms ook een proactieve rol waarin zij de nood voor nieuwe initiatieven signaleren/agenderen? Hoe zou dit proces er dan uit zien?

## A.4. Research Institutes

1. Wat is de meerwaarde van het ontwikkelen van deze modellen? Welke specifieke vraagstukken kunnen beantwoord worden door middel van de nieuwe ontwikkelingen in een LOTOS-EUROS of DALES?

2. Er is op dit moment veel interesse en activiteiten rond lokale metingen met relatief hoge nauwkeurigheid. Wat voor een groeimogelijkheden in luchtkwaliteits modellering zien jullie als gevolge van dit soort metingen?

3. De nieuwe omgevingswet stimuleert een integraler milieubeleid in gemeenten, waar bijvoorbeeld luchtkwaliteit meegenomen wordt in een grotere afweging samen met bijvoorbeeld hittestress in een buurt. Zien jullie mogelijkheden voor modellering waar meerdere van dit soort aspecten kunnen worden samengebracht?

4. In mijn gesprek met de omgevingsdienst zagen zij een mogelijkheid voor modellen die bijvoorbeeld stikstofruimte konden beoordelen in een bepaalde omgeving, zodat op basis daarvan vergunningverlening kon worden uitgevoerd. Hoe realistisch zien jullie applicaties als deze in?

5. Om gebruikt te worden in officiële beslissingen, zoals bijvoorbeeld bij wegen, moeten modellen gecertificeerd zijn. Is het verwerken van jullie modellen in het wettelijke kader van luchtkwaliteits bepaling ook een doel voor jullie (zoals nu het geval is voor het NMM, Aerius, etc.)?

6. Een van de knelpunten van het verbeteren van luchtkwaliteit op het lokale niveau is het creëren van politiek draagvlak voor beleidsmaatregelen. Denken jullie dat door bewoners bewust te maken van hun impact op de luchtkwaliteit en de gevolgen hiervan dat dit draagvlak kan ontstaan? En is dit een bewustzijn dat gestimuleerd kan worden door modellen (in plaats van metingen)?

## A.5. RIVM

1. Sinds dit jaar gaat het CIMLK de Aerius Lucht Rekentool en NSL Monitoringstool vervangen, welke grote veranderingen brengt dat met zich mee?

2. De SRM 1 en 2 zijn nog recentelijk geactualiseerd, maar hoe zit het met SRM 3/NNM?

3. Welke toekomst hebben deze rekenmethoden nog? Zal er op een gegeven moment ruimte zijn om ook andere rekenmethodes te gebruiken binnen het wettelijke kader?

4. Het RIVM heeft in 2016 de MGRI-kaart ontwikkeld, die vandaag de dag nog steeds wordt gebruikt in de gemeente Eindhoven. Wordt dit model nog steeds ontwikkeld? En in welke richting?

5. Welke andere initiatieven zijn er binnen het RIVM om luchtkwaliteit integraler mee te nemen in het beleidsproces?

6. Wat zijn in jouw ogen de voornaamste veranderingen die de nieuwe omgevingswet gaat brengen voor jullie eigen proces?

7. Welke veranderingen denk jij dat er nodig zullen zijn om verder te streven in gemeenten naar de WHO-advieswaarden?

## A.6. Other Regions

### A.6.1. DCMR

1. Welke rol speelt de DCMR in het bijstaan van gemeenten in het beoordelen van luchtkwaliteit?
2. Welke modellen gebruikt het DCMR om dit uit te voeren?
3. Welke toekomst hebben deze rekenmethoden nog? Zal er op een gegeven moment ruimte zijn om ook anderen meer integrale, rekenmethodes te gebruiken binnen het wettelijke kader?
4. Voor de gemeente Eindhoven ligt het knelpunt van luchtkwaliteit op twee grote punten, hoe zeer strijken deze obstakels bij jouw ervaring?
    - Het ontbreken van bewustzijn en politiek draagvlak/wil onder burgers om hoger te mikken dan wat door het NSL/SLA opgelegd wordt.
    - De nood voor initiatieven op alle niveaus van overheid: van Europees, naar nationaal en provinciaal, tot op het lokale niveau. Oftewel een gebrek aan een ambitieuzer multi-level governance framework.
5. Welke veranderingen denk jij dat er nodig zullen zijn om verder te streven in gemeenten naar de WHO-advieswaarden?

### A.6.2. Utrecht

1. Hoe ziet het beleidsproces voor luchtkwaliteit er uit in Utrecht? Wie is er allemaal betrokken in het ontwikkelen van beleidsadviezen en welke rol spelen zij later tijdens de besluitvorming? Wie kan er nieuwe initiatieven signaleren of op de agenda zetten?
2. Worden resultaten uit onderzoek en modellen ook meegenomen in het beleid en besluitvormingsproces? Worden er buiten de standaard CIMLK en verkeersmodellen gebruik gemaakt van andere modellen?
3. Organisaties zoals de GGD en Omgevingsdienst spelen een grote rol in het creëren en uitvoeren van luchtkwaliteitsbeleid. Hoe worden zij betrokken in het besluitvormingsproces en wat voor een invloed hebben zij in het vormgeven van nieuw beleid?
4. Het RIVM heeft in 2016 de MGRI-kaart ontwikkeld, die vandaag de dag nog steeds wordt gebruikt in de gemeente Eindhoven. Wordt het ook gebruikt in Utrecht?
5. Voor de gemeente Eindhoven ligt het knelpunt van luchtkwaliteit op twee grote punten, hoe zeer strijken deze obstakels bij jouw ervaring?
    - Het ontbreken van bewustzijn en politiek draagvlak/wil onder burgers om hoger te mikken dan wat door het NSL/SLA opgelegd wordt.
    - De nood voor initiatieven op alle niveaus van overheid: van Europees, naar nationaal en provinciaal, tot op het lokale niveau. Oftewel een gebrek aan een ambitieuzer multi-level governance framework.
6. Welke veranderingen denk jij dat er nodig zullen zijn om verder te streven in gemeenten naar de WHO-advieswaarden?

# B

# Policies

## B.1. Current air quality policies

The municipality of Eindhoven currently has an expansive list of policy measures which target multiple sources of emissions in addition to measures which are meant to reduce mixing and exposure. Policies that make use of modelling and simulation tools, or those that could be improved by them are identified. The main area that is targeted is the traffic in the city, as a municipality has significant influence over this, especially as opposed to the background concentrations from sources like Eindhoven airport (Gemeente Eindhoven, 2021).

The policies currently adopted are as follows:

- Stimulating cleaner transport modes by transitioning to 100% electric public transport by 2025
- Constructing (high-speed) bicycle routes
- The introduction of a low-emissions zone (milieuzone/environmental zone) for clean cargo transport
- The decision to move towards a zero-emission zone inside the beltway (ring van eindhoven) by 2030 with an associated roadmap with specific steps
- Introducing a traffic calming zone within the city (binnen de ring) (autoluw)
- Introducing adjacent measures like the expansion of the HOV-Network (High Quality Public Transport Network), the creation of a Park and Ride at the Aalsterweg and the expansion of bike storage in the city centre
- Improved circulation on the city beltway and arterial roads, leading to lower emissions of pollutants from idling cars in traffic

## B.2. Future air quality policies

Of course, the municipality has outlined future policies it would like to adopt in this bidbook as well. These are as follows: Further working out the traffic calming measures in the city center:

- Improving car sharing
- Influencing behaviour of residents, employees and visitors of the city
- MaaS-pilot, which offers large employers optimal transport modalities
- Expanding bike storage in the city centre and around Eindhoven Centraal station
- Continuing construction of high speed/bypass bicycle routes (regional);
- Continuing construction of Park and Ride hubs outside of the city centre connected to the HOV network

- ”Construction Hub and other transshipment points in combination with city logistics to bring as many emission-free goods as possible into the area within the ring road”

Discouraging through traffic in city center:

- Changing/redesigning the west inner beltway with a speed reduction 30km/h
- Redesign of Fellenoord and Westtangent within ”Eindhoven Internationale Knoop XL”
- Improving capacity and throughput of West Beltway
- Redesign/Upgrade Fuutlaan

Expedited electrification of taxis:

- Creating a physical information point where cab drivers can obtain free independent advice on the ownership costs of diesel versus electric taxis
- The Taxi Stand at Stationsplein-Zuid will become zero-emission, making diesel taxis forbidden there.
- Subsidizing transition to a zero-emission taxi

Further measures include:

- Scrapping scheme of old vans
- Scrapping Scheme of mopeds and scooters (the municipality calls for better national policy to help with this and regulating it)
- Moving mopeds from bike lane to roadway
- Reducing the emission of harmful pollutants through engaging citizens and informing them on the effects (the municipality calls for better national policy to help with this and regulating it)
- ILM 2.0 with citizen participation