Exploring a Scenario tool

1 Introduction to Scenario exercise

1.1 Learning goals

Key learning goals of this exercise are to:

- Explore the possibilities that integrated assessment (modelling) can provide for the planning and implementation of air pollution prevention and control policies. This includes becoming familiar with impact and costs modules, modules for air pollution prevention and control measures and simple optimization procedures.
- Build some simple baseline and alternative policy scenarios and discuss how these can be useful in the policy making process.
- Get familiar with some simple principles of optimisation in integrated assessment models for air quality management.
- Learn which data is required to build scenarios and use integrated assessment models.
- Learn and share experiences where and how this data can be obtained from.

Remember, the goal of the exercise is not to become an experienced SIM-AIR user, but rather to understand the possibilities Integrated Assessment Modelling can provide in supporting the planning and implementation of air pollution prevention and control policies!

Based on the exercise with SIM-AIR you should be able do define better your needs for Scenario Building and Integrated Assessment Modelling. We would also like to initiate discussions among workshop participants whether and how we shall further develop the emission inventory and the Malé Declaration Integrated Information and Assessment System (IIAS).

We also need to consider if and how the SIM-AIR tool itself be further developed to match your needs - even to be synchronised with the Malé Inventory tool.

1.2 Getting started

SIM-AIR uses a Microsoft Excel spreadsheet with Visual Basic macros to facilitate the development of an integrated interactive decision support system for Urban Air Quality Management. The spreadsheet allows computation of an emission inventory for key pollutants, estimates impact of emissions sources on ambient air quality, and evaluates health impacts in economic terms. Various policy, economic, and technical options can then be evaluated for their cost-effectiveness. An optimization model is also built-into the spreadsheet to determine the best combination of options that can meet desired objectives (e.g. minimum cost) subject to constraints (e.g. ambient quality standards).

SIM-AIR is a simple spreadsheet program which can be opened using Microsoft Excel. Copy SIM-AIR.XLS to your computer and launch it. Ensure that you enable 'macros' while opening the file. Simply click on 'Enable macros' when the Excel program asks for it. To use the optimization function, ensure that you have the Solver tool launched. To enable the Solver, go to Tools, click on Add-Ins and check on Solver.

1.3 Structure of SIM-AIR

SIM-AIR has a 'Summary' worksheet and a number of other worksheets for data input and data output, the latter ones showing results of various calculations and scenarios. The 'Main" worksheet contains the model interface, 19 different 'Management Options' as decision variables and the interface for optimisation.

Worksheets for data input and modification of settings are:

- Emissions data input
    - Emission distribution & emission distribution base
    - Domestic cooking and heating
    - Vehicles
    - Brickkilns
    - Open burning garbage, etc.
    - Paved road dust (PRD)
    - Industries
    - Power plants
- Transfer matrix for atmospheric dispersion
- Options for Air Pollution Prevention and Control
- Menudata

Worksheets for data output are:

- Emission data summary (output)
    - Spatial distribution emissions Current Baseline (CBL)
    - Spatial distribution emissions Target Year Baseline (TBL) uncontrolled
    - Spatial distribution emissions Target Year Controlled (TC)
    - Summary emissions Current Baseline (CBL)
    - Summary emissions Target Year Baseline (TBL) uncontrolled
    - Summary emissions Target Year Controlled (TC)
- Ambient Concentrations
    - Concentrations Current Baseline (CBL)
    - Concentrations Target Year Baseline (TBL) uncontrolled
    - Concentration Target Year Controlled (TC)
- Scenario components (Scen_Comps)

Other worksheets are Health Impacts (both input & output), Help, and Schematics.

You can browse through all worksheets to become familiar with SIM-AIR, but for the following exercise we will only look at the three worksheets *Main*, *Vehicles*, and *Scen_Comps*.

Atmospheric transport and ambient pollutant concentration in SIM-AIR

SIM-AIR comprises a simple model for atmospheric transport and emission distribution for an urban area, divided into a 4 × 4 grid with 16 cells (C-1-1 … C-4-4). Each cell is then analyzed for emissions. For the exercise we are not going to make use of this model.

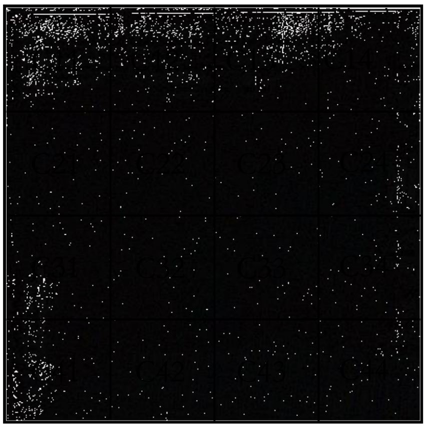


Figure: Division of city into grids

Three emission cases in SIM-AIR

In the current version, SIM-AIR allows analysis of three emission cases:

- **Current Baseline (CBL)** is the emission inventory for the present
- **Target Year Baseline (TBL)** is a projection of emissions for a target future year, assuming changes in the activity rate, but no air pollution prevention and control measures. The annual growth of the activity rate can be modified by the user in the emission input worksheets. Note that the TBL projection only gives a rough estimate of emission levels in the target year, since the effects of policies adopted (e.g. future emission standards) are taken into account. Also changes of emission factors due to, e.g the renewal of the vehicle fleet are not considered in this Target Year Baseline projection. Values for both the baseline year and the target year can be set in the *menudata* worksheet.
- **The Target Year Controlled (TC)** scenario is a projection of emissions for a future target year with additional control and management measures. These measures can be set in the *main* worksheet. The Target Year Controlled function allows the analysis of alternative policy scenarios and a comparison to the Target Year Baseline projection.

Please note that the default values of SIM-AIR for economic activities, emissions, atmospheric transport, health impact, and costs for air pollution prevention and control measures are only for illustration. For real-life application of the SIM-AIR model, users should replace all default values with site-specific data.

2 Exercises

2.1 Estimate future emissions from the transport sector

Go to the *Vehicles* worksheet. You can see that the default figure for the growth rate of the vehicle stock for the target years 2017 is set at 0 %. For the exercise build two growth scenarios:

Growth scenario A: Change the annual growth rate of all vehicle groups from the default figures of 0 % to an average **annual growth of 4 % i**n the period 2007-2017

Growth scenario B: Change the annual growth rate of all vehicle groups from the default figures of 0 % to an average **annual growth of 8 %** in the period 2007-2017

- What is the total increase of number of vehicles in both scenarios?
- Do you know at which rate vehicle numbers have been growing in the past years in your country?
- What is your best estimate for vehicle growth in your countries for the next years? Where could you obtain forecast about vehicle growth from? How could you otherwise model the future number of vehicles in use?
- What is the total increase in emissions from vehicles in both scenarios?
- Do you think that under the current policy framework of your country emissions from the vehicle sector will grow slower than vehicle numbers / vehicle activity rates?
- Do you have ideas how one could model the average emission factors of the vehicle fleet in ten years under a business-as-usual scenario where only current policies are implemented but no new policies for air pollution control are implemented?

Discuss with your colleagues.

Answers: In Scenario A vehicle numbers and emissions grow by 48%, in Scenario B vehicle numbers and emissions grow by 115%.

2.2 Building alternative policy scenarios

For this exercise we assume a growth rate in the transport sector as we have described it above in Scenario B. Please make sure that for the following exercise the number of all vehicles grows by annually 8 % from 2007 – 2017.

Go to the *Main* worksheet, which contains amongst others 19 different 'Management Options' as decision variables in order to build alternative policy scenarios. Implications on emissions, ambient concentration, costs and health impact can be viewed in the *Main* worksheet by varying the scrollbar provided in front of each management option.

By pushing the *Optimisation Set-up* button all scrollbars are set back to their default values.

Pushing the *Copy to Scenario 1/ 2/3* button copies some key result of the simulation into the *Scen_Comps* worksheet where the scenarios can be compared to each other and to the Target Year Baseline case (uncontrolled).

In this exercise we build three different alternative policy scenarios ion order to evaluate and compare different management options:

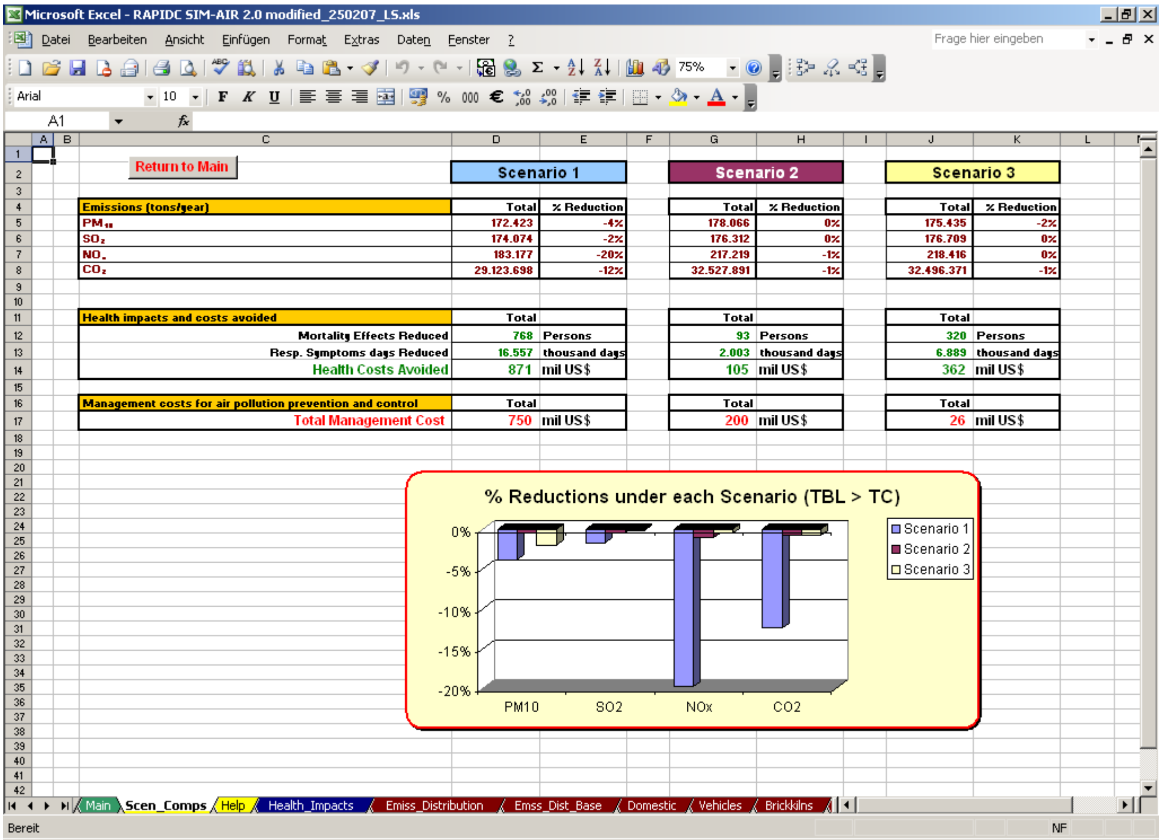
- **Policy Scenario A:** Convert 100 % of the bus fleet from Diesel to Natural Gas (NG).
- **Policy Scenario B**: All 2-stroke engine 2-wheelers and 3-wheelers are scrapped and replaced with 4-stroke engine 2-wheelers and 3-wheelers.
- **Policy Scenario C:** Ban all 3 wheelers.

Make sure to set all scrollbars back to their default values (*Optimisation Set-up* button) before building the single policy scenarios.

How do emissions of the total **vehicle stock** change in comparison to the Target Year Baseline (TBL)? Check in the *Vehicle* worksheet in cells I73 – L73. Write down the percentaged changes in the table below.

	PM_{10}	SO_x	NO_x	CO_2
Policy scenario A	-13,6%	-11,7%	-19,4%	-16,9%
Policy scenario B	-1,8%	-2,7%	-1,2%	-1,0%
Policy scenario C	-0,7%	-1,1%	-0,5%	-1,2%

You can also copy the results of the respective scenarios into the *Scen_Comps* worksheet to see the impacts of the policy intervention on the total emission load, and to compare the three Policy Scenarios on cost-effectiveness and economic efficiency. You should get three scenarios as depicted in the screenshot below:



Discussion

- Which of the three policy interventions is the most *effective* in terms of emission reductions?
- Which of the three policy interventions is the most *cost-effective*? Remember, cost effectiveness is a criterion in which the benefits are not valued in monetary terms. Rather the question is whether the same results could have been achieved with fewer resources or could the same resources be used more effectively to achieve a better result?
- Judge the three policy interventions form the perspective of *environmental efficiency*. Remember, environmental efficiency deals with the question whether the benefits to society (e.g. reduced health impact) are worth the cost imposed to society and polluters (e.g. costs for pollution abatement).
- What type of data regarding cost of abatement measures and regarding health impact is required to conduct this analysis? Where could you obtain this data from?

Remember that all results are only for illustration and based on the default values of SIM-AIR for economic activities, emissions, atmospheric transport, health impact, and costs for air pollution prevention and control measures.

2.3 Optimising Air Pollution Prevention and Control Measures

2.3.1 Brief introduction to the optimisation technique used in SIM-AIR

Optimization tools could be better used in air quality management decision making process. In many ways, optimization illustrates the classic dilemma of decision makers – that of having an objective (or several objectives), and several "knobs" or decision variables for management subject to several constraints. SIM-AIR has incorporated a sample tool to illustrate the use of optimization for air quality management decision making. The form used in SIM-AIR is as follows:

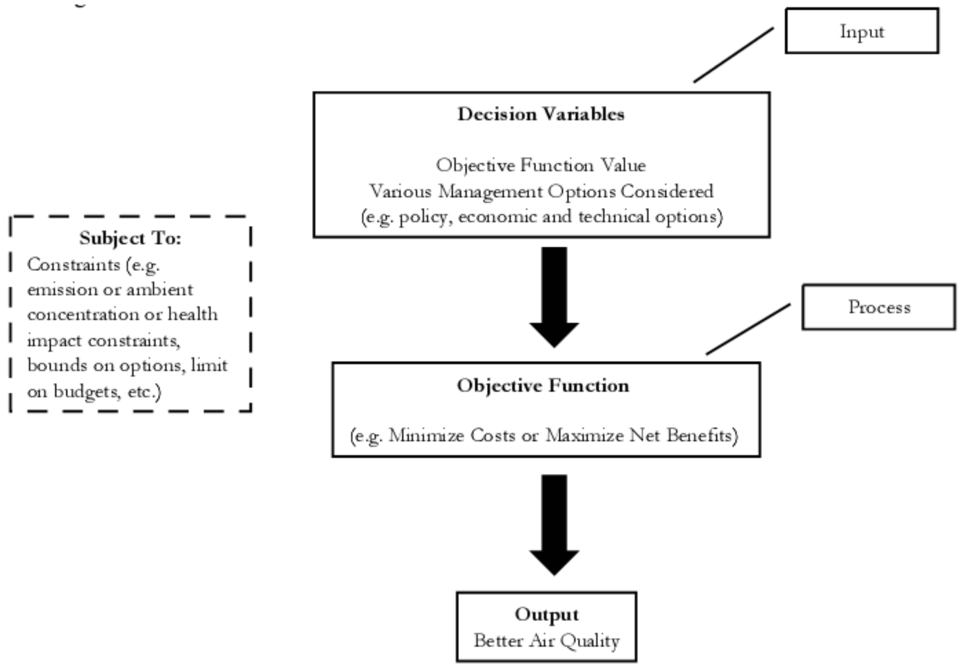


Figure: Optimisation process

- **Objective function:** An objective function is a function that is to be maximized or minimized. E.g., minimise costs, maximize benefits.
- **Decision variable:** Variable that is under the control of the decision maker and could have an impact on the solution of the problem of interest is termed a decision or control variable. E.g., Management Options are decision variables.
- **Constraint:** A constraint is a condition that the solutions of an optimization problem must meet, e.g. that a certain decision variable must be greater than zero. Often, constraints are given by equations and inequalities.

Following table lists some of the parameters which can be used in various combinations to arrive at the optimum solution.

Objective Function	Decision Variables	Constraints
Minimum management costs Minimum mortality/morbidity Minimum health effects Minimum ambient concentrations	Management options	Target emission loads • PM10 • SOx • NOx • CO_2 Average regional concentration Grid based concentration Sector based concentration Mortality/morbidity levels Minimum & maximum of management options

Table: Different parameters of optimisations

The optimized solution can be obtained using the inbuilt optimization program in Microsoft Excel. This program is known as solver. To use this feature, the user has to follow the steps below:

1. Go to Tools menu and click on Solver (if the Solver is not added in then go to Tools menu and click on Add-Ins and check on the radio-box named "Solver Add-in")
2. A window titled, "Solver Parameters" will pop-up in which various parameters need to filled in.
3. Assign the target as the desired cell.
4. Set the constraints in the "Subject to the Constraints" box. As identified earlier, the constraints would be as follows:
    - Total cost should be less than objective cost
    - Lower limit of option should always be lesser than lower limit of the option range
    - Upper limit of the option should always be greater than upper limit of the option range More number of constraints can be added by clicking on Add
5. Decision variables can be filled in the box titled, "By Changing Cells:"
6. Click on "Solve" to get the optimized result.

2.3.2 Optimisation exercise

For the following optimisation exercise we try to find the most cost-effective combination of management measures for air pollution prevention and control to achieve certain emission reductions from Target Year Baseline (TBL) scenario. This means that for the optimisation the objective function is to minimise management cost. The decision variables are the 19 management options, and the constraints are target emission loads and the minimum and maximum values of management options.

For the Target Year Baseline scenario, we assume, like in the previous exercise a growth rate of the transport sector of 8 % annually from 2007 – 2017. Other sectors grow according to the default values set in SIM-AIR.

Go to the *Main* worksheet, which contains amongst others 19 different 'Management Options' as decision variables in order to build alternative policy scenarios. Implications on emissions, ambient concentration, costs and health impact can be viewed in the *Main* worksheet by varying the scrollbar provided in front of each management option.

Optimisation Scenario A seeks to reduce PM10 emissions by 30% from the TBL scenarios at the lowest achievable cost. The optimisation procedure entails the following steps:

- Use the scrollbar in cell D38 to set a reduction target of 30% for PM10.
- Push the *Optimisation Set-up* button.
- Make sure that the *Solver add-in* is installed properly.
- Push the *Solve* button and wait until Solver finds a solution.

26					
27	**For Target Controlled - Tons/yr**	**PM10**	**SO2**	**NOx**	**CO2**
28	Domestic	10.642	7.471	4.737	9.251.184
29	Open Burning	18.836	18.836	18.836	18.836
30	Industries	19.784	39.568	3.510	-
31	Brick Kilns	1.755	2.681	877	1.462.281
32	PRD	60.168	-	-	-
33	Power Plants	19.677	83.626	4.526	590.304
34	Transport	48.087	24.791	186.939	21.425.927
35	Total	178.948	176.974	219.425	32.748.533
36					
37	Desired Reduction TBL > TC	30%	0%	0%	0%
38					0
39	Desired (tons/year)	125.264	176.974	219.425	32.748.533
40					
41	Target (tons/year)	125.264	176.974	219.425	32.748.533
42	Original (tons/year)	178.948	176.974	219.425	32.748.533
43	Actual Reductions	0%	0%	0%	0%
44					

- You may have to run several iterations with different start values of the management options to find a good solution where you can meet the reduction target at the least cost possible. Set preferably the "expensive" management options to a lower start value and then start the next iteration by pushing the *Solve* button.
- You can save interim and final scenarios in the *Scen_Comps* worksheet by pushing the *Copy to Scenario 1/ 2/3* button.
- For the optimisation you can also further constrain or exclude certain management options by changing their minimum / maximum values in cells V16:W34.
- For this task you should be able to attain a 30 % reduction of PM10 emissions with a combination of management measures for around $ 600 Million.
- You can also "play" manually with the management option scrollbars and try to find a set of policies that may attain a slightly lower reduction target (e.g. 25 % PM10 reduction) at considerably lower cost.

Try to set up **Optimisation Scenario B.** Here the goal is to achieve an emission reduction of all four pollutants (PM10, SOx, NOx, CO2) by at least 20 % at minimum cost. What is the minimum cost you can calculate after a few iteration runs?

Other optimisation approaches

The optimisation function in SIM-AIR can be used for a range of different optimisations, e.g. to determine

- the maximum achievable emission reductions for a given budget available for management measures,
- the maximum achievable health benefits for a given budget available for management measures,
- the minimum costs required to achieve certain air quality targets in one or several cells of the urban grid;

2.3.3 Discussion

- Discuss with your fellow participant of the workshop the advantages and disadvantages of optimisation modelling as conducted in the exercise.
- Where do you see limitations?
- Where do see advantages and disadvantages of using different objective functions, e.g.:
    - minimising emissions;
    - minimising ambient pollutant concentration;
    - minimising costs;
    - minimising health impacts.
- What type of optimisation could be most useful in your country and / or in your professional work environment?
- Do you think that top-level governmental officials in your country would trust the outcomes of Integrated Assessment Modelling and would consider results when taking decisions about air pollution prevention and control measures?
- How shall SEI / IIIEE further develop the emission inventory and the Malé Declaration Integrated Information and Assessment System (IIAS) to allow emission scenarios and integrated assessment modelling? Should possibly the SIM-AIR tool itself be further developed to match your needs?