CHAPTER 2

LITERATURES REVIEW

In this chapter, theory and calculation algorithm behind The Air Pollution Model (TAPM) have been provided. The scope and framework of air quality management, including literatures on application of air model toward urban air management also discussed.

2.1 The Air Pollution Model (TAPM)

In this research, the selected model is The Air Pollution Model (TAPM) developed by Commonwealth Scientific and Industrial Research Organization (CSIRO). The model is PC-based program and numerical model coupled with meteorological and air pollution components. It solved fundamental fluid dynamics and scalar transport equations to predict meteorological parameters and air pollutant concentrations that provide the necessary model input needed whereas meteorological observation data are not available. Air pollution predictions for environmental impact assessments commonly computed by Gaussian plume or puff models driven by observationally-based meteorological inputs. However, this new alternative approach is to use prognostic meteorological and air pollution models, which have many advantages over the Gaussian approach and are now becoming an effective tool for running year-long simulations. Even though the entire fundamental equations embedded in TAPM have been completely stated and explained through technical paper (Hurley, 2002) briefly introduction of meteorological and air pollution component is also given here for the next following part

2.1.1 Meteorological Component

The meteorological component of TAPM is an incompressible, non-hydrostatic, primitive equation model with a terrain-following vertical coordinate for three-dimensional simulations. The model calculates the momentum equations for horizontal wind components, the incompressible continuity equation for vertical velocity, and scalar equations for potential virtual temperature and specific humidity of water vapour, cloud water and rain water. The Exner pressure function is split into hydrostatic and non-hydrostatic components, and a Poisson equation is solved for the non-hydrostatic component. Explicit cloud micro-physical processes are included.

The turbulence terms in these equations have been determined by solving equations for turbulence kinetic energy and eddy dissipation rate, and then using these values in representing the vertical fluxes by a gradient diffusion approach, including a counter-gradient term for heat flux. A vegetative canopy and soil scheme is used at the surface, while radiative fluxes, both at the surface and at upper levels, are also included.

a) Base Meteorological variables

The mean wind is determined for the horizontal components u and v (m/s) from the momentum equations and the terrain following vertical velocity σ^* (m/s) from the continuity equation. Potential virtual temperature θ_v (K) is determined from an equation combining conservation of heat and water vapour. The Exner pressure function $\pi = \pi_H + \pi_N$ (J kg^{-1} K^{-1}) is determined from the sum of the hydrostatic component π_H and non-hydrostatic component π_N. The equations for these equations are also address in Hurley (2002)

b) Non-hydrostatic pressure

The optional non-hydrostatic component of the Exner pressure function π_N is determined by taking spatial derivatives of the three momentum equations and the time derivative of the continuity equation, and then eliminating all time derivatives in the continuity equation by substitution. The assumption of all products of Coriolis terms and terrain gradients, and all turbulence and synoptic variation terms, can be neglected.

c) Water and micro-physics

Conservation equations are solved for specific humidity, representing the sum of water vapour and cloud water, and rain water respectively. Micro-physics is based on Katzfey and Ryan (1997) for warm rain (ice processes are generally important only for temperatures less than -10°C), and includes bulk parameterizations for condensation of water vapour, evaporation of cloud water and rain water, auto-conversion and collection of cloud water to form rain water, and an expression for the rainfall terminal velocity.

d) Turbulence and diffusion

Turbulence closure in the mean equations uses a gradient diffusion approach, which depends on a diffusion coefficient K and gradients of mean variables. The scalar diffusion coefficient of 2.5 is applied based on an analysis of the second order closure equations from Andren (1990), with constants from Rodi (1985). The turbulence scheme used to calculate K is the standard E-ε model in three-dimensional terrain-following coordinates, with constants for the eddy dissipation rate equation derived from the analysis of Duynkerke (1988). The model solves prognostic equations for the
turbulence kinetic energy (E) and the eddy dissipation rate (ε)

e) Radiation

Radiation at the surface is used for the computation of surface boundary conditions and scaling variables, with the clear-sky incoming short-wave component from Mahrer and Pielke (1977), The clear-sky incoming radiation components from the previous section are modified for liquid water effects using an approach based on Stephens (1978). The method assumes clear and cloudy sky contributions can be treated separately.

f) Surface boundary conditions

The soil and vegetation parameterisations are based on suggestion from Kowalczyk et al. (1991). The single urban category can be thought of as medium density urban conditions. Central city land-use is approximated by this category, and so parameter values for roughness, urban fraction, and anthropogenic heat flux may be underestimated. Suburban land-use is approximated by rural conditions in TAPM. In urban regions the surface temperature and specific humidity are calculated using $T_0 = (1-\sigma_u)T_{g\&f} + \sigma_u T_u$ and $q_0 = (1-\sigma_u)\, q_{g\&f} + \sigma_u q_u$, where $\sigma_u = 0.5$ is the fraction of urban cover, and subscript U denotes urban, and g&f denotes the combined soil and foliage values respectively. The equations for urban temperature T_U and specific humidity q_U use a similar approach as that for soil temperature, except that the surface properties are those of urban surfaces such as concrete, asphalt and roofs.

g) Initial conditions and boundary conditions

The model is initialized at each grid point with values of u_s, v_s, θ_{vs}, q_s interpolated from the synoptic analyses. Iso-lines of these variables are oriented to be parallel to mean sea level (i.e. cutting into the terrain). Turbulence levels are set to their minimum values when the model is started during midnight. The Exner pressure function is integrated from mean sea level to the model top to determine the top boundary condition. The Exner pressure and terrain-following vertical velocity are then diagnosed using equations of vertical velocity and hydrostatic component respectively. Surface temperature and moisture are set to the deep soil values specified, with surface temperature adjusted for terrain height using the synoptic lapse rate. At the model top boundary, all variables are set at their synoptic values.

h) Assimilation of wind observations

The method used to optionally assimilate wind observations is based on the approach of Stauffer and Seaman (1994), where a nudging term is added to the horizontal momentum equations (for u and v). Note that observations at any height can be included and the observations can influence a user-specified number of model levels for each site.

2.1.2 Air Pollution Component

The air pollution component of TAPM, which uses the predicted meteorology and turbulence from the meteorological component, consists of four modules. The Eulerian Grid Module (EGM) computes prognostic equations for concentration and for cross-correlation of concentration and virtual potential temperature. The Lagrangian Particle Module (LPM) is used to represent near-source dispersion more accurately. The Plume Rise Module is used to account for plume momentum and buoyancy effects for point sources. The Building Wake Module allows plume rise in EGM or LPM mode, and dispersion in LPM mode, to include wake effects on meteorology and turbulence. The model also includes gas-phase photochemical reactions based on the Generic Reaction Set, and gas- and aqueous-phase chemical reactions for sulfur dioxide and particles. Wet and dry deposition effects are also included.

a) Eulerian Grid module

The Eulerian Grid Module (EGM) consists of nested grid-based solutions of the prognostic equation for concentration c, and is similar to that for the potential virtual temperature and specific humidity variables, and includes advection, diffusion, and terms to represent pollutant emissions S_x and chemical reactions R_x

$$\frac{d\chi}{dt} = \frac{\partial}{\partial x}\left(K_\chi \frac{\partial \chi}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_\chi \frac{\partial \chi}{\partial y}\right) - \left(\frac{\partial \sigma}{\partial z}\right) \times \frac{\partial}{\partial \sigma}\left(\overline{w'\chi'}\right) + S_\chi + R_\chi \qquad \text{(eq. 2.1)}$$

The vertical flux of tracer concentration optionally includes counter-gradient fluxes with a second-order turbulence closure for this term based on Enger (1986) with constants from Rodi (1985). The diffusion coefficient used for pollutant concentration is $K_x= 2.5K$, consistent with meteorological scalar variables. Initially χ is set to a background concentration. For pollutant concentration at inflow boundaries on the outermost grid, a background concentration is specified, while values at the boundaries of inner grids are obtained from the previous nest. At outflow boundaries, zero gradient boundary conditions are used.

b) Lagrangian module

The Lagrangian Particle Module (LPM) can be used on the innermost nest for selected point sources to allow a more detailed account of near-source effects, including gradual plume rise and near-source dispersion. In the vertical direction, particle position is updated using

$$\frac{d\sigma_{\text{particle}}}{dt} = \dot{\sigma} + \dot{\sigma}' + \dot{\sigma}'_p \qquad \text{(eq. 2.2)}$$

Where $\sigma_{particle}$ is the particle position in terrain following coordinates, $\dot{\sigma}$ is the mean ambient vertical velocity, $\dot{\sigma}'$ is the perturbation of vertical velocity due to ambient turbulence, $\dot{\sigma}'_p$ is the perturbation of vertical velocity due to plume rise effects.

2.2 Air Quality Management

The history of air pollution episode has been seriously concerned for many countries, the need of management on deteriorated air quality become more considering idea. Combination of air quality target, dispersion science of air pollutant, variation of meteorological variables, analysis of abatement strategy and involvement of public to implement air reduction policies have been very essential factors in order to ensure the wealth and health of next coming generation.

2.2.1 Conceptual of Air Quality Management

In order to develop appropriate and effective air management policy, the basic questions are needed to be answered in order to specify cooperated organization and firm approach could be addressed before implement (IPIECA, 2004).

- What are the standard targets of air quality for the country or region, and when are they expected to be achieved?
- How are existing air quality conditions that can identified the contributions of various source groups?
- How should emissions inventory that includes all relevant stationary and mobile sources be developed?
- What are the appropriate air modeling methods that can be used to simulate the impact of emission sources on the ambient air?
- What are the potential emission reduction strategies that are necessary to meet air quality standards?
- How should the potential control measures be utilized covering the growth patterns, future emissions scenarios, and their implementation?

There are several essential core elements of making appropriate air management policy upon particular area which is displayed in figure 2.1. The entire process in constructions of air management policies are building around basic answers as discussed above.

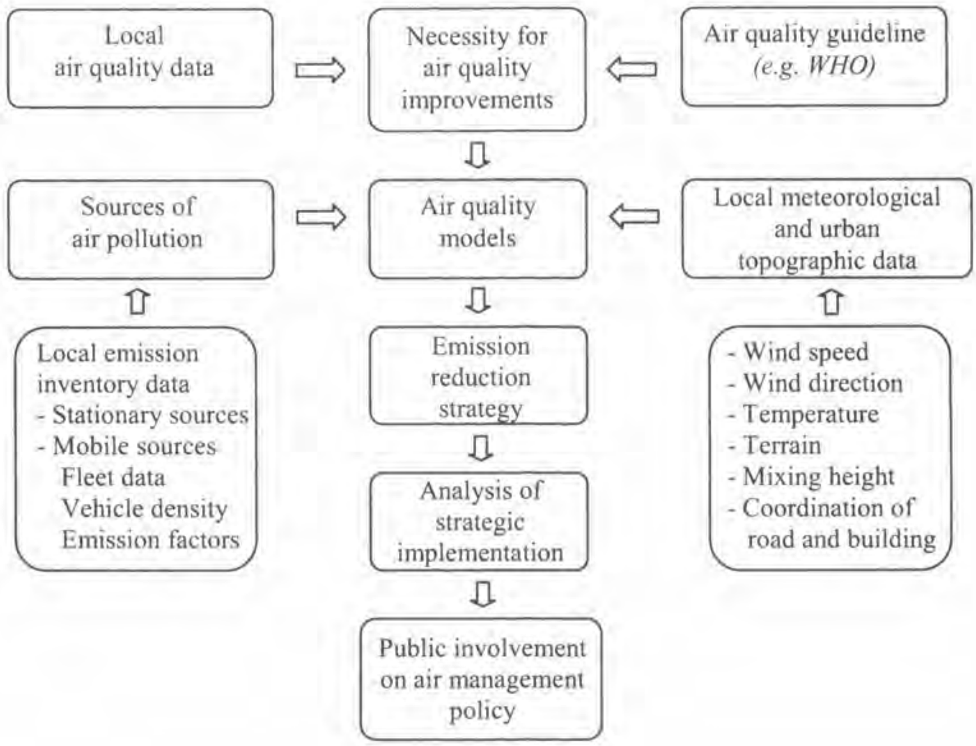

Figure 2.1 Process of air quality management in an urban area
Sources: modified from IPIECA (1997)

2.2.2 Setting Air Quality Target

In any country or region, there are deference levels of national air quality standard. However, the guideline of air quality has been established by the World Health Organization (WHO) for giving reliable suggestion on healthy air quality target global updated versio n (WHO, 2006) at which necessary documents and background information have been provided that support any countries to set national or regional ambient air quality standards suitable with environmental conditional, social, economic and cultural characters. The WHO Air Quality Guideline is worthy effort to assist countries setting significant goal reducing people exposed to the poor air quality which health effects are being concerned.

The exposure-response relationship is main consideration for setting up the range of ambient concentration that giving no adverse effect on human health, the standard setting as allowable maximum concentration of pollutant in ambient air at which exposure time given. In general, it might be observed that at allowable concentration decreasing while exposure time has been lengthened. At table 2.1 showing below give example of air pollution guideline for general air pollutants. In application of guideline, various countries have been applied into their own standard as showing in table 2.2.

Table 2.1: The WHO air quality guideline (AQG) value for common air pollutants

Pollutant	Exposure time	AQG value
Ozone, O_3	8 hour, daily maximum	100 μg/m^3
Nitrogen dioxide, NO_2	1 year 1 hour	40 μg/m^3 200 μg/m^3
Sulfur dioxide, SO_2	24 hour 10 minute	20 μg/m^3 500 μg/m^3
Carbon monoxide, CO	1 hour 8 hour	30,000 μg/m^3 10,000 μg/m^3
PM10	1 year 24 hour (99th percentile)	20 μg/m^3 50 μg/m^3
PM2.5	1 year 24 hour (99th percentile)	10 μg/m^3 25 μg/m^3

Source: WHO (2006)

Table 2.2: Application of WHO air quality guideline among various countries

Pollutant	USA (federal)	EU (directives)	Thailand	Malaysia
SO_2	365 (24-hr av.)	125(24-hr av.)	300 (24-hr av.)	105 (24-hr av.)
NO_2	100 (annual av.)	200 (1-hr av.)	320 (1-hr av.)	320 (1-hr av.)
CO	10 (8-hr av.)	10 (8-hr av.)	10.31[\1] (8-hr av.)	10 (8-hr av.)
TSP	-	-	330 (24-hr av.)	-
PM10	150 (24-hr av.)	50 (24-hr av.)	120 (24-hr av.)	150 (8-hr av.)
PM2.5	65 (24-hr av.) 15 (annual av.)	- -	- -	- -
Lead	1.5 (quarterly av.)	0.5 (annual av.)	10 (24-hr av.)	1.5 (annual av.)

Remark: Unit represents in μg/m^3, [\1] Only CO unit represents in mg/m^3
Source: IPIECA (2004)

The trend of world-wide observation indicates that concentrations of sulphur dioxide and PM are decreasing in developed countries, while NO_x and ozone are either remains constant or increasing. In developing countries, increasing traffic density and high industrial emissions lead to the raising concentrations of SO_2, NO_x, O_3 and PM. Since the strong purpose of Urban Air Quality Management is to protect the human health, the value in guidelines which were established by WHO should be considered as benchmarks or long-term approaching goal. In order to construct on going policy, prior setting of most concern pollutant is needed while not compromise to study existing potential air pollutants that may be exceeded the standard in future scheme. From management point of view, it's worth to be noted that good selective indicator would give high confidence in term of success within air management quality while the alternatives of air pollution reduction should be appropriately evaluate.

2.2.3 Current Condition of Air Quality

Inadequate information on current air quality levels may lead to failure air quality recovering program. The key air indicator and cleared target air quality goal are essential elements for synthesis appropriate air quality management policy. The support from long-term continuous air monitoring data from expanded network of monitoring sites also helpful while dispersion nature of air pollutant, number of exposure people, diurnal variation (day-to-night) and seasonal variation of pollutants should be properly research before placing down monitoring position at particular areas. For common pollutants that being in monitored elsewhere are sulphur oxide (SO_x), nitrogen oxide (NO_x), particulate matter (TSP, PM_{10} and $PM_{2.5}$), carbon monoxide (CO), ozone (O_3) and volatile organic compounds (VOC_s). Furthermore, in some developed countries; formaldehyde, ammonia and benzene had been monitored through more advance technology embedded monitoring site or special study program. It is undeniable that variety of techniques or standardize methods of monitoring may affect the monitored data. Therefore, the International Organization for Standardization (ISO) has come in place to take care and set global standard for the certainty that all monitoring networks would provide consistent and reliable record of data before air measurement station will be introduced into proposed area.

2.2.4 Development of an Emission Inventory System

There is a need to create an integrated emission inventory system which provides significant rational decision-making on emission reduction or mitigation program on concern air pollutants. The system should fill-in the gap between 'base year' and 'future year' where the growth of stationary and mobile source emission have taken into prediction through working out of air quality models. In addition, clear understanding of emission source and receptor relationship must be identified.

The updated data is needed for model compilation which is necessary for successful policy for cleaner air quality. In common, the air quality model could be break down into 2 groups of model which are the core-element of an integrated emission inventory system.

- Dispersion models, which provide simulation results of dispersion pattern of pollutants from proposed emitted sources.
- Source-receptor models are used for simulating observed measurement as 'back-tracking' to the trails or plumes of interested source that have influence to the receptor.

The emission inventory must be formed on the basis of 'base year' and then calculating the projection of the next coming years until target year is met. Linkage of various socio-economics scenarios must be connected to the developing process of emission inventory in order to ensure accuracy of prediction.

For the reason of accuracy, the integrated emission inventory system could be constructed covering all relevant source categories; stationary sources such as, fuel station, domestic activities (home cooking, heating and cooling) including some significant area sources such as; agricultural burning, forest fires and waste disposal management. In part of mobile sources, data collecting should cover light and heavy duty commercial vehicles, public transport (buses and shuttles), private vehicle, two-or-three wheeled vehicles, railed transportation and air transport. Since one activity has been already established, the emission factor could be estimated from published inventory documents (e.g. US. EPA, AP-42) based on fuel consumption and source category.

Because accurate emission inventory constructed dependently on available data, the continuous process on data collecting is necessary for data certainty which probably not too be easy for developing countries. Therefore, various extrapolation and estimation technique as well as dependable documentation cited are essential in construction of the system until inherent uncertainty is widely accepted. Emission inventory estimated for SO_2, PM_{10} and TSP calculated from major Asian city has been shown in table 2.3 following.

Table 2.3: The estimation of SO_2, PM10 and TSP emission inventory from some Asian city*

Emission sources	Type or Industry	TSP (ton/yr)	PM10 (ton/yr)	SO_2 (ton/yr)
Transport sector				
Gasoline vehicle	Cars	580	580	
	Utility vehicles	1,180	1,180	
	Motorcycle	290	290	
	Bus/truck	150	150	
Diesel vehicles	Taxi	170	170	17.0
	Utility vehicles	1,160	1,160	
	Jeepneys	1,580	1,580	
	Truck/bus	3,800	3,800	
Total veh. exhaust		8,910	8,910	
Resuspension from roads		25,000	6,250[6]	
Energy/industry sector				
Power Plant		2,120[1]	2,010[2]	101.8
Other fuel combustion	Commercial			
heavy bunker oil fuel	Domestic	14,380	12,220[3]	216.6
light diesel oil fuel		2,550	1,280[4]	24.2
kerosene		20	20	–
LPG (liquefied petroleum gas)		40	–	–
wood		–	–	–
coal		–	40	–
TOTAL FUEL COMBUSTION		16,990	13,570	–
(excluding power plants)		6,000	3,000[5]	–
Industrial Process				
Refuse burning [7]		(<) 6,000	(<) 6,000	–
Construction [7]		10,000	2,500[6]	–
TOTAL:		(<) 75,020	(<) 42,240	359.6

Remark: TSP = total suspended particulates, [1]Emission control: multicyclone, [2]PM10 = 0.95×TSP (Ref.: EPA AP-42), [3]PM10 = 0.85×TSP (Ref.: EPA AP-42), [4]PM10 = 0.50×TSP (Ref.: EPA AP-42), [5]PM10 = 0.50×TSP (rough estimate), [6]PM10 = 0.25×TSP (rough estimate), [7]rough estimates.
*Kathmandu Valley, Jakarta, Metro Manila, and Greater Mumbai (Source: IPIECA (2004), reproduced from NILU/IVM (1995))

The sufficient data play significant role on emission inventory, lacking of quality in data gathered and non-completed data requirement leading to miss judgment on environmental decision. In practical approach, data gathering is challenged by limited human work, availability of resources and insufficient time requirement, as part of trade-off activity, precision of inventory affected directly by these factors.

The air quality management policy constructed on the basis of various scenario of emission control which is varied by emission control technology or variation of pollution resources. Before conclusion on management policy has to be made, the 'base case' also required to analyze when emission factor, energy demand

and characteristic of pollution resources completely addressed. After that, the assumed scenarios have to be evaluated and implement the air quality management program. The figure 2.2 below describes the main process in base case construction.

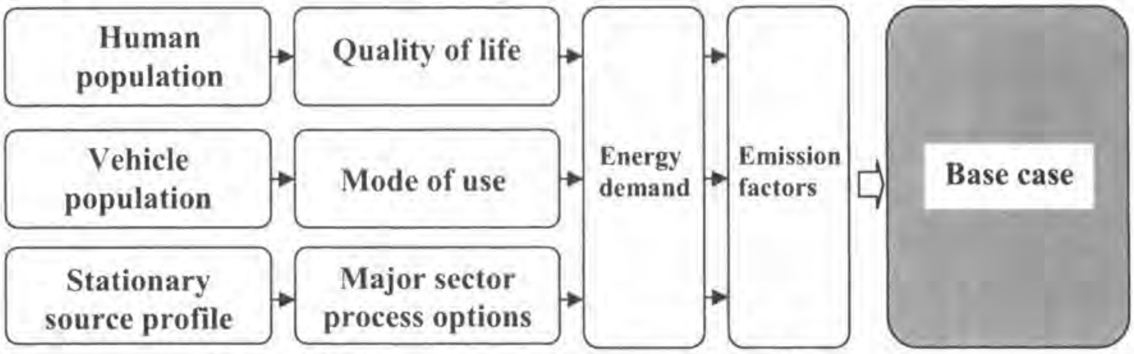

Figure 2.2: The main process construction of base case

In fact, the of emission inventory is typically applied for 2 objectives; first is to predict absolute emission in case that emission model is applied to use as input data for air dispersion model which overall correction is to be check for giving 'correct answer'. The second objective is to determine sensitivity analysis explaining how much of changing output toward input data such as; industry emission, vehicle emission factor, fleet composition or etc,. Thus, the 'relative answer' has expected rather than 'correct answer' or sensitive relationship between input and output was investigated not being an absolute accuracy.

Based on modeler experiences, it's should be highlighted that by highly detailed and reliable quality of data is adequate to justify model performance specially when using in the area of complexity and the evaluation of advanced model has performed where availability of data is provided.

2.2.5 Selection of Air Quality Models

Since massive amount of data needed to develop a packaged of air quality management plan will require the calculation capability of computer-based models. Therefore, the availability of data should be first consider on selected model, specially on urban airshed modeling systems which required excellence quality of needed information, that probably not be available in regions and areas at the stage of planning the process. Typically, air quality modeling systems consist of three main parts:

- Emission forecasting model: is use to predict the effects of already-agreed measures and possible future measures on emissions from road transport as well as other (e.g. stationary) sources.
- Meteorological transport model: is applied to forecast wind patterns, atmosphere inversions, temperature impacts, etc.
- Dispersion model: aimed to determine the contribution related to movement of transport and of emissions from different sources to ground-level air concentrations. Satisfied models will also predict changes due to atmospheric chemical reactions. Something should be taken into consideration that there is no 'standard' for air quality model working out, and most air quality modeling systems need to be adjusted to study area or region. The schematic illustration among 3 main parts of model depicted on figure 2.3

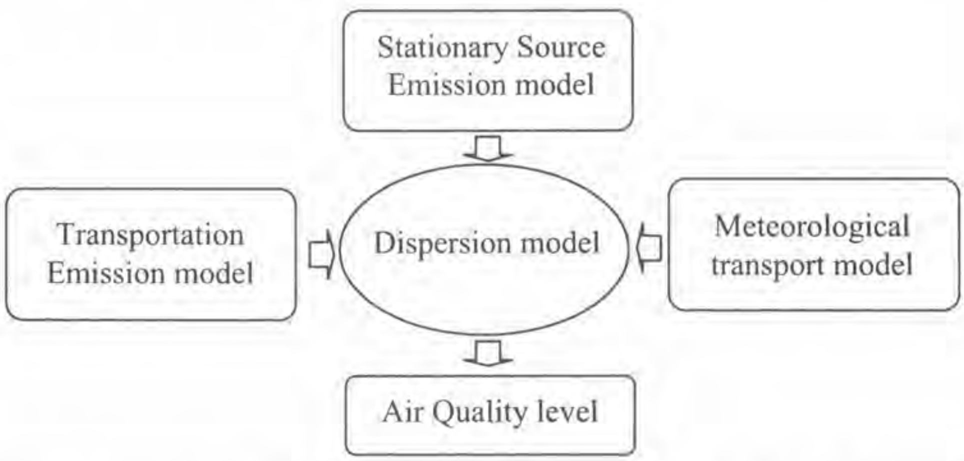

Figure 2.3: Connection of emission model, meteorological model and dispersion model in calculating air quality level

The chosen modeling system uses the meteorological, topographic, and emission data to derive a 'base year' prediction of air quality. The modeled result is then evaluated against current air quality measurements, to confirm that the chosen model adequately represents the spatial and temporal distribution of ambient air concentrations. This stage of the analysis is sometimes referred to as the 'model performance evaluation' and it is critical to establishing the validity of the data generated by the modeling system. For most cases, the differences between modeled result and measurement data expected to be in range $\pm$15–20 % as the result of the complexity of the systems behind. After the relationship between emissions and air quality in the base year has completely evaluated, the model then be applied to forecast potential air quality trends based on the driving force generating future emission patterns. These future emissions data should be derived from the socio-economic forecasting scenario studies, which take into account:

- Growth potential rate of mobile and stationary source emissions.
- Future scenario driven by improved vehicle emission control technology and fuel quality changes.
- Possible changes in type and quality of energy sources.
- Future legislation that might be impact on emissions or possible agreement of new standard for exhausted emission over time.

2.2.6 Forecasting of Future Air Quality

The foundation of creating long-term air forecasting quality are developed on basis of socio-economic scenarios which relevant influential factors in particular proposed area or region are included. The future emission combined with all significant sources (mobile, stationary and area), play significant parts for future air quality improvement whereas macro economic should be integrated into scenario construction. The population growth, potential of economic growth, national productivity and personal income are worthwhile to do statistical analysis gathered with sufficient year-back history data; these focusing economic should not be neglect while as growth of industry sectors and vehicle ownership per capita that increasing energy demand and fuel mix should also be added into consideration. As a result of emission rate based on future socio-economic scenarios and model integrated working out, forecasted air quality would be clearly reveal that lead to decision-making on which would be effective control emission option conducted in air management program

2.2.7 Emission Control Alternative Identification

The potential emission control alternatives should be listed while priority would be given based on options that showing the best air reduction efficiency over the period of time during implementation. The focused alternatives could be categorized to stationary and mobile source as described as follow;

For stationary source, emission restriction of key pollutants from existing and new stationary sources such as; dry cleaning, localized industrial power plants and electric generators should be concerned. In the same way, as mobile emission control, tail-pipe emission standard, retrofit technology, inspection and maintenance (I&M) including traffic planning initiatives or transport management control have to be taken into account.

Indeed, emission factor for stationary sources can be estimated from fuel type and reduction of energy consumption in new introduced technology. But for mobile technology, published emission factor may be helpful in order to estimate first thought emission factor when highly detailed are not applicable. The good example of published emission factors are those contained in EU COPERT model as well as FOREMOVE and TREMOVE model which are already applied in European countries.

2.2.8 Evaluation of Air Quality Improvement

After air quality model has been run with essential information on future scenarios of air emission sources and emission factor from reduction potential from future technology or any management initiatives, modeled result should be compared against target air quality by the year addressing in the air management program. After modeled working out, the improvement of air quality among various attempted alternatives could able to be assessing, and then, the best solution for achieving target air quality in proposed scenario would be plainly discussed.

2.2.9 Prioritization of Abatement Policy

In order to fulfill purpose of air quality management program, possible abatement policy should be provided to policy maker with objective-oriented assessment aiming to improve ambient air quality and attain established air quality target. This objective-oriented assessment can be taken in form of comparative ranking of the cost-effectiveness of all feasible policy.

For particular abatement policy, these undeniable costs should be brought to analyze like following;

- Investment or capital cost for implementing policy
- Direct operating cost
- Administrative and regulatory costs in related to monitoring and policy enforcement.
- Indirect costs (i.e. changing in fuel consumption)
- Welfare costs arising causing by relative prices or employment opportunity

- Reduction of indirect health costs due to reduced air pollution-related morbidity.

In perspective of economic analysis, only the incremental costs of introducing air abatement policy are relevant. Any costs which is not affected by a policy or the policy had not been introduced are not taking into account. As well as the costs that merely represent a transfer from one part of the economy to another, such as taxes, however changes in overall tax revenue may showing influential and studies should therefore still be carried out in order that they may be appropriately discounted.

In order to ensure justice and consistency in the comparing of different abatement policies, all cost data should be converted to a common basis. All costs should be measured in constant prices for an agreed base year. The flow of costs between the base year and the target year must be discounted. The calculation back to the base year must be applying a discount rate of an agreed percentage. The Net Present Value (NPV) of these costs has to be computed by summing the discounted cash flow; and the NPV should be divided by the economic lifetime of a particular abatement policy to calculate the annual economic costs of that policy.

The final step is cost-effectiveness prioritization when the minimization of the total costs of the range of measures considered for reducing stationary and mobile source emissions by given amounts for a given year have been totally analyzed. The capability to handle simultaneous emission reduction targets for several pollutants and generation of marginal cost curves that showing the relationship between the cost of implementing different combinations of technical policy and their impact on emissions. As discuss earlier, these necessary points should be considered when selecting an approach for conducting cost-effectiveness analysis and prioritization as part of the decision making process.

2.3 Literatures Review

2.3.1 Urban Air Model

Clarke et al. (2004) applied new meso-scale Lagrangian model in London by using published emission inventory determined size distribution of particulate matter from vehicular sources which blew across the city. They used published vehicular emission inventory which corrected to the time of day, while other emissions are assumed to be steady. Vertical dispersion processes and dry deposition processes defined from boundary layer depth, Monin–Obukov (MOB) length and friction velocity which preprocessed from official meteorological data. Even though they applied background level obtained from rural sites but result showed that they need regional scale air model to provide adequate input data. The results also indicated upward dispersion being dominant affected to vehicular emission. The model embedded with function of wet-dry deposition and coagulation process but result showed deposition and coagulation process having small effect on the size distribution in urban atmosphere. They also noted that the method dealing with meteorological input need revision.

Tsai and Chen (2004) used the RNG k–ε turbulence model measured three dimensional (3D) airflow and dispersion of carbon monoxide (CO) and other gaseous pollutant of urban street canyon in Taiwan. Traffic composition were recorded and counted into 3 vehicle types; light-duty gasoline vehicles (LDGV), heavy duty diesel vehicles (HDDV) and motorcycles (MC). Both on-field measurements and model simulations revealed that pollutant concentrations typically follow the traffic flow rate; declined as the height increases, and being higher on the leeward side than on the windward side. In this research, the ability of 3D simulation had clearly shown behavior of streamline entering the canyon. When compared model against measured data, model prediction agreed quite well with measured data, they also recommended about traffic induced turbulence and nearby traffic emission should be included for further study.

Soulhac et al. (2003) estimated urban atmospheric pollutant in Lyon city, France using new developed modeling system consisted of regional scale model (SAIMM/UAM-V), an agglomeration scale model (MERCURE) and two local scale models (ADMS-3 and SIRANE). The meteorological input calculated by SAIMM which based on a four-dimensional data analysis applying with prognostic equation for the turbulent kinetic energy, and then, given as input data for UAM-V for estimating pollutant concentration. Industrial sources emission inventory taken from published report altogether with traffic model coupled with COPERT-II for providing vehicle emission rate. In conclusion, the comparison between the model calculations and the data confirm the advantage of the combined model (meteorological model and air pollution model) than using only single agglomeration model.

2.3.2 The Application of air model on urban area

Mensink (2003) applied The AURORA model to 11 selected streets in the city of Anwerp, Belgium in order to make an assessment against the air quality limit values as provided by the Council directives. Comparisons with a nearby urban measurement station in a representative street in Antwerp show agreements that are within the uncertainty range given by the guidelines in the EU directives, except for the NO2 values. An analysis of the measured and modeled concentrations and percentiles allows an evaluation of the contribution from traffic for each of the pollutants considered. The model shows that traffic contributions are relatively important for NO2, benzene and CO and less important for SO2 and PM10, where background concentrations are predominant. The result for PM10 is not confirmed by the measured higher percentiles. The (emission) model seems to underestimate the daily variations in PM10 caused by traffic. Based on the 1998 assessment calculations on street level, in term of urban air quality management, it can be concluded that without further emission reductions for NO2 and PM10, their limit values are expected to be exceeded in 2005 and 2010.

Lyons et al. (2003) suggested urban air quality management policy through box model explanation and vehicle kilometers of travel (VKT), hoping to provide universal basic consideration for any urban models. They found strong relationship between VKT and urbanized land area, while box model providing air pollution concentration when emission rate and meteorological were added as input data, VKT also be used as surrogate for vehicular emissions in order to represent urban vehicular emission. Wind speed and average mixing height were adopted for box model scenario calculating and compared against published references. Future scenario based on VKT clearly stated advantage of non-automobile support program in reducing transport emission that many cities may followed. Including with expansion of physical infrastructure for city which may minimize transport emission from urban vehicle. They also gave notice on United State and European as examples of urban development which support high quality of public transport and helping people not rely only motorized-transport.

Corfa et al. (2004) assessed short-range air pollution near bus and railway station using CFD software package applying with air pollution modeling to study different scenarios. For a bus station, first scenario, they simulated a typical morning peak hour situation and study in detail how the pollution is accumulated in the station courtyard and the impact on the close vicinity. The rest 2 scenarios are presented as one with classical diesel engine and one with buses using AQUAZOLR or NGV fuel. For a railway station, they simulated a situation in a real railway station within the city of Paris. By the result, bus simulation, because of improper geometry of building surrounded bus station causing trapping condition for air pollution inside. In other hand, using NGV and Aquazole fuel clearly showed improvement on air pollution. In part of railway station simulation, it clearly noticed that stationary sources gave the main impact for the "worst" meteorological situation. For the "frequent" meteorological situation, the maximum was due to the addition of the stationary plum and the transient cloud just behind a building (wake effect). In conclusion, they confirmed that CFD software package applied to atmospheric flow is an efficient tool to evaluate the implementation of different policies and to assist in decision making concerning infrastructure and local air quality problems. These tools allow evaluating the impact of new fuels as NGV or Aquazole and can give quantitative information concerning air pollution relevant for the organization of train departures at railway stations.

Mediavilla-Sahagun and ApSimon (2003) investigated various options for reducing the emission of fine particulate matter (PM10) from traffic in London. Abatement strategies were developed based on numerical simulations of the USIAM model (Mediavilla-Sahagun et al., 2002). Their work indicated that the most cost effective strategies involve the use of alternative fuels, particularly switching from diesel vehicles to LPG and/or CNG. The simulations also suggest that the measures involving a road-user fee appears to be less effective.

2.3.3 TAPM Verification Works

Hurley et al. (2003) verified the Air Pollution Model (TAPM) applied with the EPA Victoria multi-pollutant emission inventory for the Port Phillip region (including Melbourne city approximately covered 24,000 km^2) in Australia. It was used to simulate 1 year of hourly averaged air pollution concentrations for smog and particles, both without and with meteorological data assimilation. Model results have been compared with data from the EPA Victoria air-monitoring network. Their results showed good agreement between TAPM prediction and monitoring data, model predicted year-long extreme concentration for hourly averaged smog (NO_2 and

O_3) and for 24-hourly averaged particles (PM10 and PM2.5), even when no local meteorological data were assimilated into the model. In case of paired-in-time results, measurement such as correlation coefficient, factor-of-two and gross error, also show that TAPM was performing well, with average values for all monitoring sites. Results for the simulation with meteorological data assimilation were very close to those from the simulation without meteorological data assimilation. They also noted that high quality of emission inventory provide significant output quality of model.

In Hurley et al. (2001) TAPM has been applied and aimed for model verification, it predicted both the meteorology and the sulfur dioxide concentration in the Kwinana industrial region of Western Australia for 1997. The results were compared with the regulatory plume model, DISPMOD, in order to verify the performance of TAPM. The root mean square error and index of agreement values for temperature and winds indicate that TAPM performed well at predicting the meteorology. TAPM performed better than both DISPMOD-O (which used observational meteorological data) and DISMOD-T (which uses meteorological data predicted by TAPM) for the prediction of air pollution concentrations. The comparison these three set of data (TAPM, DISMOD-O and DISMOD-T) further suggests that TAPM is the preferred regulatory model; even when meteorological observations are not available

Luhar and Hurley (2003) evaluated TAPM for fine scale plume dispersion of a point source by using the 1985 Indianapolis and 1980-1981 Kincaid field data sets. A comparison of the TAPM output with a number of commonly used plume/puff models, which do not calculate meteorology, indicates that the performance of TAPM is comparable to the best of these models. TAPM gave better concentration predictions when the observed winds are assimilated, and the results without data assimilation are almost as good. The latter implies that the model predicts the local meteorology well. TAPM under predicted concentrations in the nighttime stable and neutral conditions and slightly over predicted concentrations in the daytime convective and neutral conditions. This bias is perhaps due to the fact that the local urban effects are not properly accounted for by the generic single-layer canopy scheme used.