# Developing a Practical Assessment Framework for Vehicle Emissions Control Measures

by

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A thesis submitted in partial fulfillment of the requirements for the degree

of Master of Philosophy

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# CERTIFICATE OF ORIGINALITY

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it reproduces no material previously published or written, nor material that has been accepted for the award of any other degree or diploma, except where due acknowledgement has been made in the text.

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Abstract of dissertation entitled

"**Developing a Practical Assessment Framework for Vehicle Emissions Control Measures**"

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An assessment from World Health Organization (WHO) showed that there are burden of disease caused by air pollution. More than 2 million premature deaths each year could be attributed to the effects of air pollution. In the past decades, People have been heavily suffering the street-level air pollution, which keeps posing a significant threat to human health. The particulate matters and nitrogen oxides can cause respiratory illness and reduce the lung function, indeed certain fine particles can lead to cancer risk. In fact, a wide range of measures was introduced to control emission with targets to reduce particulate matters and nitrogen oxides, particularly emission from vehicles. It is however not easy to say that there are significant ameliorations, somehow it is perhaps deteriorating in certain extents. It is questioned whether every year the government administrations spend substantial expenses to a worthy use on the subject of vehicle emission control. Clearly, it is necessary to establish an assessment framework which helps draw a clear picture in determining vehicle emission control strategies so as to minimize the inappropriate determination during decision-making processes.

In this study, a practical assessment framework concerning vehicle emission control was proposed, comprising two elements, namely policy evaluation criteria and control strategies. The policy evaluation criteria simply aim to assess the performance of the control strategies in several aspects. The selections of these elements based on their universalities. In order to maximize the result reliability, it was decided to gather the opinions from experts regarding these two elements through conducting questionnaire surveys in workshop and international conference. The questionnaires requested the experts ranked these two elements based on their importance and favourite, else rated the control strategies in accordance with the criterion individually. It was observed that the experts' considerations contained differences in the aspects of tackling the vehicle emission regarding their background. The preliminary results showed that the criteria of effectiveness and political acceptability were always recognized as the utmost predominant two while the modification of existing system was the favourite control strategy. These primary results helped identify the weighed coefficient of each policy evaluation criterion. The performance score of each control strategy was further worked out from the rating results. On the basis of the strategy performance score, the implementation lists for Hong Kong and China were recommended. It seemed that the suggested control strategies fairly fitted with their current situation. Else a good combination of control strategies as well as a good selection of policy instrumentation can lead to much more successes. This practical assessment framework can be easily adopted in the other types of environmental issues, such as waste and water pollution, by re-selecting the appropriate policy evaluation criteria and control strategies in accordance with the concerned issues.

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# LIST OF SYMBOLS AND ABBREVIATIONS

| | |
|---|---|
| A | Degree of deviation from existing system |
| AFs | Alternative fuels |
| AFVs | Alternative fueled vehicle |
| B | Effect time |
| BPEVs | Battery-powered electric vehicles |
| c | Evaluation criterion |
| C | Political acceptability |
| $\chi^2$ | Chi Square |
| CNGVs | Compassed natural gas vehicles |
| CO | Carbon monoxide |
| D | Administer-ability |
| df | Degree of freedom in calculating Chi Square |
| E | Cost of implementation |
| $E_{ij}$ | Expected frequency for the cell in the ith row and the jth column |
| F | Effectiveness |
| GNI | Gross national income |
| HC | Hydrocarbons |
| HEVs | Hybrid electric vehicles |
| I | Restriction on drivers |
| I/M | Inspection amd maintenace |
| II | Modification of existing transportation system |
| III | Introduction of alternative fuels |
| IV | Land use planning and control |
| L | Number of columns in calculating Chi Square |
| LPGs | Liquefied petroleum gas vehicles |
| N | Total number of subjects |
| R | Number of rows in calculating Chi Square |
| $r_{s_n,c_m}$ | Rating of strategy n and control measure m, |
| s | Control strategy |
| Score | Performance score of control strategy/measure |
| $S_s$ | Total performance score of a specific strategy |
| Ti | Total of subjects in the ith row, |
| Tj | Total number of subjects in the jth column |
| W | Weights of the evaluation criteria |

# CHAPTER 1.0 INTRODUCTION

Transportation acts as a key role in the economic life of a city as well as in the daily lives of the citizens. It has huge negative effects such as accidents, traffic congestion, air pollution, noise pollution, energy consumption and consumption of other natural resources, etc. Especially, air pollution from motor vehicles becomes a more and more considerable environmental issue in many mega cities.

Besides factories and power stations, motor vehicles are one of the main sources of the air pollution, which particularly influence the urban air quality. Obviously, vehicles caused major urban air quality problems in busy streets and roads, such as heavy-duties diesel vehicles, including trucks and transit buses, etc., are one of major sources of particulate matters and nitrogen oxides. High concentrations of particulate matters and nitrogen oxides were exhausted to the ambiance and further influence our health and daily lives.

Enable to minimize the vehicular sources, the Local Government Administrations introduced various comprehensive strategies and policies. The key measures included adopting tighter fuel and vehicle emission standards, introducing cleaner alternatives to replace the heavy-duties diesel fuel vehicles, controlling emissions from remaining diesel vehicles with devices that trap the pollutants, strengthen vehicle emission inspections, enforcement against smoky vehicles and promoting better vehicle maintenance and eco-driving habits. Many different strategies and policies have been developed and implemented to avoid further

deterioration of the problems. Factually, some achievements have been seen, but the improvements are still not good enough to control the worsening problem completely, especially the street level air quality. The rapidly increasing number of lung cancer and respiratory diseases as well as the raising awareness in global warming issue clearly reflected that the government administration got to avoid the deterioration urgently.

Different parties such as non-government environmental protection organizations and political parties urged that the Government Administrations should solve the vehicular emission problems shortly. With the increases in the awareness of vehicular emission control, Government Administrations are under pressure to keep on introducing comprehensive strategies and policies in controlling the vehicle emissions. Unfortunately, the improvements might not be easily observed because longer effective time is required as well as the acceptability of the local citizen might slow down the implementation progresses. In some of the developed countries, the improvements from these implemented control strategies have tended to be offset by the increases in emission from the rapidly growing vehicle numbers and kilometers driven. Apparently several billions dollars has been spent on implementing control programs to reduce the vehicular emission which seemed not really worthy.

Before implementing the control strategies, assessment should be conducted. Some popular practices such as Cost and Benefit Analysis and Cost-effectiveness Analysis are effective for looking at the economic/financial impacts, they are however not adequate to evaluate the performance of the control strategies comprehensively. Apart from these common analytic assessments, many researches

have addressed various evaluation criteria in assessing the performance of the control strategies. For example, Acutt and Dodgson (1997), Moavenzadeh and Liddle (1999), Molina and Molina (2004) and Rienstra et al. (1996), discussed implementation feasibility. Moavenzadeh and Liddle (1999) further advanced that the implementation feasibility was affected by financial capability and institutional barriers coming from the government and public. Else Plaut (1998) explored efficiency and effectiveness policy assessments in her framework. She additionally proposed that the vehicle emissions abatement policy alternatives can be evaluated by efficiency, effectiveness, equity, costs of implementation and political feasibility. It is a tendency that the scholars adopt multiple criteria in their analyses. Besides these studies, a considerable amount of researches have been adopted mulitcriteria approaches in control strategies evaluation, which combines different aspects of criteria together and constructs a rather comprehensive assessment. Such as, Tzeng et al. (2002) utilized multicriteria approach to evaluate the strategies on improving air quality so as to obtain priority of implementation. Since the multicriteria approach has been developed to enhance the process of decision making, a great deal of research has been widely studied on its application and theory (e.g. Bana e Costa, 1990; Chankong and Haimes, 1983; Steuer at el, 1996; Stewart, 1992). Unfortunately, the whole process is time-consuming and not easy to handle.

Although formulating proper policy control measure to reduce vehicle emission is a complex issue, it seems that there is lack of time-saving and unsophisticated assessment to evaluate the control strategies and measures thoroughly. I question whether there are any alternative methods that can be efficient and simple to assist in selecting appropriate control strategies, it can then quickly

come up with a clear picture on vehicular emission control strategies. It is definitely necessary to work out an assessment framework to speed up the evaluation process in determining air pollution control strategies and measures as well as providing a more comprehensive picture for policy determination. This is particularly relevant and imperative to developing or undeveloped cities due to the rapid economic development and uncertainties occurrences.

In the view of above, the aim of study is to construct a practical assessment framework for vehicle emission control strategies, in the hope of assessing the performance of the vehicle emission control strategies simply as well as determining the control strategies efficiently, then obtaining a clear picture on vehicle emission control strategies.

The chapters of the dissertation are organized as follows:

Chapter 1 Introduction: the current chapter.

Chapter 2 Study approach: this presents information in earlier researches, the methodology and limitations in this study.

Chapter 3 Developing a practical assessment framework: this shows a demonstration of the proposed assessment framework. First, this constructs the key framework elements, then observes the results from questionnaire surveys and finally presents a performance assessment for vehicle emission control strategies.

Chapter 4 Discussion: this discusses the appropriateness of the evaluation criteria and findings, else limitations are concluded.

Chapter 5 Summary, implications and further studies: this summaries the findings and describes the implications, and further suggests some studies to strengthen the whole framework.

# CHAPTER 2.0 STUDY APPROACH

This chapter presents the study approach of the proposed assessment framework and demonstrates the approach of the study. It begins with a review of literature on policy-making processes. The design of the proposed framework will then be presented. The purpose of this review is to provide an understanding in this area, as well as providing a rationale for the choice of methodology in the present study.

## 2.1 Policy-making Processes

A policy is a plan of action to guide decisions and actions. The term may apply to government, private sector organizations and groups, and individuals. The policy process includes the identification of different alternatives, such as programs or spending priorities, and choosing among them on the basis of the impact they will have. Policies in short can be understood as political, management, financial, and administrative mechanisms arranged to reach explicit goals.

In order to implement the most appropriate measure, policy analysis is imperative. Policy analysis refers to the analysis of existing or prospective policies with the intention of improving social welfare. One common methodology is to

define the problem and evaluation criteria; identify alternatives; evaluate them regarding the evaluation criteria; and finally come up with policy option(s).

There are two traditional assessment methods to dominate the policy-making. These methods are formal assessment models and multidisciplinary expert panels. Formal assessment models seek to represent important issue to be studied, for examples environmental impact assessment and risk assessment. It is also popular in the area of research activity especially on assessment of environmental issue, such as the climate change issue in the studies of Dowlatabadi (1995) and Toth (1995). These assessment models are integrated to form a causal chain from the determinants of emissions to the valuation of impacts as well as providing information being used as a framework. Multidisciplinary expert panels are to gather the collected expert judgment of people together through senior advisory panels.

Parson (1997) acknowledges the formal models are particularly strong for characterizing instrumental relations and ordinary uncertainty, and hence for identifying key uncertainty and guiding enquiry. They may also be of some use in valuing consequences, since under the stringent assumptions necessary to justify valuation thought Willingness-to-pay Methods and Benefit-Cost Analysis, they can identify tradeoffs and welfare-maximizing policies. But, the weakness with which the formal models can represent policies also reflects two others factors. One is limited spatial and sectoral resolution, which makes it impossible to represent

reasonably complex or realistic policy. Other is weak underlying knowledge regarding the effect of policies.

Expert assessment panels can make useful contributions to knowledge need by bring forward and integrating identified pieces of knowledge. Similar difficulties confront panels in assessing strategic uncertainties. Such assessments depend on judgments and speculations of what particular actors might do. When panels report to a pluralistic political body, such judgments are virtually certain to offend somebody. They also require modes of thought and work different from the normal character of committee deliberations, including serious efforts to put oneself inside other people's head. This can best be facilitated through approaches that bring together diverse expertises and views, shake people up, provoke non-conventional thinking, which conventional deliberations are unlikely to provide. There is a procedural device to refine consensus, of which the best-known is Delphi. This method is to iterate the polling of multiple experts and with unattributed sharing of responses between rounds. Estimates generally converge over successive rounds, but this may reflect subtle social pressures for conformity in addition to genuine development of consensus (Dalkey, 1972). In a variant of Delphi, it is widely useful and full arguments for each participant's estimates are exchanged between rounds rather than the estimates alone.

Formal models are a representational approach to assessment. On the other hand, multidisciplinary expert panels are an advisory approach. Both methods can

make useful and important contributions to assessment, but both have important weakness in meeting the range of knowledge needs on the policy issue. There are several classes of knowledge needs in environmental issues and the conventional assessment methods are not well equipped to provide. Their common problem is obtaining adequate representation of collective knowledge of uncertain physical parameters or other facts, whether as consensus estimates or ranges. The formal models require specified point estimates and are of limited help in development. The expert panels may tabulate published estimates for unknown physical quantities or summarize these to a range, but only rarely aggregate these to consensus estimates. Both methods are devices to generate a single estimate or narrow down the range of estimates from a divergent set. Yet the Delphi method extends the range of knowledge needs compared with the traditional assessment methods and narrows the problem of disagreement over specific factual knowledge.

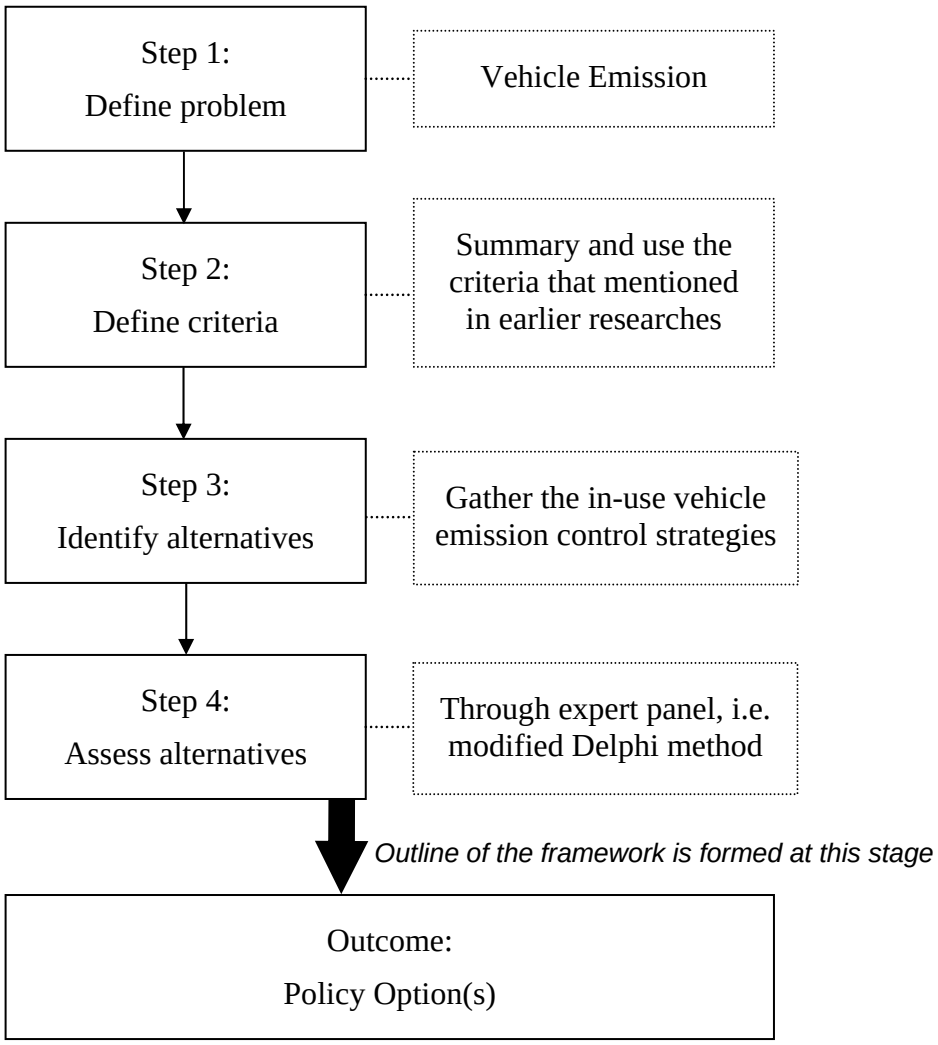
Experienced politician with rich knowledge and skill in the field of vehicle emission control would be anticipated to do an integrated assessment on vehicle emission control. It is difficult for a beginner who is just starting to study on this topic. Plenty of readings will be required in order to fully understand the current situation of the issue. Apart from these, subjective notions on the issue will be obtained as well. On the other hand, Delphi Technique is a widely used method of gathering group opinions from a panel of knowledgeable persons, i.e. the experts. In this study, experts have to be within the field of vehicle emission control with

relevant experiences. Delphi is also a popular quantitative research method on policy-making. It is apparent that Delphi method was a good technique to be selected and employed in this study, however the difficulty is on how to construct an expert panel. Without powerful authority, forming an expert group is difficult and impossible, so that the procedure of Delphi method got to be modified, which details are described in the following section. After modification, this assures anonymity of responses, reduces group pressure for conformity, and take less time for panelists than traditional methods of pooling opinion. Indeed, it also obtains subjective opinions from the experts. Its reliability is more precise than the individual assessment.

## 2.2 Methodology of the Proposed Assessment Framework

In the review of the above, the most basic and simple method of policy-making will be adopted in this framework, i.e. define the problem and evaluation criteria, then identify alternatives for controlling vehicular emission and assess them through experts regarding defined evaluation criteria, finally come up with policy option(s). The criteria and alternative can be understood as the key elements in the framework. The flow chat below shows the design and moving steps of the proposed framework.

Figure 2.1 Flow chart of the proposed assessment framework



As is shown in Figure 2.1, there are several steps in the proposed assessment framework, which describe as follows.

Step 1 is to define the problem. It is apparent that the policy problem which urges to solve is reducing and controlling the vehicular emission.

Step 2 is to define the policy evaluation criteria. This basically follows the criteria that have been discussed in several assessments of earlier research studies, mainly in vehicle emission and air pollution control. The six evaluation criteria were finalized and the whole discussion will present in Chapter 3.

Step 3 is to identify the alternatives in vehicles emission control. This is regarding the common control strategies that have been adopted around Asian cities. Once again, the whole description will appear in Chapter 3. There is four main strategies being identified and there are sub-programs/measures under these four main strategies.

Step 4 is to assess the performance of the defined alternatives through modified Delphi method regarding the defined evaluation criteria. In this step, there involves two important moves, which are data collection and analysis.

### 2.2.1 Data Collection

As it is mentioned, Delphi technique was employed in this study, but it was modified. General speaking, Delphi is a systematic interactive forecasting method based on independent inputs of experts and it is widely applied on policy judgments (Turoff, 1975). Effectively, it is a participatory exercise in which recognized experts within a field are queried regarding the issue under consideration (Utgikar and Scott, 2006). The technique is a procedure and administers to obtain the most reliable consensus of opinion from an experts group by a series of intensive questionnaires or interviews (Dalkey and Helmer, 1963; Scapolo and Miles, 2006).

Apparently, the more simpler way to understand the procedure of Delphi is to form a group of experts who are within a particular field, and through questionnaire surveys to gather experts' opinion so as to obtain more reliable results. Following this concept, the study employed questionnaire surveys to collect information from experts, but without forming a proper expert panel. The reason of not forming the expert group was the ability to manage a group of experts, i.e. insufficient power to invite experts who are within the field of vehicle emission control. In fact, there was alternative way to gather expert's opinion, which is conducting the questionnaire surveys in conferences or workshops. Luckily, in May 2006, there was a motor vehicle control workshop that held in Hong Kong. Taking this valuable opportunity, the first questionnaire survey was conducted.

There was three parts in the first questionnaire, including the personal information, ranking and rating questions. Part one was the personal information that contained the questions of the origin, working experiences and affiliation information. The reason of asking those personal questions was to investigate the experts' aspect among different background information, which also aims at identifying the group of experts. The working experiences and knowledge on vehicle emission control and policy-making identified as two important parameters. Part two was two set of ranking question, which requested the experts ranked the defined evaluation criteria and control strategies based on their importance. The aim of this part was to review the order of importance and further calculated the weighting factors. It was presumed that the importance of these two key elements is not identical. Part III was the rating questions, which was the main information that needed to be collected. There was several vehicle emission control program under four main strategies and required the experts rated against six evaluation criteria. Only three rating level was chosen because of minimizing the difficulties while rating. The aim of rating question is to obtain the score of each program regarding the defined evaluation criteria.

Since amounts of invalid data appeared in Part II of the first questionnaire survey, second survey was decided to conduct. The second round of questionnaire survey conducted in an international conference called Better Air Quality, which held in Indonesia in December 2006. With the help of organizing committee, a booth was set up to demonstrate and explain the idea of assessment framework, which

assisted the respondents to understand more about this questionnaire survey. Because of the dissatisfaction in first survey, Indonesian student helpers were employed to assist the experts as well as ensure the experts provided valid information on questionnaire sheets. The second questionnaire sheet was slightly different with the first one. The second survey still contained three parts. Past I was personal questions which are similar to previous one. Part II was ranking question that is exactly same as the first survey. Part III is totally different since the feedback from the pervious indicated that the rating questions were difficult to answer in the first question. Hence, the second questionnaire was replaced by ranking questions.

Samples of the two questionnaire sheets are demonstrated in Appendix, Questionnaire 1 and 2.

### 2.2.2 Data Analysis

Generally, two set of data have been collected, which were the ranking and rating data. Different methods have been used for analyzing those data.

First is ranking data. Those data obtained from the section two, i.e. Part II, in both surveys and the section three, i.e. Part III, in second survey. However, the ranking data in first survey would be ignored as the respondents mis-understood the question requirements, then invalid ranking values were filled. Therefore, only the ranking data in second survey were examined. There were three sets of ranking data for the six evaluation criteria, four control strategies and several control programs

under each control strategies. Two indicators were used for investigation, which were the weights and the probability of a Chi Square. On the basis of the ranking results, the weight was calculated according to the following formula:

$$Weight_i = \frac{Score_i}{Sum\ of\ \ Score} \qquad \ldots \text{Eq.1}$$

In Equation 1, subscript i represents the criterion, control strategy and program, whereas the score is the summation of the product of rank and number of interviewees give the rank to a particular criterion, control strategy and program. For example, if 1st rank is assigned a score 6, if 2nd rank is assigned a score 5, and so on. For criterion A, if 10 interviewees grade 1st rank and 5 interviewees grade 2nd rank, then the score of criterion A is 85 = 10×6+5×5. The sum of score is obtained from adding up all the criteria scores. The highest weight means the most important criterion. Conversely, the lowest weight represents the least important criterion.

The probability of Chi Square test of independence was another indictor. The aim of this indicator is to strengthen the analysis so as to observe the significant differences within various groups. The steps are as follows.

Before testing the significant difference between groups, the contingency tables have to be formed. The contingency table is used to examine the relationship between subjects. For examples, the result of effectiveness in lower and upper income class, the contingency table is shown below,

Table 2.1 Examples of contingency table

| Condition | Rank 1 | Rank 2 | Rank 3 | Rank 4 | Rank 5 | Rank 6 | Total |
|---|---|---|---|---|---|---|---|
| Lower | 4 | 5 | 6 | 7 | 4 | 5 | 31 |
| Upper | 29 | 28 | 9 | 4 | 5 | 3 | 68 |
| Total | 33 | 23 | 15 | 11 | 9 | 8 | 99 |

One thing that needs to pay attention is that the total number of subjects should be at least 20. Afterwards the expected frequency needs to be calculated. The general formula for expected cell frequencies is

$$E_{ij} = \frac{T_i \times T_j}{N} \qquad \text{… Eq.2}$$

In equation 2, $E_{ij}$ is the expected frequency for the cell in the $i^{th}$ row and the $j^{th}$ column, $T_i$ is the total of subjects in the $i^{th}$ row, $T_j$ is the total number of subjects in the $j^{th}$ column, and $N$ is the total number of subjects in the whole table. Examples are shown below.

$$E_{11} = \frac{33 \times 31}{99} = 10.3 \qquad E_{12} = \frac{23 \times 31}{99} = 7.2 \qquad \text{and so on….}$$

$$E_{21} = \frac{33 \times 68}{99} = 22.7 \qquad E_{22} = \frac{23 \times 68}{99} = 15.8 \qquad \text{and so on….}$$

The table with expect frequencies are shown below.

Table 2.2 Table of expected frequencies

| Condition | Rank 1 | Rank 2 | Rank 3 | Rank 4 | Rank 5 | Rank 6 | Total |
|---|---|---|---|---|---|---|---|
| Lower | 4 (10.3) | 5 (7.2) | 6 (4.7) | 7 (3.44) | 4 (2.82) | 5 (2.51) | 31 |
| Upper | 29 (22.7) | 28 (15.8) | 9 (10.3) | 4 (7.56) | 5 (6.18) | 3 (5.49) | 68 |
| Total | 33 | 23 | 15 | 11 | 9 | 8 | 99 |

The formula for Chi Square test for independence is

$$\chi^2 = \sum \frac{(E-O)^2}{E} \qquad \text{… Eq.3}$$

In equation 3, $\chi^2$ is the Chi Square, $E$ is the expected frequency and $O$ is the observed frequency. For example,

$$\chi^2 = \frac{(10.3-4)^2}{10.3} + \frac{(7.2-5)^2}{7.2} + \frac{(4.7-6)^2}{4.7} + \cdots\cdots + \frac{(6.18-5)^2}{6.18} + \frac{(5.49-3)^2}{5.49}$$

$$\chi^2 = 16.8$$

The degree of freedom is equal to (R-1)(L-1) where R is the number of rows and L is the number of columns. In this example, R = 6 and L = 2, so df = (6-1)(2-1) = 5. A Chi Square table can be used to determine that df = 2, a Chi Square of 16.8 has a probability value of 0.0048. The acceptable level of significant difference set as 0.05. Therefore, there is significant difference between lower and upper income class.

Regarding these two indicators, i.e. the weights and probability of Chi Square for independence, more accurate observations can be obtained. The reason of getting clear observation is to assist the selection of expert panel, which is the alternative way to form the expert panel that was mentioned above. Gathering the expert's

opinions in conference and workshop is time-saving and convenient. Based on the observations, the particular group of respondents will then identify as the members of the expert panel. Such reliable opinions can be still produced.

Second is the rating data. Those data obtained from the section three of the questionnaire sheets, i.e. Part III, in the first survey. This section required interviewee rated the control programs regarding the six evaluation criteria. The rating range was within 1 to 3. It based on their mode, i.e. the highest frequency value, to determine their corresponding rating. For example, in Program A regarding Criterion A, 2 respondents select 1, 3 respondents select 2 and 5 respondent select 3, then 3 will pick as the rating value under Program A regarding Criteria A. Finally, a 17 × 6 matrix will be formulated, like below. The subscript number, i.e. 1 to 17, represents the control measures while the subscript capital letter, i.e. A to F, represents the six evaluation criteria.

$$Rating = \begin{bmatrix} r_{s_1,c_1} & \cdots & \cdots & r_{s_1,c_m} \\ \vdots & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ r_{s_n,c_1} & \cdots & \cdots & r_{s_n,c_m} \end{bmatrix} \quad \ldots \text{Eq.4}$$

In equation 4, $r_{s_n,c_m}$ is the rating of strategy n and control measure m, s is control strategy and c is evaluation criterion. On the basis of the above matrix, a performance score of each program will be obtained through multiplying a 6 × 1 weight matrix, see below. In equation 5, *W* represents the weights of the evaluation

criteria. First, identical weights, i.e. $W = 1$, will be considered. Second, from the weights that were mentioned above, weights' coefficients can be found for each criterion. By multiplying a weighting coefficient, it can enhance the whole analysis as well as reducing the duplications because narrow rating range was used. Regarding this score, the best policy option can be addresses.

$$\begin{bmatrix} r_{s_1,c_1} & \cdots & \cdots & r_{s_1,c_m} \\ \vdots & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ r_{s_n,c_1} & \cdots & \cdots & r_{s_n,c_m} \end{bmatrix} \begin{bmatrix} W_{s_1} \\ \vdots \\ \vdots \\ W_{s_n} \end{bmatrix} = \begin{bmatrix} Score_1 \\ \vdots \\ \vdots \\ Score_n \end{bmatrix} \quad \text{… Eq.5}$$

# CHAPTER 3.0 DEVELOPING A PRACTICAL ASSESSMENT FRAMEWORK

This chapter begins with an overview of research and literature on the use of policy evaluation criteria and vehicle emission control strategies, which demonstrates the selection of evaluation criteria and control strategies in the proposed assessment framework. Along these elements, a preliminary assessment framework is basically formulated. The studies on how to weigh the selected elements will then be addressed, which presents a rather quick and effective weighting method than the normal practices.

## 3.1 Overview the Assessment Framework Elements

There are two key elements that were identified in the proposed assessment framework, which were evaluation criteria and vehicle emission control strategies. These two key elements will be discussed in the following sections. Referring to the study approach that was mentioned, the followings present the step 2 and 3, i.e. defining criteria and identifying alternatives.

### 3.1.1 Policy Evaluation Criteria

The purpose of a policy evaluation criterion is to assess the performance of a control measures so as the implementation complexity of the measures with different intensities can be easily observed. In order to evaluate the control measures comprehensively, many scholars proposed the evaluation criteria shall comprise the social, economic, political and technical judgments.

Hahn (1989) proposed a policy evaluation framework. The rationales of his framework are to assess the criteria of efficiency and effectiveness as well as the feasibility of implementation of the measures. He first proposed a set of criteria to evaluate the efficiency and effectiveness of alternative policies. He then tried to identify key factors that affect policy implementation. Rusco and Walls (1995) considered where two policies achieved the same level of pollution reduction, then the less costly method would be adopted in vehicle emission issue. They recognized that the optimal level of pollution reduction depended on the costs of reduction. Economists use the principle of equating marginal costs with marginal benefits to choose the optimal level of pollution control. In general, the marginal cost of air pollution reduction increases as the total reduction increases. Both researchers clearly identified the rationales of their evaluation, leading to formulating the appropriate criteria.

Plaut (1998) suggested that the emissions abatement policy alternatives can be evaluated by efficiency, effectiveness, equity, costs of implementation and political feasibility. She also mentioned about the term of sustainability, but it was

not yet well-defined in a clear manner. Along her study, Tzeng et al. (2002) proposed similar factors such as efficiency and effectiveness, sustainability and level of authority. Else the feasibility of implementation of the measures suggests in some studies, such as Acutt and Dodgson (1997), Moavenzadeh and Liddle (1999), Molina and Molina (2004), and Rienstra et al. (1996).

In Recent years, many government administrations put emphasis on sustainability development. Some researchers discussed their own criteria in their studies. Like, Hung (1996) arbitrarily identified five assessment criteria in his transport policy hierarchy to achieve the sustainable transportation development. The criteria were (a) degree of deviations from the current system, (b) predictability, (c) political acceptability, (d) ease of administration, and (e) economy. In Söderberg and Kain's (2006) sustainable assessment on waste management alternatives, it is precision-guided framework and they concern eight indicators. The indicators are (a) environmental aspects, including transportation needs, material flow analysis, energy for operation and maintenance and process emissions; (b) business economy, which calculate with the current situation as point of reference; (c) local economy is referring to economic possibilities with alternatives, such as more jobs, recycling as a business and decreased rents; (d) spatiality is about required space for different system alternatives, and whether the alternatives represent aesthetical qualities; (e) robustness is the most complex evaluation area, including household aspects, such as attitudes to different alternatives, technical functionality, flexibility and institutional capacity to manage different system alternatives. (f) pedagogy is focusing on the ability of system alternatives to trigger learning among users. (g) well-being is about

foul smell, accessibility, inconveniences, and the risk of wasps and seagulls in waste collection bins; and (h) social aspects defined as collective social activities, among other things, discussing whether different alternatives strengthened the local community.

Enable to success the sustainability, the researchers are beginning concern many criteria to fulfill and satisfy the requirements on different aspects. Although concerning as many as criteria will allow the assessment became substantial, it also becomes hard to evaluate. To keep the simplicity of the evaluation, six main assessment criteria were selected in this research, which are considering the social, economic, political and technical judgments to evaluate the performance of the vehicle emission control measures. These performance criteria are with the reference to the results of various studies on policy evaluation criteria, which are:

A. Degree of deviations from existing system, which refers to the intensity of strategies to the community during the implementation of the strategies, for examples, changes in-used vehicles and fuels, re-urbanization. It is referring to the uncertainties imposed on the stakeholders during the strategies implementation. Very often, additional supplements and amendments of legal acts might be needed for implementing the vehicle emission control strategies.

B. Effect time, which is the time span for the strategies to take effect. Since there is an increasing concern of the adverse impacts of vehicle emissions on human health, an efficient control measure is always required, especially the strategies for improving the road side air quality.

C. Political acceptability, which is referring to the willingness of the public to accept the selected strategies. The degree of public cooperation for the measure implementation influences the outcome. Introduction of alternative cleaner fuel is a good example. The use of alternative cleaner fuels in vehicle can reduce air pollutants efficiently, yet without the support and cooperation of the public, it is hard to gain a success.

D. Administer-ability, which is referring to the procedural complexity of implementing the strategies. The level of involvement of different parties to manage the measures is important. The different parties include governmental departments, automobile manufacturers, fuel producers and public transport operators, etc. Each party has to have the know-how, skills and equipments to implement the strategies. Of course, the more parties are involved, the more complicated it becomes.

E. Cost of implementation, which refers to the investments, including capitals, resources and technology, require establishing the measures. The costs of implementing strategies are of grief concerns to governments especially in developing countries. Governments have to justify expenditures for implementing costly vehicle emission reduction alternatives. Very often, a cost-effectiveness analysis has to be conducted before or after implementation.

F. Effectiveness, which refers to the level of attainment in emission control after the execution. It is crucial to consider how well the improvement would be after the particular strategy implemented. The rationale of selecting alternatives is to control vehicle emissions and these measures must be effective to warrant

consideration. Effectiveness refers to the level of attainment in emissions control of the strategy.

### 3.1.2 Vehicle Emission Control Strategies

There is a wide range of emissions abatement policies implemented in different countries. Although all measures bear the same aim, which are mitigating vehicle emissions, they have different targets. Some policies target at reducing transport emissions directly while others target indirectly. Researchers summarize and group the measures into various categories based on different attributes.

In Plaut's (1998) study, the vehicular emissions are produced in two ways. These are the burning of fuel while traveling and during the process of the 'cold start' ignition. She therefore concerns four main methods, which are (I) switching to cleaner fuels; (II) controlling the vehicle and fuel-system emissions; (III) reducing the fuel consumption; (IV) minimizing the use of cars, to solve the mobile sources emissions problems. These methods can be identified as a direct consideration to minimize the vehicular emission.

Pargal and Heil (2000) divide the factors of transport air emissions into (I) emission per unit of fuel; (II) units of fuel passenger kilometer; and (III) passenger kilometers traveled. Linkages and feedback mechanisms surround in their idea. They further discuss various kinds of policies among these determinants, such as controlling fleet size, reducing number and length of trips, reducing congestions and urbanization patterns. These can be identified as indirect control measures.

According to the information of Asian Development Bank (2003), the understanding of what kind of factor influenced the level of pollution by individual vehicle is highlighted. Air pollution from vehicles is caused by several factors, particularly the engine characteristics and the use of emission control device such as a catalytic converter. The maintenance of the engine and pollution control device are also related. Fuel type and quality is the second main factor which determines the level of emissions. Also, the driving behaviors affected the emission levels. They concluded that the factors influencing levels of vehicle emissions will be engine characteristics, fuel characteristics and use of vehicle. They considered the nature of the measures and grouped them into (I) emissions standards and regulations, which provide guidelines for vehicle owners, motor vehicle manufacturers and fuel producers; (II) fuel efficiency improvement and alternative fuels, which aim at modifying the fuels to reduce emissions; (III) inspection and maintenance, which ensure proper operation of in-use vehicles; and (IV) transport planning and traffic demand management, which enhance better coordination of transports. Some similar notion also observed in Litman's (1999) and OECD's (1995) study.

Molina and Molina (2004), Moavenzadeh and Liddle (1999) and Lee (2002) grouped different measures according to the way of implementation. Four categories were summarized including (I) education and information campaign, which targeted at arousing public awareness of the benefits of emission control; (II) regulations, which include standards, restrictions and technological mandates, promoting cleaner vehicles and fuels; (III) economic incentives, which include charges to polluters and

subsidizes for encouraging emissions control; and (IV) transport and land use control aiming at controlling the traffic.

On the basic of the importance of sustainability, Hung (1996) and Hung and Hills (1997) stratified the measures into four levels based on a set of decision criteria. Their levels were (I) restricting drivers; (II) manipulation and modification of existing transport system; (III) introducing alternatively fuelled vehicles; and (IV) practicing good land-use planning and control. These levels considered the control measures into three terms which were short, medium and long terms as well as containing direct and indirect measures.

Being an environmental protection administrator, the performance of the measures and the feasibility of strategy implementation are the crucial considerations in policy formulation. The political trend of controlling vehicle emission are trying to comprise direct and indirect measures in order to fulfill short, medium and long term considerations, so that the studies of Asian Development Bank (2003), Hung (1996) and Hung and Hills (1997) have been synthesized and modified. Ultimately the vehicle emission control measures are formulated into four categories in this study. The categories are level I: restriction on rivers; level II: modification of existing transportation system; level III: introduction of alternative fuels; and level IV: land use planning and control. This order is according to their feasibility of implementation as well as comprising oblique and straightforward control measures.

In order to have more detailed measures on each category, I have reviewed the current situation of implementing control measure in the vehicle emission

problem. Tables A1 to A14 in Appendix show the examples of measures implemented in some Asian cities. According to these existing or implemented control measures in those cities, the seventeen control measures have been recommended under the four defined categories. The categorization adopted in this study is largely based on the studies of Hung (1996) and Asian Development Bank (2003). Table 3.1 presents a list of the vehicle emission control strategies that are adopted in this study. A description of the categorization is given below.

Table 3.1 List of common vehicle emission control strategies

| | |
|---|---|
| **Level I:** | **Restriction on drivers** |
| I – 1. | Limitation on Car Ownership |
| I – 2. | Control of Car Use |
| I – 3. | Educate the Drivers |
| **Level II:** | **Modification of existing transportation system** |
| II – 1. | Improvement of Fuel Quality |
| II – 2. | Promotion of Cleaner Fuel |
| II – 3. | Vehicle Technology Advances |
| II – 4. | Inspection and Maintenance Program |
| II – 5. | Traffic Management |
| II – 6. | Strengthen Regulations and Enforcements |
| **Level III:** | **Introduction of alternative fuels** |
| III – 1. | Infrastructure for Alternative Fuels |
| III – 2. | Retrofit Vehicles with Alternative Fuels kits |
| III – 3. | Promotion of Alternative Fuels |
| III – 4. | Purchasing Alternative Fuel Vehicles |
| **Level IV:** | **Land use planning and control** |
| IV – 1. | Reformation of Public Transports |
| IV – 2. | Use of Non-motorized Vehicles |
| IV – 3. | Rail System |
| IV – 4. | Re-conceptualization of Town Plan |

### *Level I: Restriction on Drivers*

This level of control induces minimal change to the current system. The drivers as one of the major stakeholders of the land transport system play a significant role in the proper operation of the system. Through educating and restricting the drivers, it is hoped that some wasteful journeys can be saved and irrational driving behaviour can be rectified. There are three recommend control measures under this level of control; two of which worth a discussion here.

#### Level I – 1. Limitation on car ownership

It was found that the number of vehicles is not closely related with the wealth of the cities, especially in some wealthy cities, where the control of automobile is very effective (Kenworthy and Laube, 1999). It will be a direct yet effective control measure, which are not in accordance with the financial condition of the country. To limit the growth of vehicles, governments impose high tax on car purchases and ownership or indirectly impose tax on fuels. A stricter policy is vehicle quota system as instituted in Singapore. It is a market-based mechanism in which the vehicle owners have to purchase a limited certificate for registering their vehicles. The governments develop other modes of transports so that the riders could have other transportation choices. This instrument has been proved to be success in the wealthy cities, for instances, Tokyo, Singapore and Hong Kong, where the growth of vehicles has reduced in recent years (The World Bank, 2000). For the middle to low-income

cities, attention should be paid for the motorized two- and three-wheelers, which are popular but the exhausts is significant.

### Level I – 2. Control of car use

Control of car use can be implemented in many directions. Firstly, it is by the control of access. The common method is to restrict the use of certain areas. However, it may shift the traffic congestion to other areas. Therefore, electronic road pricing has recently practiced in some effluent cities to control the traffic flow, but it requires significant planning and investment (Litman, 2003). Secondly, it is by the control of parking, such as limiting the parking space and parking restriction. Other valuable approaches are by parking charges and parking management, which are not as complicated as electronic road pricing, but it still requires good planning (Acutt and Dodgson, 1997; Litman, 2003). Thirdly, it is by the control the use of vehicles such as a ban on the import or entry of polluted vehicles. Some cities may provide subsidizes to encourage the replacement of polluted and old vehicles. Fourthly, it is by reducing the number of vehicles on roads, which is generally voluntary-based, such as carpooling and plate number scheme. Shortly, control of car use can be very effective to those cities with high administer-ability.

### *Level II: Modification of Existing Transportation System*

This level of control does not induce huge change to the current land transportation system but tries to manipulate the key components of the system in all fronts to achieve a reduction in vehicle emissions. There are six types of measures under this level of control and two more commonly adopted ones are briefly discussed below.

### Level II – 1. Improvement of fuel quality

The introduction of emissions standards highly depends on the vehicles and fuels available. For example, the use of catalytic converter invented in 1977 to break down pollutants so as to reduce emissions is only effective with unleaded petrol (Organization for Economic Co-operation and Development, 1995). Many countries have, therefore, started to introduce unleaded gasoline and gradually phased out the lead in gasoline. Besides, as sulfur is an activated component affecting the performance of emission control devices, lowering sulfur level in gasoline and diesel is important. With stricter control measures on fuel quality, the emissions standards could be tightened. As shown in Table 3.2, Tokyo is in the lead in both introducing unleaded petrol and completely phasing out of lead petrol in mid to late 1980s, while other cities mostly introduced unleaded petrol in early 1990s and just completely phased out lead in early 2000s. With the ultra low sulfur diesel (0.005% by weight) introduced in the cities, the performance of particular matter reduction devices can be improved (Hirabayashi, 2002). Fuel standards are directly related with the refinery

capability in those cities with oil refining companies, while the acceptability of the use of modified fuels are related with the affordability of the publics (Asian Development Bank, May 2001). These two aspects can be stimulated by government incentives, i.e., promotion of cleaner fuel and emission control devices.

Table 3.2 Fuel quality changes in the 14 Asian cities

| City | Year for introduction of unleaded gasoline | Year for completely phased out of lead in gasoline | Sulfur content in gasoline in % by weight (Year) | Sulfur content in diesel in % by weight (Year) | References |
|---|---|---|---|---|---|
| Kathmandu | 1999 | | 0.100 | 0.250 | (Jha, 2001) |
| Manila | 1994 | 2000 | | 0.050 (2004) | ( Krupnick et al., December 2003) |
| Delhi | 1995 | 1998 | 0.050 (2000) | 0.050 (2000) | (Ministry of Environment & Forests, 2003) |
| Ho Chi Minh City | 1991 | 2001 | <0.150 | <0.500 (2001) | (Duc, 1999) |
| Beijing | 1997 | 2000 | 0.050 (2003)<br>0.015 (2005) | 0.050 (2003)<br>0.035 (2005) | (Beijing Environmental Protection Bureau, 2003) |
| Jakarta | 2001 | 2003 | 0.020 | 0.500 | (Asian Development Bank, 2003) |
| Kuala Lumpur | 1991 | 1998 | | 0.050 (2000) | (Ishak, 2001a) |
| Guangzhou | 1997 | 2000 | 0.080<br>0.050 (2005) | 0.050 (2004) | (Guangzhou Environmental Protection Bureau, 2003) |
| Bangkok | 1993 | 1996 | | 0.050 (1999) | (Chongpeerapien, 1991; Wangwongwatana & Warapetcharayut, 2001 ) |
| Seoul | 1987 | 1993 | 0.013 (2002)<br>0.005 (2006) | 0.050 (1998) | (Park, 2002) |
| Taipei | 1988 | 2000 | 0.018<br>0.005 (2007) | 0.035 (2007) | (Newsys Environmental Tech. Inc., 2003) |
| Singapore | | 1998 | | 0.050 (1999) | (National Environment Agency, 2003) |
| Hong Kong | 1991 | 1999 | 0.015 | 0.050 (1997)<br>0.005 (2000) | (Hung et al., 2001; Environmental Protection Department, 2004) |
| Tokyo | 1975 | 1980 | 0.005 (2005) | 0.050 (1997)<br>0.005 (2005)<br>0.001 (2007) | (Hirota & Minato, 2001) |

### Level II – 4. Inspection and maintenance (I/M) programmes

I/M programmes to control emission from in-use vehicles are essential complement to emission standards for new vehicles. High quality I/M programmes can reduce CO and HC exhaust emissions by approximately 20 to 30% (Organization for Economic Co-operation and Development, 1995). As shown in Table 3.2, those selected cities have implemented I/M programmes. Their I/M practices are however in fact different resulting in different efficiency. Firstly, it depends on the accuracy of emission testing method adopted. The widely adopted methods include idle test for gasoline vehicles and free acceleration test for diesel vehicles, which are easy and cheap to carry out. However, these tests cannot reflect the emissions in real driving conditions. Therefore, loaded tests using chassis dynamometer with developed driving cycles have recently been applied but with much expensive operational cost. Secondly, it depends on the stringency of enforcement, i.e., the frequency of inspection and maintenance and the type of vehicles being inspected. The inspection frequency of in-use vehicles should be determined by their purposes and ages. Usually the heavily used vehicles (e.g., truck, commercial vehicles) and old vehicles (e.g., age 8 or above) should have the more frequent test in an effective I/M program. Thirdly, the quality and reliability of I/M workshops are important for I/M performance. There are mainly two types of I/M workshops, centralized (inspection only) and decentralized (inspection and repair). The latter one is more convenient but with difficulties in being audited as the vehicles maybe repaired before test in the workshop. Fourthly, roadside inspection could strengthen the periodic I/M. The

vehicle owners are not informed in advance in spot-check. Table 3.3 summarizes the performance of I/M in the selected Asian cities.

Table 3.3 I/M programmes in selected Asian cities

| City | Emission testing methods | Inspection workshop | Maintenance system | Roadside inspection | References |
|---|---|---|---|---|---|
| Kathmandu | Confidential information | Centralized | Privately owned without government registration | With | (Jha,2001) |
| Manila | Opacimeter; gas analyzer; smokemeter | Centralized | | With | (Philippines Land Transportation Office, 2002) |
| Delhi | Idle Emission / Smoke test for gasoline vehicle; Full load smoke and free acceleration smoke for diesel vehicles; Chassis dynamometer for gasoline vehicles with Indian driving cycle (not yet fully developed due to inappropriate vehicles used) | Decentralized | | Without | (Chaudhari, 2004; Kathuria, 2002) |
| Ho Chi Minh City | Opacity | Centralized | Government owned but without enforcement on maintenance | Without | (Thanh, 2001) |
| Beijing | Double idle speed test and steady-state loaded mode for gasoline vehicles; Free acceleration for test diesel vehicles; Short transient driving cycle for light-duty gasoline vehicles; ASM test and lug down test for all in-use vehicles | Centralized | Privately owned with qualification from government | With | (Beijing Environmental Protection Bureau, 2003) |
| Jakarta | Idle test for gasoline vehicles and diesel vehicles | Centralized | Privately owned with government inspection | With | (Soekamdi, 2001) |
| Kuala Lumpur | Idle speed for gasoline vehicles; Free acceleration method for diesel vehicles | Centralized | Privately owned with government inspection | With | (Ishak, 2001b) |
| Guangzhou | Idle test | | | | (Shao & Zhang, 2001) |
| Bangkok | Idle test using filter and opacity methods for gasoline vehicles; Snap acceleration test using filter and opacity methods for diesel vehicles; Dynamometer smoke test for bus is conducted under the Japanese pilot project | Centralized | | With | (Warapetcharayuth, 2004) |
| Seoul | Transient test cycle for emission test | Centralized | | With | (Park, 2002) |
| Taipei | Dynamometer smoke test for diesel vehicles with loaded speed test and unloaded acceleration test | Centralized | Privately owned with government inspection | | (Newsys Environmental Tech. Inc., 2003) |
| Singapore | Acceleration simulation mode test on petrol driven vehicles; Dynamometer smoke test for diesel vehicles with loaded test | Centralized | | With | (National Environment Agency, 2003) |
| Hong Kong | Dynamometer smoke test for light diesel vehicles with lug down test; Free acceleration smoke test | Centralized | | With | (Environmental Protection Department, 2004) |
| Tokyo | Dynamometer smoke test for diesel vehicles with its developed driving cycles: 10-15 mode, 6 mode, new mode. | Centralized | Privately owned with certification from government | With | (Hirota & Minato, 2001; Tokyo Metropolitan Government, 2003) |

Note: Centralized: authorized under Governmental departments and inspection

### *Level III: Introduction of Alternative Fuels*

This level of measure induces major change to the key components of the current land transportation system. Introduction of alternative fuels requires new refueling infrastructure and probably new requirements of inspections and maintenance of the system.

Currently, there are still lots of uncertainties concerning the design of alternative fueled vehicles (AFVs), especially the safety, performance and high capital cost, which affect the market acceptances (Alternative Fuel Group, 2000). Only liquefied petroleum gas vehicles (LPGVs) and compassed natural gas vehicles (CNGVs) are most ready for large-scale use (Asian Development Bank, May 2001). As listed in Table 3.4, most cities have these two types of AFVs available. The richer cities have tried electric vehicles as well. However, the use of alternative fuels will be determined not only by local availability and the price considerations (Asian Development Bank, May 2001), but also the involvement from the government. The generalization of AFVs depends on the incentives provided and complementary infrastructures developed by governments. Incentives are mostly in the form of subsidies and tax concessions to stimulate the introduction and use of alternative fuels (Asian Development Bank, 2001). However, development of AFs fueling stations and supportive service industry are very costly, which are obstacles for AFs to be widely used.

Table 3.4 Type of alternative fuel vehicles introduced in the 14 Asian cities

| Cities | Type of alternative fuel vehicles developed | | | | | References |
|---|---|---|---|---|---|---|
| | LPGVs [a] | NGVs [b] | BPEVs [c] | HEVs [d] | Others | |
| Kathmandu | Y* | | Y | | | (Clean Energy Nepal, 2003) |
| Manila | Y | Y | | | Coco- biodiesel | (LPG-CNG Workshop, 2002; Monsada, 2001) |
| Delhi | Y | Y | | | | (Kathuria, 2002) |
| Ho Chi Minh City | Y | | | | | (Multi-sectoral Action Plan Group, 2002) |
| Beijing | Y | Y | Y | | | (Kim & Qiang, 2001) |
| Jakarta | Y | Y | | | Biodiesel vehicles | (The Partnership for Clean Emission (MEB), 2002) |
| Kuala Lumpur | | Y | | | | (Ishak, 2001a) |
| Guangzhou | Y | Y | Y | | | (Kim & Qiang, 2001) |
| Bangkok | Y | Y | Y | | | (Wangwongwatana & Warapetcharayut, 2001) |
| Seoul | Y | Y | Y | Y | Biodiesel vehicles | (Park, 2002) |
| Taipei | Y | Y | Y | Y | | (Wang, 2004) |
| Singapore | Y | Y | Y | Y | | (Ministry of the Environment and Water Resources, 2006) |
| Hong Kong | Y | Y | Y | | | (Environmental Protection Department, 2004) |
| Tokyo | Y | Y | Y | Y | Methanol-fuelled vehicles, Fuel-cell electric vehicles | (Ahman, 2006) |

[a] Light petroleum gas vehicles (LPGVs)

[b] Natural gas vehicles (CNGVs)

[c] Battery-powered electric vehicles (BPEVs)

[d] Hybrid electric vehicles (HEVs)

* “Y” represents the implementation of that AFVs.

### *Level IV: Land Use Planning and Control*

This level of control will certainly induce immense change to the current traveling habits, both for the passenger and freight transportation.

Applying land use planning and control can reduce both the demand for travel and the distance of travel, and certainly will have huge impacts on vehicle emissions. Many Asian cities have introduced non-motorized vehicles (The World Bank, 2000; The Partnership for Clean Emission (MEB), 2000), such as bicycle (Tokyo Metropolitan Government, 2003; Geetam, 2002; Hwang, 2001), and provided more pedestrian paths in urban area to limit the car entrance (Hwang, 2001; Li, 2000). Bicycle would be one of environmental and user friendly transportation modes. And, more pedestrian paths and fewer roads would also improve the urban air quality (Li, 2000). In fact, a good transportation system will be necessary. Hence, good development on railway network will be a good choice. Provided with adequate ridership, railway is a more environmental friendly transport. Developed Asian cities, such as Japan (The World Bank, 2000), with a high financial capability can afford to re-conceptualize the town plan that is difficult and complicated, but highly effective.

## 3.2 Results from Questionnaire Surveys

The assessment framework elements were described in above section. The preliminary outline of the framework can be previewed. In this section, the results from the questionnaires surveys will present. Before assessing the alternatives, an appropriate expert group needs to be selected on the basis of the findings from surveys. Hence, the ranking result in second survey will be addresses firstly.

The first survey was conducted in Motor Vehicle Emission Control Workshop in May 2006. The workshop was held in Hong Kong. We totally obtained 80 returns, however most of interviewees filled in the questionnaire sheets incorrectly. There were only 12 valid samples after screening off the defective samples. The number of returns was significantly tiny. We decided to conduct another survey regarding the problem of insufficient sampling size. In December 2006, one of the biggest international conferences in air quality issues was held in Indonesia. We took this opportunity to gather experts' opinions. This time, the questionnaire sheet was modified and the interviewees completed the questionnaire sheet with the assist of trained student helpers. There were 217 returns in total. After screening off the invalid samples, we received 188 correct samples, which was 85% of the total returns. Table 3.5 displays the brief information about the first and second surveys.

Table 3.5 Information of questionnaire surveys

| | | Round 1 | Round 2 |
|---|---|---|---|
| | | Numbers (%) | Numbers (%) |
| The survey was conduct in | | Motor Vehicle Emission Control Workshop 2006 | Better Air Quality 2006 |
| Total of returns | | 80 (100%) | 217 (100%) |
| Valid samples | | 12 (15%) | 188 (86.64%) |
| Invalid samples | | 68 (85%) | 29 (13.36%) |
| **Valid samples** | | | |
| Experiences in Vehicle Emission Control | With experiences[1] | 11 (91.67%) | 108 (57.45%) |
| | Without experience[2] | 1 (8.33%) | 80 (42.55%) |
| Affiliation | Government | 5 (41.67%) | 67 (35.64%) |
| | Non-Government | 7 (85.33%) | 121 (64.36%) |

Note: 1. With experiences: > 0 year experience in vehicle emission control
2. Without experience: 0 year experience in vehicle emission control

Table 3.6 presents the findings of the interviewees' background information in the surveys. The data that displays in Table 3.6 were the survey results in Section A of questionnaire sheets of Questionnaire 1 and 2 in Appendix, however it was only regarding the valid samples in Section B in the first and second surveys. There were three main information collected from interviewees, including origin, affiliation and experiences in vehicle emission control. We further classified these information into various groups so as to investigate the variations within their background. The data clearly displayed in Table 3.6 shows that the returned samples from the first survey were insufficient, such not much description of the first survey will be addressed. The country of origin is based on the data of gross national income (GNI) per capita provided by the World Bank (World Bank, 2007). Three country classes, which are low, medium and high income classes, are defined. The GNI per capita of low, medium and high income classes is US$585, US$2647 and US$35264 respectively. No interviewees were from lower income class countries in the first round while

more interviewees came from middle income class countries in the second round. More than half of interviewees were working with non-governmental organizations in the both rounds. The interviewees with no working experience in vehicle emission in the first round were lesser than the second round. There were more experienced interviewees in the first round on the basis of percentage. It was perhaps because the first survey was conducted in the workshop which was focused on vehicle emission control. The second survey was conducted in an international conference which was less focused on vehicle emission control. The sample size of the first survey was significantly smaller than second survey.

Table 3.6 Summary of interviewees' background information

| | | Round 1 Survey | **Round 2 Survey** |
|---|---|---|---|
| | | Numbers (%) | **Numbers (%)** |
| Total Valid Samples | | 12 | **188** |
| Country | Lower income class | 0 (0%) | **31 (17%)** |
| | Middle income class | 6 (50%) | **89 (47%)** |
| | Upper income class | 6 (50%) | **68 (36%)** |
| Affiliation | Government | 5 (42%) | **67 (36%)** |
| | Non-Government | 7 (58%) | **121 (64%)** |
| Experiences in vehicle emission control | 0 year | 1 (8%) | **80 (43%)** |
| | Above 0 to 2 years | 3 (25%) | **31 (17%)** |
| | Above 2 years to 5 years | 2 (17%) | **40 (21%)** |
| | Over 5 years to 10 years | 2 (17%) | **14 (7%)** |
| | Over 10 years | 4 (33%) | **23 (12%)** |

### 3.2.1 Policy Evaluation Criteria

Six evaluation criteria were defined, namely degree of deviations from existing system (A), effect time (B), political acceptability (C), administer-ability (D), cost of implementation (E) and effectiveness (F).

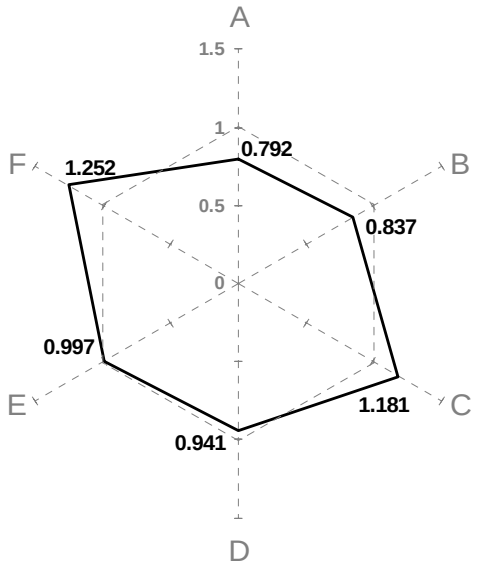
The radar graph displayed in Figure 3.1 shows that the weighting value of the evaluation criteria among the valid samples from the second survey. The total number of valid samples is 188. As is shown in Figure 3.1, the black line represents the calculated overall weighting value from the results of second survey while the gray dash line represents the even weighting value that is 1.

The two highest weighting values clearly occurred in the criteria of the effectiveness (F) and political acceptability (C), which raised the paramount importance of these two criteria. The corresponding weighting values for the effectiveness (F) and political acceptability (C) were 1.252 and 1.181 respectively. These two criteria were significantly higher, which got rises of 25.23% and 18.09% for the effectiveness (F) and political acceptability (C) respectively while compared with the even value. The two lowest weighting values appeared in the criteria of the degree of deviations from existing system (A) and effect time (B). Their weighting values were 0.792 for the degree of deviations from existing system (A) and 0.837 for effect time (B). Their weighting value reflected that these two criteria were the least important among the six criteria. The criteria of the cost of implementation (E)

and administer-ability (D) were just slightly lower than the even value, which were 0.997 and 0.941 respectively.

It can be clearly seen from Figure 3.1 that the gray dash hexagon narrowed down to the black hexagon with two sharp angles. It seemed that the weights of the degree of deviations from existing system (A) and effect time (B) were shifted to the effectiveness (F) and political acceptability (C).

Figure 3.1 Weighting values of the evaluation criteria from all valid samples in second survey



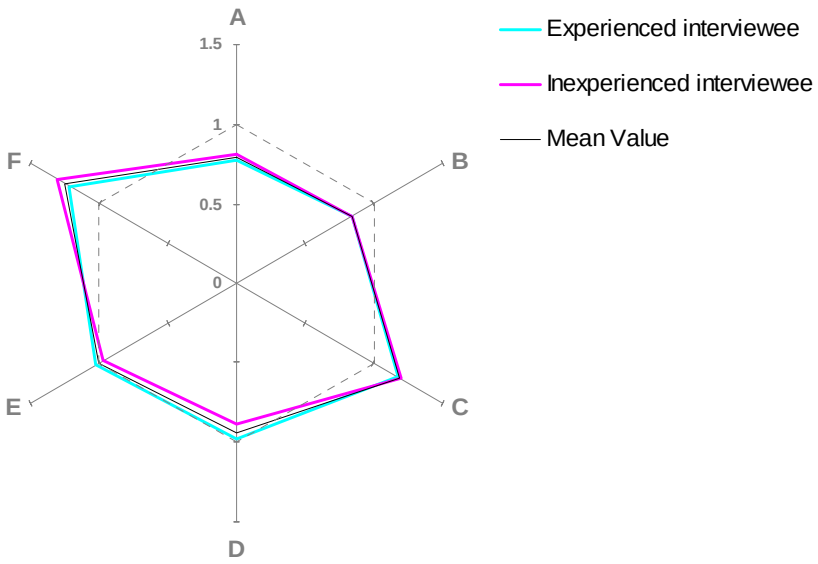

We assumed that the interviewee' background influenced the weights findings. Enable to deepen the observations, the interviewee were divided into three various groups to observe the difference within the groups. Due to inadequate sample size in the first round survey, only the second round results will be discussed.

The first observation group was the interviewee' experiences in vehicle emission control. The respondents were categorized into inexperienced and experienced group. Figure 3.2 below shows the results of the weighting values of the six criteria regarding the interviewee' experiences in vehicle emission control. As is shown in Figure 3.2, the blue and pink bold line represents the experienced and inexperienced interviewee respectively whereas the black line represents the overall weighting values. The experienced interviewee meant the interviewee with experiences in vehicle emission while the inexperienced interviewee meant the interviewee with no experience. According to Table 3.6, about 43% is inexperienced interviewee while about 57% is experienced interviewee. In the group of experienced interviewee, about 15%, 38% and 47% were from lower, middle and upper income class country respectively. In the group of inexperience interviewee, there was about 19% from lower, 60% from middle and 21% from upper income class. Else, about 49% of experienced interviewee belonged to governmental affiliation and about 15% of experienced interviewee were from non-governmental affiliation. For inexperienced interviewee, there was about 29% worked for governmental affiliation and 71% worked for non-governmental affiliation (Table 3.7).

It can be seen from Figure 3.2 that the shape of the three radar graphs looks analogue as well as with identical importance orders. It implied that the views of experienced and inexperienced interviewee were very similar. The two highest peaks with approximate weighting values occurred in the criteria of effectiveness (F) and political acceptability (C). Especially, in the inexperienced group, the effectiveness (F) got a maximum rise of 30.71% with compared to even value. Whoever the

experienced or inexperienced interviewee, the criteria of the degree of deviations from existing system (A), effect time (B) and administer-ability (D) were below the gray even line. Particularly, the degree of deviations from existing system (A) and effect time (B) were relatively lower, which got falls of 16% to 22% with compared to even weighting value. Both weighting values of the criterion of the cost of implementation (E) were approximate to the even weighting value.

Figure 3.2 Weighting values of the evaluation criteria among their experiences in vehicle emission control




Perhaps the differences might be eliminated regarding the above calculation. In order to obtain more accurate observations, the statistical method of Chi Square test was used to investigate the difference between the experienced and inexperienced groups. Regarding the findings from Chi Square test (Appendix, Table A15), it can be observed that there was no significant difference within these two groups. Hence, we further divided the group into three, which were inexperienced respondents (i.e. respondents with 0 year's experience), respondents with over 0 to 5

years' experiences and respondents with over 5 years' experiences. Regarding this classification, there was also no significant difference within these three groups. So that the two experienced groups above were then narrowed down the ranges and categorized into 4 groups. The respondents with over 0 to 5 years were divided into two which were respondents with over 0 to 2 years experiences and respondents with over 2 to 5 years experiences. On the other hand, the respondents with over 5 years experiences were separate into two which were respondents with over 5 to 10 years' experiences and respondents with over 10 years' experiences. There was significant difference found in the former groups, i.e. respondents with over 0 to 2 years' experiences and respondents with over 2 to 5 years' experiences (Appendix, Table A16-A21). The significant difference with a probability value of 0.05 appeared in the criterion of degree of deviations from existing system (A). For the latter groups, i.e. respondents with over 5 to 10 years' experiences and respondents with over 10 years' experiences, there was no significant difference. In order to understand clearly that whether there are any differences within the experienced groups, the difference within the respondents with over 2 to 5 years' experiences and respondents with over 5 to 10 years' experiences was examined. The significant difference with a probability value of 0.03 also appeared in the criterion of degree of deviations from existing system (A). Previously, the difference between the respondents with over 0 to 5 years' experiences and respondents with over 5 years' experiences was examined. The finding showed no significant difference in between. But, while the experienced groups were categorized into smaller groups, the significant difference was observed. It implied that the difference in between was eliminated while broad range was used. From this observation, perhaps the respondent with 5 years'

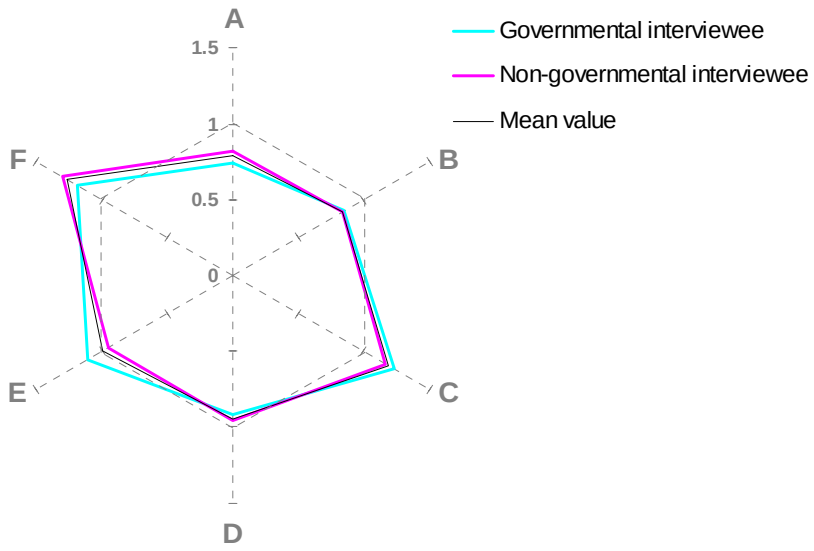
experiences in vehicle emission control was the separation point within the experienced groups. It is supposed that over 5 years' experiences in vehicle emission control can be a good referencing point to form the expert panel for the survey.

The second observation group was based on the respondent's affiliation. Figure 3.3 indicates the weighting values of the evaluation criteria in the groups of governmental and non-governmental respondents. The blue hexagon represents the governmental respondent. The pink hexagon describes the findings from the non-governmental respondents. As it shows in Table 3.5, about 36% of respondents worked for government while the rest of 64% worked for non-governmental organization in the second survey. In the governmental group, about 28% of interviewee came from lower income class, 45% came from middle and 27% came from upper. In the non-governmental group, the respondents from lower, middle and upper income class were about 10%, 49% and 41% respectively. Around 43% of governmental interviewee had experiences in vehicle emission control while about 47% of non-governmental interviewee had experiences in vehicle emission control.

The importance order was totally different although the two highest weighting values were at the criteria of the effectiveness (F) and political acceptability (C). In the governmental group, the weight of political acceptability (C) was slightly higher than the effectiveness (F). It was contrary in non-governmental group, which was higher in the effectiveness (F). It implied that the views of governmental and non-governmental respondents were slightly different. Similar phenomena also appeared in the criteria of the administer-ability (D) and cost of implementation (E). The weight of cost of implementation was higher in the

governmental group whereas the weight of administer-ability was higher in the non-governmental group. Just like the inexperienced and experienced groups, the governmental and non-governmental respondents selected the criteria of degree of deviations from existing system (A) and effect time (B) as the lowest two with falls of 15% to 26%.

Figure 3.3 Weighting values of the evaluation criteria among their affiliation




Same as previous group, the statistical method of Chi Square test was applied and shown in Appendix, Table A21. All the policy evaluation criteria had no significant difference between governmental and non-governmental group.

The third observation group depended on the origin of the interviewee. Figure 3.4 describes the weights of the evaluation criteria in the groups of origin. The respondents were classified into various income class groups based on their GNI per capita, which groups were named as lower, middle and upper income class. The data in Table 3.6 describes that 17% were from lower, 47% were from middle and 36%

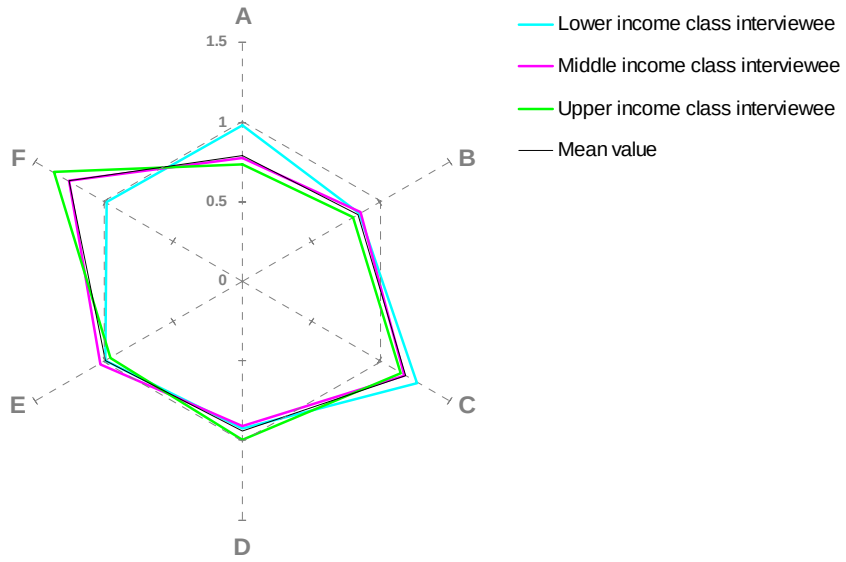
were from upper income class. In the group of lower income class, about 61% worked for government while about 39% worked for non-government. There were 48% of lower income class respondents with experiences in vehicle emission control. In the middle income class, the respondents who worked for government and non-government were about 34% and 66% respectively. Around 54% of respondents in middle income class had experiences in vehicle emission control. In the upper income class, there were 26% of respondents from governmental organization and 74% from non-governmental organization. There were 25% respondents of upper income class with experiences in vehicle emission control.

As is shown in Figure 3.4, blue, pink and green represent lower, middle and upper income class interviewee respectively. The shape of blue hexagon was significantly different than the other hexagons. Beside the criteria of effect time (B), political acceptability (C) and administer-ability (D), the rest of the criteria were approximate to the gray even line in the lower income class. Unlike the other groups, the lower income class group only had one shape angle, which appeared in the political acceptability (C). The other two groups were just like the previous groups, i.e. the groups of affiliation and experiences in vehicle emission control, had two sharp peaks of the effectiveness (F) and political acceptability (C). Else, the two lowest weights in the lower income class appeared in the criteria of effect time (B) and administer-ability (D). For the other two income group, the two least important criteria was degree of deviations from existing system (A) and effect time (B).

Once again, the differences within the groups were examined through Chi Square test. There were three pairs of comparisons, which were lower against upper,

lower against upper and middle against upper. The significant difference was observed in the first comparison, i.e. lower against upper. A probability value of 0.0048 appeared in the criteria of effectiveness (F).

Figure 3.4 Weighting values of the evaluation criteria among their origin




The Chi Square test was to strengthen the investigation of the variation among various groups. Combining the observations from the weights calculations and Chi Square test, several interesting findings can be expressed. Table 3.7 reveals the summary of the findings in the second survey. As is shown in Table 3.7, the weighting values in red represent those values are over the even weighting value. Else, the values highlight in yellow represent the highest two while the values highlight in orange represent the lowest two. On the basis of the findings, several particular findings are identified as below.

In general speaking, the data showed that the effectiveness (F) should be the most important criteria in most of time. This result is perhaps not surprising as the

level of improvement in pollution matters is always the main parameters while determining appropriate control strategies during implementation. It can be seen that most of respondents were generally satisfied the trend of the highest two in the effectiveness (F) and political acceptability (C) and the lowest two in the degree of deviations from existing system (A) and effect time (B). Only the lower income class respondents were dissatisfied with this trend. The effectiveness (F) was significantly lower in the lower income class group while only the political acceptability (C) had a relatively higher weighting value. This finding differs distinctively from the results of other groups. Obviously, the respondents from lower income class had a different perspective on the importance of effectiveness. This difference was also showed in the Chi Square test.

The results indicated that the criteria of effect time (B) and degree of deviations from existing system (A) were always the least important two besides the group of lower income class. These findings are reasonable since the strategies with short effect time and insignificant influence to current system were hardly acquired. For example, introducing alternative fueled vehicles, regardless of significantly longer effect time and substantial influence to current system, the government nevertheless adopted this measure. This evidence showed that the effect time (B) and degree of deviations from existing system (A) were neglected during consideration because the difficulties were seemingly unavoidable.

Regarding the Chi Square test, there was no significant difference among the affiliation. But, the weights findings showed that the governmental respondents particularly paid more attentions on the political acceptability (C) than the

effectiveness (F). This reflected the deviations of aspect between governmental and non-governmental interviewees. In the case of governmental interviewees, it is possible that they more concerned the difficulties on cooperating within government and public while implementing new vehicle emission control measures. They would feel more comfortable using new control measures with better performance on political acceptability that would make the implementation processes become easier and smoother. A good example can be found in Hong Kong. On November 2007, the Hong Kong government proposed new vehicle emission control measures of switching off the car engine while waiting. Perhaps this strategy might not have a great improvement on vehicle emission control, yet this strategy would be easier to implement comparing with the other control measures such as introducing natural gas vehicle.

One of interesting findings is in the group of experiences in vehicle emission. Regarding the weights results, the weight presented that the difference within the inexperienced and experienced respondents was limited. However, while the year ranges were narrowed down, the significant difference appeared via chi square test. It was found that 5 years of experiences in vehicle emission would be a valid referencing point.

Regarding the weights results, common phenomena can be observed. The six policy evaluation criteria could distinguish into three levels. The criteria of effectiveness (F) and political acceptability (C) positioned at the highest level. The criteria of administer-ability (D) and cost of implementation (E) located at the

intermediate level. Finally, the degree of deviations form existing system and effect time placed at the lowest level.

Table 3.7 Summary of the weighting values of the evaluation criteria among different groups

| | | | Overall | Group | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Experiences in vehicle emission control | | Affiliation | | Origin/Income class | | |
| | | | | With Exp. | No Exp. | Gov. | Non-Gov. | Lower | Middle | Upper |
| Total valid samples | | | 188 | 108 | 80 | 67 | 121 | 31 | 89 | 68 |
| Interviewee' backgrounds | Exp. in vehicle emission control | With Exp. | 108(57%) | - | - | 23(34%) | 57(47%) | 15(48%) | 48(54%) | 18(26%) |
| | | No. Exp. | 80(43%) | - | - | 44(66%) | 64(53%) | 16(52%) | 41(46%) | 50(74%) |
| | Affiliation | Gov. | 67(36%) | 44(41%) | 23(29%) | - | - | 19(61%) | 30(34%) | 17(25%) |
| | | Non-Gov. | 121(64%) | 64(59%) | 57(71%) | - | - | 12(39%) | 59(66%) | 51(75%) |
| | Origin/Income class | Lower | 31(17%) | 16(15%) | 15(19%) | 19(28%) | 12(10%) | - | - | - |
| | | Middle | 89(47%) | 41(38%) | 48(60%) | 30(45%) | 59(49%) | - | - | - |
| | | Upper | 68(36%) | 51(47%) | 17(21%) | 18(27%) | 50(41%) | - | - | - |
| | | | Weighting Value | | | | | | | |
| Criteria | | A | 0.792 [6] | 0.775 [6] | 0.814 [6] | 0.738 [6] | 0.822 [6] | 0.977 [4] | 0.774 [6] | 0.731 [6] |
| | | B | 0.837 [5] | 0.839 [5] | 0.836 [5] | 0.849 [5] | 0.831 [5] | 0.848 [6] | 0.857 [5] | 0.807 [5] |
| | | C | **1.181** [2] | **1.172** [2] | **1.193** [2] | **1.224** [1] | **1.157** [2] | **1.272** [1] | **1.175** [2] | **1.147** [2] |
| | | D | 0.941 [4] | 0.981 [4] | 0.886 [4] | 0.913 [4] | 0.956 [3] | 0.922 [5] | 0.905 [4] | 0.996 [3] |
| | | E | 0.997 [3] | **1.021** [3] | 0.964 [3] | **1.096** [3] | 0.942 [4] | 0.995 [2] | **1.030** [3] | 0.954 [4] |
| | | F | **1.252** [1] | **1.212** [1] | **1.307** [1] | **1.181** [2] | **1.292** [1] | 0.986 [3] | **1.258** [1] | **1.366** [1] |

Note: ( ) is the percentage. [ ] is the importance order.

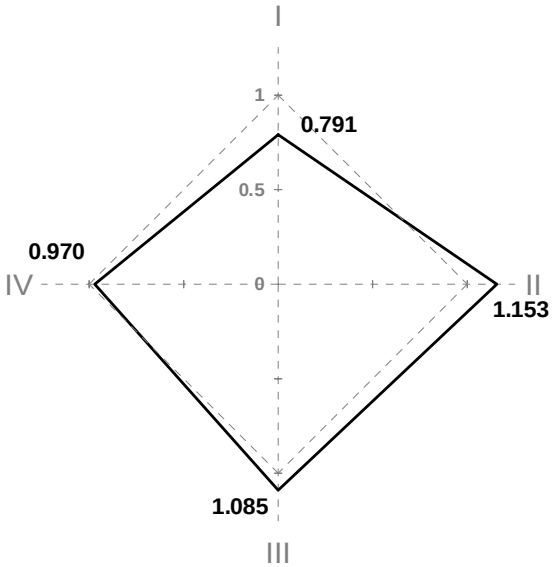
### 3.2.2 Vehicle Emission Control Strategies

Four vehicle emission control strategies were identified, which are restriction on drivers (I), modification of existing transportation system (II), introduction of alternative fuels (III) and land use planning and control (IV). These strategies can be simply classified as short, medium and long term control. Restriction on drivers (I) should be short term control measure while modification of existing transportation system (II) and introduction of alternative fuels (III) should be medium term control measure. Finally, land use planning and control (IV) would be long term control measure.

The radar graph below displayed in Figure 3.5 describes the respondents' opinions on the vehicle emission control strategies in second survey. The black line represents the overall results while the gray dash line represents the even weighting value.

It can be easily seen that modification of existing transportation system (II) was placed at the top with a relative high weighting value of 1.153. The maximum percentage difference occurred in restriction on drivers (I), which got fall of 21% with compared to the even value. Restriction on drivers was selected as the least important one. The rest of two categories, i.e. introduction of alternative fuels (III) and land use planning and control (IV), were closed to the even weighting value.

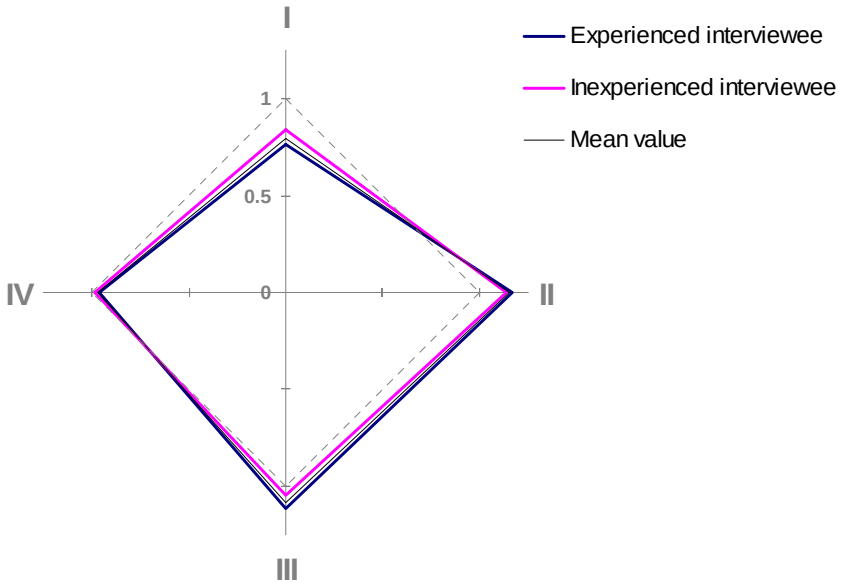
Figure 3.5 Weighting values of the control measure category from all valid samples in second survey



Same as the previous section of the policy evaluation criteria, we use the previous classification to investigate the interaction within the groups in the control strategies.

The first group is the experiences in vehicle emission control. Figure 3.6 below shows the findings of the weights of the control measure category among the respondents' experiences in vehicle emission control. According to Figure 3.6, blue represents the experienced respondents while pink represents the inexperienced respondents. General speaking, the results of the two groups were similar to the overall result. However, it is an interesting finding that the variation in significance within the category was obvious in the experienced group. Apparently, the experienced respondents placed the weights heavier in the strategies that were selected as the important one while they weighed less heavier in the category that were selected as the least important one. For examples, the most important strategy of modification of existing transportation system (II) was weighed slightly heavier in experienced group while the least important strategy of restriction on drivers (I) was weighed less heavier. This reflected that the experienced respondents had more critical thinking on vehicle emission control issue, then a rather clear variation in importance within the strategies were observed in experienced group.

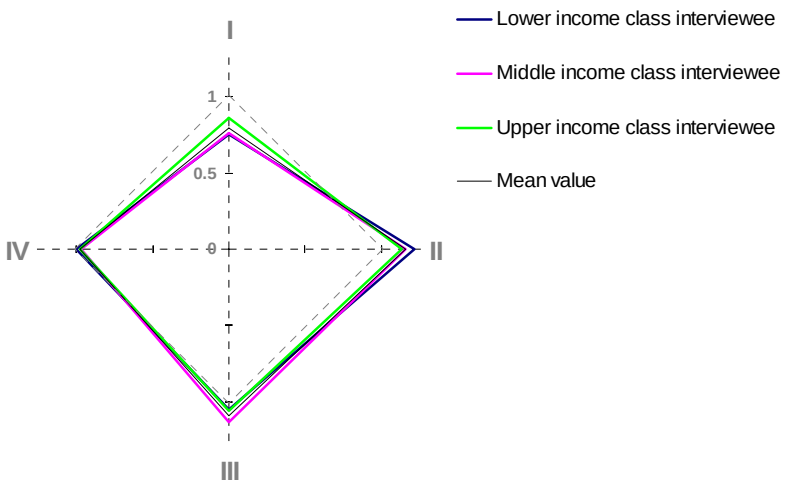
Figure 3.6 Weighting values of the control measure category among their experiences in vehicle emission control




The second group is to observe the difference within the respondents' origin. The weight results of the control measure category within various income classes are shown in Figure 3.7. The blue, pink and green radar graphs represent the lower, middle and upper income class respectively. There was not much big variations with compared to the overall results as the order of importance was exactly same, but it can be observed that special phenomenon appeared in three strategies. The phenomenon is that the weight in certain group was relatively higher than the other two groups with approximate values. Like, in restriction on drivers (I), the weights in lower and middle income class were relatively lower than upper income class. Same phenomenon was discovered in modification of existing transportation system (II) and introduction of alternative fuels (III). For the modification of existing transportation system (II), the weight in lower income class was slightly higher than

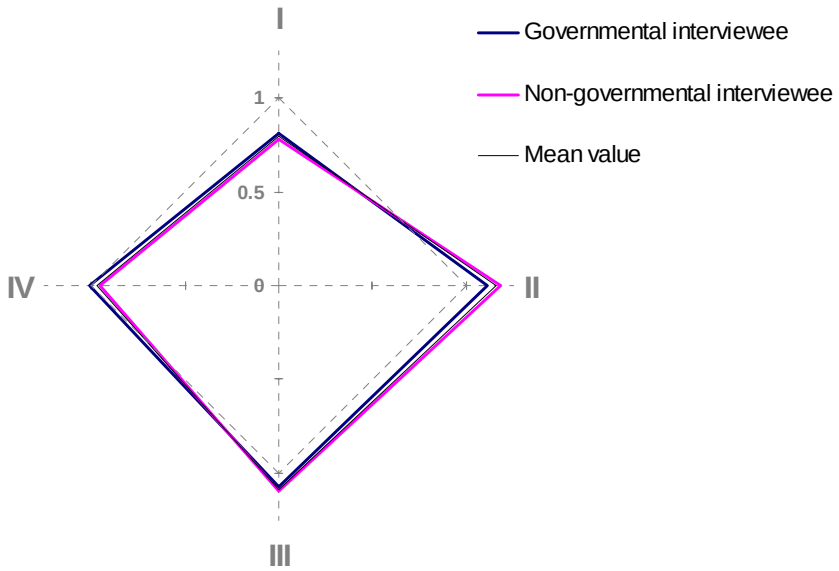
middle and upper income class. In introduction of alternative fuel, the weight was slightly higher in middle income class (III).

Figure 3.7 Weighting values of the control measure category among their origin




The third group is to observe the variation among their affiliation. The radar graphs below are Figure 3.8, which describes the results of the weighting values for the control measure category under two groups of affiliation. As is shown in Figure 3.8, blue represents the governmental interviewee while pink represents the non-governmental interviewee. In general, the order of significance was the results of non-governmental interviewee were similar to the overall results. One particular finding was observed in governmental group. The governmental group had slightly higher weighting value in land use planning and control (IV) with compared to the other groups. Regarding the findings above, the weighting value of land us planning and control (IV) were always below the even weighting value.

Figure 3.8 Weighting values of the control measure category among their affiliation




Finally, the Chi Square test was examined to strengthen the investigation. General speaking, there was no significant difference among most of the groups. The comparison of governmental and non-governmental interviewees displayed significant difference on introduction of alternative fuels (III) with a probability value of 0.0077. Else, the groups of respondents with over 5 to 10 years' experiences and respondents with over 10 years' experiences occurred significant difference on modification of existing transportation system (II) with a probability value of 0.0259.

Table 3.8 reveals the results summary of control measures category in the second survey. As is shown in Table 3.8, the weighting values in red represent those values are over the even weighting value. Else, the values highlight in yellow represent the highest while the values highlight in orange represent the lowest. Generally, the findings were consistent within the group. The respondents satisfy with the modification of existing transportation system (II) as the most important

strategy. Regarding the Chi Square test, the significant differences appeared in two strategies under the two particular groups in affiliation and experiences in vehicle emission. It implied that the behavior difference within these groups. Such difference did not influence the weights of the strategies, the overall results were fairly identical. General phenomena showed that the modification of existing transportation system (II) was the most favorite control strategies while the restriction on drivers (I) was the least favorite control strategies.

Table 3.8 Summary of the weighting values of the control measure category among different groups

| | | | Overall | Group | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Experiences in vehicle emission control | | Affiliation | | Origin/Income class | | |
| | | | | With Exp. | No Exp. | Gov. | Non-Gov. | Lower | Middle | Upper |
| Total valid samples | | | 188 | 108 | 80 | 67 | 121 | 31 | 89 | 68 |
| Interviewee' backgrounds | Exp. in vehicle emission control | With Exp. | 108(57%) | - | - | 23(34%) | 57(47%) | 15(48%) | 48(54%) | 18(26%) |
| | | No. Exp. | 80(43%) | - | - | 44(66%) | 64(53%) | 16(52%) | 41(46%) | 50(74%) |
| | Affiliation | Gov. | 67(36%) | 44(41%) | 23(29%) | - | - | 19(61%) | 30(34%) | 17(25%) |
| | | Non-Gov. | 121(64%) | 64(59%) | 57(71%) | - | - | 12(39%) | 59(66%) | 51(75%) |
| | Origin/Income class | Lower | 31(17%) | 16(15%) | 15(19%) | 19(28%) | 12(10%) | - | - | - |
| | | Middle | 89(47%) | 41(38%) | 48(60%) | 30(45%) | 59(49%) | - | - | - |
| | | Upper | 68(36%) | 51(47%) | 17(21%) | 18(27%) | 50(41%) | - | - | - |
| | | | Weighting Value | | | | | | | |
| Control Measure Category | | I | 0.791 [4] | 0.759 [4] | 0.835 [4] | 0.812 [4] | 0.780 [4] | 0.748 [4] | 0.760 [4] | 0.853 [4] |
| | | II | **1.153** [1] | **1.167** [1] | **1.135** [1] | **1.110** [1] | **1.177** [1] | **1.213** [1] | **1.155** [1] | **1.124** [1] |
| | | III | **1.085** [2] | **1.115** [2] | **1.045** [2] | **1.069** [2] | **1.094** [2] | **1.045** [2] | **1.124** [2] | **1.053** [2] |
| | | IV | 0.970 [3] | 0.959 [3] | 0.985 [3] | 1.009 [3] | 0.949 [3] | 0.994 [3] | 0.962 [3] | 0.971 [3] |

Note: ( ) is the percentage. [ ] is the importance order.

Combining all the evaluation criteria and control strategies that addressed above, an outline of assessment framework is shown in Table 3.9. $r_{s,c}$ represents the rating score of control measure regarding particular criterion while subscript $s$ and $c$ mean the strategy and criterion respectively. The total score, $S_s$, is the sum of the rating scores, i.e. $S = \sum r_{s,c}$. The higher the score is, the best the policy option is recommended.

Table 3.9 Preliminary assessment framework outline

| Strategies | Control Measures/programs | Degree of deviations from existing system (A) | Effect time (B) | Political Acceptability (C) | Administer-ability (D) | Cost of Implementation (E) | Effectiveness (F) | Total Score |
|---|---|---|---|---|---|---|---|---|
| I. Restriction on Drivers | 1. Limitation on car own | $r_{1,A}$ | $r_{1,B}$ | $r_{1,C}$ | $r_{1,D}$ | $r_{1,E}$ | $r_{1,F}$ | $S_1$ |
| | 2. Control of car use | $r_{2,A}$ | $r_{2,B}$ | $r_{2,C}$ | $r_{2,D}$ | $r_{2,E}$ | $r_{2,F}$ | $S_2$ |
| | 3. Educate the driver | $r_{3,A}$ | $r_{3,B}$ | $r_{3,C}$ | $r_{3,D}$ | $r_{3,E}$ | $r_{3,F}$ | $S_3$ |
| II. Modification of Existing Transportation System | 4. Improvement of fuel quality | $r_{4,A}$ | $r_{4,B}$ | $r_{4,C}$ | $r_{4,D}$ | $r_{4,E}$ | $r_{4,F}$ | $S_4$ |
| | 5. Promotion of cleaner fuel | $r_{5,A}$ | $r_{5,B}$ | $r_{5,C}$ | $r_{5,D}$ | $r_{5,E}$ | $r_{5,F}$ | $S_5$ |
| | 6. Vehicle technology advances | $r_{6,A}$ | $r_{6,B}$ | $r_{6,C}$ | $r_{6,D}$ | $r_{6,E}$ | $r_{6,F}$ | $S_6$ |
| | 7. Inspection and maintenance program | $r_{7,A}$ | $r_{7,B}$ | $r_{7,C}$ | $r_{7,D}$ | $r_{7,E}$ | $r_{7,F}$ | $S_7$ |
| | 8. Traffic management | $r_{8,A}$ | $r_{8,B}$ | $r_{8,C}$ | $r_{8,D}$ | $r_{8,E}$ | $r_{8,F}$ | $S_8$ |
| | 9. Strengthen regulations and enforcements | $r_{9,A}$ | $r_{9,B}$ | $r_{9,C}$ | $r_{9,D}$ | $r_{9,E}$ | $r_{9,F}$ | $S_9$ |
| III. Introduction of Alternative Fuels | 10. Infrastructure for alternative fuels | $r_{10,A}$ | $r_{10,B}$ | $r_{10,C}$ | $r_{10,D}$ | $r_{10,E}$ | $r_{10,F}$ | $S_{10}$ |
| | 11. Retrofit vehicles with alternative fuels kit | $r_{11,A}$ | $r_{11,B}$ | $r_{11,C}$ | $r_{11,D}$ | $r_{11,E}$ | $r_{11,F}$ | $S_{11}$ |
| | 12. Promotion of alternative fuels | $r_{12,A}$ | $r_{12,B}$ | $r_{12,C}$ | $r_{12,D}$ | $r_{12,E}$ | $r_{12,F}$ | $S_{12}$ |
| | 13. Purchasing alternative fuel vehicles | $r_{13,A}$ | $r_{13,B}$ | $r_{13,C}$ | $r_{13,D}$ | $r_{13,E}$ | $r_{13,F}$ | $S_{13}$ |
| IV. Land Use Planning and Control | 14. Reformation of public transports | $r_{14,A}$ | $r_{14,B}$ | $r_{14,C}$ | $r_{14,D}$ | $r_{14,E}$ | $r_{14,F}$ | $S_{14}$ |
| | 15. Use of non-motorized vehicles | $r_{15,A}$ | $r_{15,B}$ | $r_{15,C}$ | $r_{15,D}$ | $r_{15,E}$ | $r_{15,F}$ | $S_{15}$ |
| | 16. Rail system | $r_{16,A}$ | $r_{16,B}$ | $r_{16,C}$ | $r_{16,D}$ | $r_{16,E}$ | $r_{16,F}$ | $S_{16}$ |
| | 17. Re-conceptualization of town plan | $r_{17,A}$ | $r_{17,B}$ | $r_{17,C}$ | $r_{17,D}$ | $r_{17,E}$ | $r_{17,F}$ | $S_{17}$ |

The above findings reflected that the background of experts, i.e. origin and experiences in vehicle emission, influenced the results of weight and the distributional difference within group. On the basis of the above observations, the requirements of forming experts groups for this study were identified. First, the respondents who have over 5 years' experiences in vehicle emission will be selected as the expert group. Second, the respondents who came from same income class will be selected in the same expert group.

### 3.2.3 Policy Option(s)

Using the same rules which were addressed above, the data in the section C of first survey, i.e. rating questions, were separated the respondents into two major groups regarding their origin. These two expert groups were Hong Kong and China. They represent two different income classes. The former is upper income class while the latter is middle income class.

Twelve respondents were chosen as the Hong Kong's expert group in the first round survey. Most of the respondents were from the non-governmental organizations. The average experience in vehicle emission was closed to eight years and half. Table 3.8 displayed the results of rating questions in the section three of the first survey under the expert group from Hong Kong. As is shown, the bold number is the rating value of the control measure under particular criterion while the percentage below is the rating value represents how many experts selected that rating

value. It can be seen that most of the percentages were above 40% and only three of them, which were the underlined values in Table 3.10, were relatively lower.

Table 3.10 Rating results under Hong Kong's expert group

| Strategies | Control Measures/programs | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|
| I. Restriction on Drivers | 1. Limitation on car own | **1.0** 58.3% | **2.0** 58.3% | **1.0** 50.0% | **2.0** 41.7% | **3.0** 50.0% | **2.0** 50.0% |
| | 2. Control of car use | **1.0** 50.0% | **3.0** 41.7% | **1.0** 41.7% | **3.0** 41.7% | **2.0** 58.3% | **3.0** 50.0% |
| | 3. Educate the driver | **2.0** 41.7% | **1.0** 75.0% | **3.0** 58.3% | **1.0** 41.7% | **2.0** 58.3% | **1.0** 33.3% |
| II. Modification of Existing Transportation System | 4. Improvement of fuel quality | **1.0** 41.7% | **2.0** 41.7% | **3.0** 50.0% | **2.0** 58.3% | **1.0** 41.7% | **3.0** 66.7% |
| | 5. Promotion of cleaner fuel | **1.0** 41.7% | **1.0** 50.0% | **2.0** 58.3% | **2.0** 50.0% | **3.0** 41.7% | **3.0** 66.7% |
| | 6. Vehicle technology advances | **2.0** 41.7% | **2.0** 41.7% | **2.0** 50.0% | **2.0** 50.0% | **2.0** 50.0% | **3.0** 58.3% |
| | 7. Inspection and maintenance program | **2.0** 58.3% | **2.0** 58.3% | **2.0** 58.3% | **2.0** 50.0% | **1.0** 50.0% | **3.0** 66.7% |
| | 8. Traffic management | **2.0** 50.0% | **2.0** 58.3% | **2.0** 66.7% | **2.0** 58.3% | **2.0** 75.0% | **2.0** 58.3% |
| | 9. Strengthen regulations and enforcements | **2.0** 83.3% | **2.0** 58.3% | **2.0** 50.0% | **2.0** 83.3% | **3.0** 41.7% | **3.0** 50.0% |
| III. Introduction of Alternative Fuels | 10. Infrastructure for alternative fuels | **1.0** 66.7% | **1.0** 75.0% | **1.0** 50.0% | **1.0** 58.3% | **1.0** 58.3% | **2.0** 58.3% |
| | 11. Retrofit vehicles with alternative fuels kit | **1.0** 58.3% | **1.0** 41.7% | **2.0** 66.7% | **1.0** 50.0% | **2.0** 41.7% | **2.0** 58.3% |
| | 12. Promotion of alternative fuels | **1.0** 50.0% | **1.0** 50.0% | **2.0** 50.0% | **2.0** 58.3% | **2.0** 50.0% | **2.0** 50.0% |
| | 13. Purchasing alternative fuel vehicles | **2.0** 58.3% | **2.0** 66.7% | **2.0** 50.0% | **2.0** 50.0% | **2.0** 58.3% | **1.0** 50.0% |
| IV. Land Use Planning and Control | 14. Reformation of public transports | **1.0** 58.3% | **1.0** 58.3% | **1.0** 66.7% | **2.0** 50.0% | **1.0** 58.3% | **3.0** 50.0% |
| | 15. Use of non-motorized vehicles | **1.0** 50.0% | **3.0** 41.7% | **2.0** 58.3% | **2.0** 50.0% | **3.0** 50.0% | **2.0** 41.7% |
| | 16. Rail system | **2.0** 41.7% | **1.0** 50.0% | **1.0** 33.3% | **3.0** 33.3% | **1.0** 50.0% | **3.0** 58.3% |
| | 17. Re-conceptualization of town plan | **2.0** 75.0% | **2.0** 41.7% | **1.0** 58.3% | **1.0** 66.7% | **2.0** 41.7% | **3.0** 58.3% |

Note: Bold letter: rating value of control measures;
%: percentage of experts that selected the specified rating values.

Regarding to the matrix equation Eq.4 in Chapter 2, the performance scores were calculated as follows.

$$[\text{Rating Matrix}]\times[\text{Identical Weight Matrix}] = [\text{Score Matrix}]$$

$$\begin{bmatrix} 1 & 2 & 1 & 2 & 3 & 2 \\ 1 & 3 & 1 & 3 & 2 & 3 \\ 2 & 1 & 3 & 1 & 2 & 1 \\ 1 & 2 & 3 & 2 & 1 & 3 \\ 1 & 1 & 2 & 2 & 3 & 3 \\ 2 & 2 & 2 & 2 & 2 & 3 \\ 2 & 2 & 2 & 2 & 1 & 3 \\ 2 & 2 & 2 & 2 & 2 & 2 \\ 2 & 2 & 2 & 2 & 3 & 3 \\ 1 & 1 & 1 & 1 & 1 & 2 \\ 1 & 1 & 2 & 1 & 2 & 2 \\ 1 & 1 & 2 & 2 & 2 & 2 \\ 2 & 2 & 2 & 2 & 2 & 1 \\ 1 & 1 & 1 & 2 & 1 & 3 \\ 1 & 3 & 2 & 2 & 3 & 2 \\ 2 & 1 & 1 & 3 & 1 & 3 \\ 2 & 2 & 1 & 1 & 2 & 2 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 11 \\ 13 \\ 10 \\ 12 \\ 12 \\ 13 \\ 12 \\ 12 \\ 14 \\ 7 \\ 9 \\ 10 \\ 11 \\ 9 \\ 13 \\ 11 \\ 11 \end{bmatrix}$$ and

$$[\text{Rating Matrix}]\times[\text{Calculated Weight Matrix}] = [\text{Score Matrix}]$$

$$\begin{bmatrix} 1 & 2 & 1 & 2 & 3 & 2 \\ 1 & 3 & 1 & 3 & 2 & 3 \\ 2 & 1 & 3 & 1 & 2 & 1 \\ 1 & 2 & 3 & 2 & 1 & 3 \\ 1 & 1 & 2 & 2 & 3 & 3 \\ 2 & 2 & 2 & 2 & 2 & 3 \\ 2 & 2 & 2 & 2 & 1 & 3 \\ 2 & 2 & 2 & 2 & 2 & 2 \\ 2 & 2 & 2 & 2 & 3 & 3 \\ 1 & 1 & 1 & 1 & 1 & 2 \\ 1 & 1 & 2 & 1 & 2 & 2 \\ 1 & 1 & 2 & 2 & 2 & 2 \\ 2 & 2 & 2 & 2 & 2 & 1 \\ 1 & 1 & 1 & 2 & 1 & 3 \\ 1 & 3 & 2 & 2 & 3 & 2 \\ 2 & 1 & 1 & 3 & 1 & 3 \\ 2 & 2 & 1 & 1 & 2 & 2 \end{bmatrix} \begin{bmatrix} 0.82 \\ 0.85 \\ 1.10 \\ 1.02 \\ 0.98 \\ 1.23 \end{bmatrix} = \begin{bmatrix} 11.09 \\ 13.16 \\ 10.03 \\ 12.46 \\ 12.50 \\ 13.18 \\ 12.18 \\ 12.00 \\ 14.19 \\ 7.18 \\ 9.29 \\ 10.31 \\ 10.82 \\ 9.39 \\ 13.06 \\ 11.22 \\ 11.06 \end{bmatrix}$$

From above matrices, the left hand side was calculated while the criteria's weights are identical. The right hand side was calculated while the criteria are weighed, which weights were from the results in section two of the second survey. It can be observed that the differences between these two sets of scores were insignificant, however the duplicated scores were reduced after multiplied a weighting coefficient. The priority of policy option can clearly be recognized. Table 3.11 displays the scores and their corresponding rank of the control measures. As is shown, the bold number in red are the top five of the control measures. Under the conditions of identical weights, it can be seen that there were more duplicated score appeared. However, after the weighting coefficients were multiplied, no more consistent score occurred. Whatever multiplied by the identical or differential weights, the top five measures were under the strategy's categories of restriction on drivers (I), modification of existing transportation system (II) and land use planning and control (IV). Else, the top five were more or less among same control measures, but differentiated between the ranks. From the modified scores, the control measures of strengthen regulations and enforcements (9), vehicle technology advances (6) and promotion of cleaner fuel (5) were the top one, two and five respectively. These three measures were under same strategy, i.e. modification of existing transportation system (II). The top three and four were control of car use (2) and use of non-motorized vehicles (15). They were under the strategies of restriction on drivers (I) and land use planning and control (IV) respectively.

Table 3.11 Summary of scores and their corresponding rank under Hong Kong's expert group

| Strategies | Control Measures/Programs | Multiple by Identical Weights | | Multiple by Calculated Weights | |
|---|---|---|---|---|---|
| | | Score | Rank | Rank | Score |
| I Restriction on Divers | 1. Limitation on car own | 11 | 9 | 10 | 11.09 |
| | 2. Control of car use | 13 | **2** | **3** | 13.16 |
| | 3. Educate the driver | 10 | 13 | 14 | 10.03 |
| II Modification of Existing transportation System | 4. Improvement of fuel quality | 12 | **5** | 6 | 12.46 |
| | 5. Promotion of cleaner fuel | 12 | **5** | **5** | 12.50 |
| | 6. Vehicle technology advances | 13 | **2** | **2** | 13.18 |
| | 7. Inspection and maintenance program | 12 | **5** | 7 | 12.18 |
| | 8. Traffic management | 12 | **5** | 8 | 12.00 |
| | 9. Strengthen regulations and enforcements | 14 | **1** | **1** | 14.19 |
| III Introduction of alternative Fuels | 10. Infrastructure for alternative fuels | 7 | 17 | 17 | 7.18 |
| | 11. Retrofit vehicles with alternative fuels kit | 9 | 15 | 16 | 9.29 |
| | 12. Promotion of alternative fuels | 10 | 13 | 13 | 10.31 |
| | 13. Purchasing alternative fuel vehicles | 11 | 9 | 12 | 10.82 |
| IV Land Use Planning and Control | 14. Reformation of public transports | 9 | 15 | 15 | 9.39 |
| | 15. Use of non-motorized vehicles | 13 | **2** | **4** | 13.06 |
| | 16. Rail system | 11 | 9 | 9 | 11.22 |
| | 17. Re-conceptualization of town plan | 11 | 9 | 11 | 11.06 |

Eleven respondents were chosen as the China's expert group. Almost half of the respondents were from the governmental organizations. The average experience in vehicle emission was almost 13 years, which was slightly more than the Hong Kong's expert group. Table 3.12 displayed the results of rating questions in the section three of the first survey under the expert group from China. The bold number is the rating value of the control measure under particular criterion while the percentage below the rating value represents how many experts selected that rating value. Most of the percentages were above 40% and about 12.7% of the rating values, which were the underlined values in Table 3.12, were below 40%.

Table 3.12 Rating results under China's expert group

| Strategies | Control Measures/programs | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|
| I. Restriction on Drivers | 1. Limitation on car own | **1.0** 36.4% | **3.0** 36.4% | **1.0** 54.5% | **1.0** 36.4% | **3.0** 72.7% | **1.0** 45.5% |
| | 2. Control of car use | **1.0** 45.5% | **1.0** 45.5% | **1.0** 45.5% | **2.0** 36.4% | **3.0** 54.5% | **3.0** 45.5% |
| | 3. Educate the driver | **2.0** 45.5% | **1.0** 72.7% | **3.0** 54.5% | **2.0** 63.6% | **2.0** 36.4% | **2.0** 45.5% |
| II. Modification of Existing Transportation System | 4. Improvement of fuel quality | **1.0** 54.5% | **1.0** 54.5% | **3.0** 54.5% | **2.0** 45.5% | **1.0** 72.7% | **3.0** 54.5% |
| | 5. Promotion of cleaner fuel | **3.0** 45.5% | **1.0** 45.5% | **3.0** 54.5% | **1.0** 36.4% | **1.0** 45.5% | **3.0** 36.4% |
| | 6. Vehicle technology advances | **1.0** 45.5% | **1.0** 63.6% | **3.0** 54.5% | **1.0** 45.5% | **3.0** 36.4% | **3.0** 63.6% |
| | 7. Inspection and maintenance program | **1.0** 63.6% | **1.0** 72.7% | **3.0** 36.4% | **1.0** 63.6% | **2.0** 45.5% | **3.0** 72.7% |
| | 8. Traffic management | **2.0** 72.7% | **1.0** 45.5% | **2.0** 54.5% | **2.0** 72.7% | **2.0** 54.5% | **2.0** 63.6% |
| | 9. Strengthen regulations and enforcements | **2.0** 45.5% | **1.0** 45.5% | **1.0** 45.5% | **2.0** 54.5% | **2.0** 54.5% | **2.0** 54.5% |
| III. Introduction of Alternative Fuels | 10. Infrastructure for alternative fuels | **1.0** 45.5% | **1.0** 45.5% | **1.0** 54.5% | **1.0** 54.5% | **1.0** 81.8% | **2.0** 45.5% |
| | 11. Retrofit vehicles with alternative fuels kit | **2.0** 45.5% | **2.0** 63.6% | **2.0** 45.5% | **2.0** 54.5% | **2.0** 54.5% | **2.0** 54.5% |
| | 12. Promotion of alternative fuels | **3.0** 45.5% | **3.0** 45.5% | **2.0** 63.6% | **2.0** 54.5% | **1.0** 45.5% | **2.0** 54.5% |
| | 13. Purchasing alternative fuel vehicles | **1.0** 54.5% | **3.0** 54.5% | **2.0** 45.5% | **1.0** 45.5% | **1.0** 36.4% | **3.0** 45.5% |
| IV. Land Use Planning and Control | 14. Reformation of public transports | **2.0** 45.5% | **2.0** 45.5% | **1.0** 45.5% | **1.0** 72.7% | **1.0** 54.5% | **3.0** 54.5% |
| | 15. Use of non-motorized vehicles | **3.0** 45.5% | **2.0** 36.4% | **3.0** 36.4% | **2.0** 45.5% | **3.0** 54.5% | **3.0** 54.5% |
| | 16. Rail system | **3.0** 45.5% | **2.0** 54.5% | **2.0** 45.5% | **2.0** 72.7% | **1.0** 54.5% | **3.0** 72.7% |
| | 17. Re-conceptualization of town plan | **2.0** 36.4% | **2.0** 54.5% | **2.0** 45.5% | **2.0** 54.5% | **3.0** 36.4% | **2.0** 54.5% |

Note: Bold letter: rating value of control measures;
%: percentage of experts that selected the specified rating values.

The performance scores for each control measures were calculated regarding to the matrix equation that was discussed in pervious chapter, which is shown as follows. From below matrices, the left hand side was calculated with identical weights while the right hand side was worked out by multiplying the calculated weights, which weights were from the results in section two of the second survey. It can be seen the variations between these two sets of scores were insignificant. Once again the duplicated scores were reduced after multiplied a weighting coefficient. The best policy option was clearly recommended.

$$[\text{Rating Matrix}]\times[\text{Identical Weight Matrix}] = [\text{Score Matrix}]$$

$$\begin{bmatrix} 1 & 3 & 1 & 1 & 3 & 1 \\ 1 & 1 & 1 & 2 & 3 & 3 \\ 2 & 1 & 3 & 2 & 2 & 2 \\ 1 & 1 & 3 & 2 & 1 & 3 \\ 3 & 1 & 3 & 1 & 1 & 3 \\ 1 & 1 & 3 & 1 & 3 & 3 \\ 1 & 1 & 3 & 1 & 2 & 3 \\ 2 & 1 & 2 & 2 & 2 & 2 \\ 2 & 1 & 1 & 2 & 2 & 2 \\ 1 & 1 & 1 & 1 & 1 & 2 \\ 2 & 2 & 2 & 2 & 2 & 2 \\ 3 & 3 & 2 & 2 & 1 & 2 \\ 1 & 3 & 2 & 1 & 1 & 3 \\ 2 & 2 & 1 & 1 & 1 & 3 \\ 3 & 2 & 3 & 2 & 3 & 3 \\ 3 & 2 & 2 & 2 & 1 & 3 \\ 2 & 2 & 2 & 2 & 3 & 2 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 10 \\ 11 \\ 12 \\ 11 \\ 12 \\ 12 \\ 11 \\ 11 \\ 10 \\ 7 \\ 12 \\ 13 \\ 11 \\ 10 \\ 16 \\ 13 \\ 13 \end{bmatrix} \text{ and}$$

$$[\text{Rating Matrix}]\times[\text{Calculated Weight Matrix}] = [\text{Score Matrix}]$$

$$\begin{bmatrix} 1 & 3 & 1 & 1 & 3 & 1 \\ 1 & 1 & 1 & 2 & 3 & 3 \\ 2 & 1 & 3 & 2 & 2 & 2 \\ 1 & 1 & 3 & 2 & 1 & 3 \\ 3 & 1 & 3 & 1 & 1 & 3 \\ 1 & 1 & 3 & 1 & 3 & 3 \\ 1 & 1 & 3 & 1 & 2 & 3 \\ 2 & 1 & 2 & 2 & 2 & 2 \\ 2 & 1 & 1 & 2 & 2 & 2 \\ 1 & 1 & 1 & 1 & 1 & 2 \\ 2 & 2 & 2 & 2 & 2 & 2 \\ 3 & 3 & 2 & 2 & 1 & 2 \\ 1 & 3 & 2 & 1 & 1 & 3 \\ 2 & 2 & 1 & 1 & 1 & 3 \\ 3 & 2 & 3 & 2 & 3 & 3 \\ 3 & 2 & 2 & 2 & 1 & 3 \\ 2 & 2 & 2 & 2 & 3 & 2 \end{bmatrix} \begin{bmatrix} 0.64 \\ 0.77 \\ 1.27 \\ 1.16 \\ 1.12 \\ 1.03 \end{bmatrix} = \begin{bmatrix} 9.78 \\ 11.47 \\ 12.51 \\ 11.78 \\ 11.89 \\ 12.86 \\ 11.74 \\ 11.23 \\ 9.96 \\ 7.03 \\ 12.00 \\ 12.29 \\ 10.88 \\ 9.47 \\ 16.07 \\ 12.55 \\ 13.12 \end{bmatrix}$$

Table 3.13 displays the scores and their corresponding rank of the control measures for China expert's group. As is shown, the bold numbers with red present the best five control measures. Without concerning the calculated weights, there were more than five control measures in top five, which was similar to the Hong Kong expert group. The duplicated scores appeared if the weighting coefficients were not taken into account. After the calculated weights were considered, the best five control measures were more easily to be recognized. In accordance with their ascendancy, the best five control measure were use of non-motorized vehicle (15), re-conceptualization of town plan (17), vehicle technology advances (6), rail system (8) and educate the drivers (3).

Table 3.13 Summary of scores and their corresponding rank under China's expert group

| Strategies | Control Measures/Programs | Multiple by Identical Weights | | Multiple by Calculated Weights | |
|---|---|---|---|---|---|
| | | Score | Rank | Rank | Score |
| I Restriction on Divers | 1. Limitation on car own | 10 | 14 | 15 | 9.81 |
| | 2. Control of car use | 11 | 9 | 11 | 11.65 |
| | 3. Educate the driver | 12 | **5** | **5** | 12.41 |
| II Modification of Existing transportation System | 4. Improvement of fuel quality | 11 | 9 | 10 | 11.71 |
| | 5. Promotion of cleaner fuel | 12 | **5** | 7 | 12.03 |
| | 6. Vehicle technology advances | 12 | **5** | **3** | 12.92 |
| | 7. Inspection and maintenance program | 11 | 9 | 9 | 11.78 |
| | 8. Traffic management | 11 | 9 | 12 | 11.24 |
| | 9. Strengthen regulations and enforcements | 10 | 14 | 14 | 10.06 |
| III Introduction of alternative Fuels | 10. Infrastructure for alternative fuels | 7 | 17 | 17 | 7.14 |
| | 11. Retrofit vehicles with alternative fuels kit | 12 | **5** | 8 | 12.00 |
| | 12. Promotion of alternative fuels | 13 | **2** | 6 | 12.32 |
| | 13. Purchasing alternative fuel vehicles | 11 | 9 | 13 | 10.98 |
| IV Land Use Planning and Control | 14. Reformation of public transports | 10 | 14 | 16 | 9.75 |
| | 15. Use of non-motorized vehicles | 16 | **1** | **1** | 16.16 |
| | 16. Rail system | 13 | **2** | **4** | 12.70 |
| | 17. Re-conceptualization of town plan | 13 | **2** | **2** | 13.14 |

# CHAPTER 4.0 DISCUSSIONS

This chapter presents the discussions of the study. It begins with the appropriateness of the assessment framework elements, then follows by addressing the findings from questionnaires survey and finally goes through the limitations in this study.

## 4.1 Appropriateness of the Assessment Framework Elements

Six evaluation criteria are proposed, namely degree of deviations from existing system (A), effect time (B), political acceptability (C), administer-ability (D), cost of implementation (E) and effectiveness (F). In order to examine the appropriateness of selected criteria, Keeney and Raiffa (1993) recommended four requirements. Tzeng et al. (2002) and Lahdelma et al. (2000) also cited these requirements after the evaluation criteria were finalized. These requirements are (I) completeness, (II) operational feasibility, (III) nonredundancy and (IV) minimum size. Completeness means all the important points of view of problem are covered. Operational feasibility means the set of criteria can be measured and used meaningfully. Nonredundancy means two or more criteria should not measure the same thing. Minimum size means the dimension of problem should be kept to a minimum.

The defined evaluation criteria comply with the completeness requirement because they cover the aspects of concerns relating to the implementation of

strategies and control measures in this study. The requirement of operational feasibility is addressed by the criteria of effectiveness, cost of implementation and effect time. However, the other criteria of political acceptability, administer-ability and degree of deviations from existing system are not easy to be quantified. Although not all the evaluation criteria are measurable quantities, these criteria can be graded on a discrete scale. As such, our criteria can be still considered operational. Furthermore, we reckon that our proposed six evaluation criteria meet both the nonredundancy and minimum size requirements. There is no contradictory criterion being selected while the number of criterion is reasonable.

## 4.2 Design of the Questionnaire Surveys

The design of the questionnaire surveys is the important part of this assessment framework, as it influences the validity of the gathered data. The questionnaire surveys were selected to conduct in workshop and conference because it is anticipated the participation involved experienced respondents who have rich knowledge on vehicle emission control. Since the data collection process replied on workshop and conference, such constraint became a significant limitation in this assessment exercise. However, without forming a proper expert panel, conducting questionnaires survey in such workshop and international conference is the alternative way to form the expert panel indirectly.

The aims of the questionnaire surveys are to collect information on the importance of evaluation criteria and control measure. However, the first survey was unsuccessful to collect valid data due to the respondents overlooked or

misunderstood the introduction on the questionnaire sheets. The answering method provided on the survey sheet misled the respondents to fill in invalid data. Such reflected that the format of the survey sheet acts an imperative role in data collection. Thus, getting the unsuccess experiences in the first survey, the questionnaire sheets were modified in second survey, meantime student helpers were employed, so that the respondents completed the questionnaire sheet under a proper supervision that helps obtaining more valid data in second survey. As mentioned above, the data collection process just relied on workshop and conference, the opportunity that I can participate the workshop and conference and conduct questionnaire survey is limited. Because of such constraint, conducting 2 rounds of survey in a year tend to be a maximum. Thus, the iteration process cannot be conducted in this study. However, if the first survey was successful, it was anticipated that the iteration process should be proceeded accordingly in second round of survey. It is suggest adopting an alternative way to undergo the data collection, like sending questionnaire sheets through post to particular respondents, however the amount should be substantial since the reply from respondents shall be decreased gradually over rounds, else invalid data might be increased. Thus, it is questioned either obtaining more valid data with less rounds or obtaining more invalid data with more rounds. Apparently, it is preferable to obtain more valid results instead of invalid results, so conducting questionnaire survey in workshop and conference do have its own advantage and obtain more valid results. For long time consideration, the questionnaire survey exercise can conduct in some particular workshop and conference as an annual basis and aims at reviewing the latest picture on vehicle emission control strategies.

## 4.3 Discussions of Findings

### 4.3.1 Weight Values of the Assessment Framework Elements

Generally speaking, in accordance with its importance, the ascending order is effectiveness (F), political acceptability (C), cost of implementation (E), administer-ability (D), effect time (B) and degree of deviations from existing system (A). For the control strategies, the ascending order is modification of existing transportation system (II), introduction of alternative fuel (III), land use planning and control (IV) and restriction on drivers (I) regarding the favorite of the respondents.

As it is mentioned above, the six criteria could be simply divided into three levels in accordance with the surveys' findings. Each level involves two evaluation criteria. The first level is effectiveness (F) and political acceptability (C), the second level is cost of implementation (E) and administer-ability (D) and the third level is effect time (B) and degree of deviations form existing system (A). Different prospective can be observed regarding the findings that will be discussed as follow.

The first level contains the two most important criteria, i.e. effectiveness (F) and political acceptability (C). Among the experts' groups with different background, the effectiveness and political acceptability were always the highest two. In overall, the effectiveness is known as the most important criteria. Such the effectiveness becomes more and more crucial concern while implementing vehicle emission control strategies. It is not a surprising result since many people are currently suffering the pollutants from motor vehicles, especially in well-developed and

developing cities. The phenomenon is observed from the findings, which shows that the weight of the effectiveness is descending regarding their income class. It is meant that the upper income class respondents weighed the effectiveness higher than the middle income class respondents and middle was higher than lower income class. In the country that defined as upper income class, such as Hong Kong, most of the people rely on motor vehicles as the main daily transportation. In the western country, such as United States and Canada, most of the people own at least one car in a family. It is easy to recognize that those countries at upper income class have substantial demands on car use. Meantime, they are seriously suffering large amounts of air pollutants from vehicles. In the middle income class country, such as China and India, they are currently expanding their economy and the transportation plays a crucial role in economic development. This leads to rapid increase in the growth of vehicles usage. Consequently, they begin experiencing the worsening vehicular pollution problem. On the other hand, the experts from lower income country selected political acceptability as the highest one. They seem to pay more attention on the political acceptability than effectiveness. It is possibly because the vehicular pollution was not seriously deteriorating like the current problems in the upper and middle income class country, so that they rather pay more attention on political acceptability instead, which leads the effectiveness became less important in lower income country.

In accordance with their experiences in vehicle emission control, another phenomenon can be discovered that the respondents who had more experiences weighed the effectiveness slightly higher than the respondents who had less experience. The weight of effectiveness was inversely proportional to the year of the experiences. One possible explanation is that the experienced experts recognize some

control measures might reduce the vehicle emission effectively, but the whole implementation process might contain many difficulties and uncertainties which are not easy to tackle, for example lack of public support would be a problem. It can be observed that the experienced experts shift their awareness to the other evaluation criteria such as political acceptability. If the experts who are with more experiences, then it was observed that the weighed values of effectiveness and political acceptability got closed to each other, indeed the weight value of political acceptability was over the effectiveness and became the most important evaluation criteria. Similar observation also appeared among the group of affiliation. Once again, the political acceptability was selected as the highest one under the governmental group. On the contrary, the non-governmental concerned the effectiveness more than political acceptability. It is easily recognized that the public willingness always plays a major role in implementation processes whatever the policies and strategies are. Without the public supports, policies and strategies are hard to achieve a success even though those policies and strategies can tackle the concerning problem effectively. It is also the same reason for why experienced respondents selected political acceptability as the top one. The experienced respondents also realized that the public willingness is one of crucial factors that help showing the way to success. That leads the political acceptability prevailed over the effectiveness under some conditions.

The intermediate level comprises the criteria of the cost of implementation (E) and administer-ability (D). They were selected as the less important criteria compared with the effectiveness and political acceptability under most of the conditions. The evidence showed that the country income influenced the weight of

cost of implementation. The findings reflected that the middle income country would put significant concerns on implementation cost. It is because the middle income countries like China and India are rapidly developing their economy so that their government administrations could consider carefully about the use of the annual expenses. Similar situation also appeared in lower income class country. They strain to develop their economic system, so they cannot afford heavy expenses in vehicle emission controls. Seemingly, it is not easy to achieve a great harmonization between economic development and pollution deterioration at present situation. The aspects from the higher income class are contrary to the lower and middle income classes. Most of higher income countries are well-developed, they possess a stable financial condition which allows affording costly yet effective control strategies. Like Hong Kong has been facing the deterioration of street-level pollution because of over relying on motor vehicles as daily transportation. To tackle the emissions from vehicles, the government administration spent millions on control vehicular emission programs, such as providing financial incentives to the drivers to replace their commercial use vehicles with cleaner fueled vehicles. They tend to spend more money to control emission due to there is a raising awareness that air pollutants pose a significant harmful to health. Meanwhile the government can strengthen their competitiveness and reputation from urban air quality improvement so as to attract more business sectors that select Hong Kong as their base as well as enhancing tourism.

In accordance with their working background, which means the experts are either belonging to governmental or non-governmental organizations, the findings show that the experts who worked with the government placed a relatively higher

rate on the criteria of cost of implementation than the non-governmental experts. It is consistence with the experts from lower and middle income class countries. The governmental sides concern the manipulation of the spendable expenses. This might be because the vehicular emission is not the only issue in the policy agenda, there still contains imperative problems that require to be solved and more expenditure could possibly require. It is reasonable to make sure the goals of spending certain amount of expense in accordance with the policy agenda.

The lower level contains the criteria of the effect time (B) and degree of deviations from existing system (A). They were recognized as the least important two within these six criteria in the questionnaire survey. The findings indicate that the experienced experts, the governmental experts, the experts from middle and upper income class put a significant lower rate on the criteria of degree of deviations from existing system. It is not surprising since these two criteria are not easy to reach a satisfactory level. Currently, several advanced technology can reduce the emissions from vehicles with great effectiveness, however not easy to fit with the existing infrastructures. Cleaner alternative fueled vehicle is a good example. Compared with the diesel and gasoline fueled vehicle, the alternative fueled vehicle, such as natural gas and hybrid, emits relatively low content of polluted emissions. To promote the use of alternative fueled vehicle successfully, a well-developed infrastructure, for instances, filling stations and maintenance services, is strongly needed. In this case, the current system will require more changes as well as long time will be offered. It is sensible that these two criteria were situated at the lower level among these six criteria.

The weight results in control strategies were fairly gentle. It seems that all the experts have similar perspectives on vehicle emission control strategies. One reason for this consistence is a general tendency around the world. Every year, there are many different kinds of conferences being held around the world, particularly for the issues of air pollution due to the raising awareness on the issues of climate change and human health. The experts and government administrations continue sharing and contributing the knowledge and technique with each other to tackle the air pollution. They therefore build up a similar conceptualization in controlling vehicle emission.

The findings in the evaluation criteria prove that the background of the experts significantly influenced the weights of evaluation criteria. One of typical examples is the group of the experts from lower income class country. It was mentioned in Chapter 3 that it was decided to select a particular group of expert and use their opinions to obtain the performance scores of the strategies. Ultimately, two experts' groups were selected, including Hong Kong and China, as examples.

Table 4.1 presents the weight values from the study of Tzeng at el. (2002) and the weight values from this study. The study of Tzeng et al. (2002) was to review the air quality improvement strategies in Taipei through multicriteria analysis, which looked similar to this study. Their evaluation criteria were identified by environmental protection experts, government authorities, academic research groups and local residents. Their seven criteria in their study include implementation cost, cooperation of government administration, existing legal acts, social equity, acceptance by non-polluters, acceptance by polluters and amelioration of air quality. Some of similar evaluation criteria were used in both studies. It can be seen that the

criterion of effectiveness and political acceptability are similar to their criterion of amelioration of air quality and cooperation of government administration, else the term of implementation cost is exactly the same. The terms of effectiveness and political acceptability are also located at a similar position among the set of criteria, which confirm the findings that are fairly reasonable in this study.

Table 4.1 Comparison of the weight values between the study of Taipei air quality and current study

| The study of Tzeng at el. (2002) | | This study | | | |
|---|---|---|---|---|---|
| Criteria | Values of criteria weight | Criteria | Values of criteria weight | | |
| | Taiwan | | Overall | China | Hong Kong |
| Implementation cost | 0.07 [6] | Cost of implementation | 0.997 [3] | 1.12 [2] | 0.98 [4] |
| Cooperation of government administration | 0.164 [2] | Political acceptability | 1.181 [2] | 1.27 [1] | 1.1 [2] |
| Existing legal acts | 0.157 [3] | | | | |
| Social equity | 0.119 [4] | | | | |
| Acceptance by non-polluters | 0.108 [5] | | | | |
| Acceptance by polluters | 0.062 [7] | | | | |
| Amelioration of air quality | 0.32 [1] | Effectiveness | 1.252 [1] | 1.03 [3] | 1.23 [1] |
| | | Effect time | 0.837 [5] | 0.77 [5] | 0.85 [5] |
| | | Administer-ability | 0.941 [4] | 1.16 [2] | 1.02 [3] |
| | | Degree of deviations from existing system | 0.792 [6] | 0.64 [6] | 0.82 [6] |

Note: [] represent its corresponding rank among the set of criteria.

### 4.3.2 Policy Option(s)

Two performance priority lists for the seventeen control strategies were obtained in the last section of Chapter 3. The performance assessments present reasonable outcomes in these two examples, Hong Kong and China. Hong Kong is one of the examples representing the higher income class while China is one of the examples representing the middle income class.

In the results, two sets of performance scores were presented. One was considering as identical weight of the evaluation criteria while the other was considering with the weighed values. Although the deviations with the performance scores are insignificant, the ranking/priority was much easier to recognize after multiplied a weighed factors. Regarding the results from respondents, it proved that the assumption of varied weight/importance of the evaluation criteria is correct. It will have different consideration on the evaluation criteria while policy implementation or determination regarding the existing situation of the country or city. Taking consideration of the weights of the evaluation criteria is necessary, which allow forming the implementation priority with ease.

Most of the prior policy options for Hong Kong are under the category of modification of existing transportation system. It is fairly satisfied with the current situation in Hong Kong. This is because some of control measures are not easy to be implemented, for instances, introduction of alternative fuels. If substantial changes involve, it is not easy to be accepted by the public and large amount of investment will be required, then this will increase the difficulties in implementation processes.

This evidence can be seen from the findings since the category of introduction of alternative fuels was neglected by the experts from Hong Kong.

Several control measures under the category of modification of existing transportation system have been emphasized in the assessment results, like the control measure of strengthen regulations and enforcements. Being one of leading megacity in Asia, the vehicle emission standard and regulation in Hong Kong is far away behind Tokyo and Singapore. In recent year, not much control programs were related to regulations and enforcements, such evidence reflected from the assessment findings and the expert panel pointed out that action from government administrations is a need. Other control measure of vehicle technology advances was also raised out from the findings. Several major implemented or on-going programs related to vehicle technology advances were the subsidy scheme to assist retrofitting particulate reduction devices in pre-Euro diesel vehicles (i.e. diesel vehicles that was first registered before the implementation of the Euro I emission standards) of permitted gross vehicle weight up to four tones, the incentive scheme to encourage early replacement of old diesel commercial vehicles with new commercial vehicles and the tax incentives for environmentally friendly cars. The results reflected that such programs are not sufficient to satisfy the need of reducing vehicle emission vehicle, the government administrations are offered to provide more attractive financial incentives programs to the drivers, especially the commercial drivers. In fact, the control measures of strengthen regulations and enforcements and vehicle technology advances could be implemented simultaneously and gently, so as to mutually offset their deficiency. Thus, the modification of existing transportation system would be the prior policy option for Hong Kong to tackle the vehicle

emissions. These findings are contrary with the policy option outcome from the expert panel of China. Most of the prior policy options for China are under the category of land use planning and control. China is the third biggest country in the world. Since there are plenty of lands that have not yet been developed in China, it is easy to establish conceptualization of town planning in undeveloped area. This can benefit on the plan of transportation system so as to minimize the effect of vehicle emissions to public health. So far the transportation system has not been yet developed to a comprehensive level, not many actions for modification can be taken. Now, government administrations of China intend to put more considerations on land use planning and control in order to provide a better living environment to citizen. They keep expanding the rail system with contemplating carefully concerns on the land use. The government administrations keep promoting efficient use of resources as well as optimizing environment protection to ensure sustainable economic development.

## 4.4 Limitations

There are several limitations to this study that restrict the generalization of its results. First is how to define the framework elements in systematic manner. Not much study presented the methodology on how to identify their evaluation criteria. It seems that most of the identification processes for evaluation criteria are fairly subjective, such situation is also occurred in selecting the vehicle emission control strategies. In this study, the key framework elements, i.e. evaluation criteria and control strategies, were selected on the basis of literatures. It is suggested to determine these two framework elements through conducting another questionnaire surveys in a wider spectrum of surveyed subjects, which means not limiting the respondents participated to experts only and increase the public participation. In fact, public participation are the global trends, the extension of the survey subjects to the general public may provide a more completed picture of developing evaluation criteria and control strategies.

Second is how to collect the opinions from experts in more reliable way. Normal practice for Delphi method is to invite the experts to form an expert panel, but it is difficult to gather a group of professional experts without any substantial powers. To gather the opinions from experts in a simpler way, it was decided to conduct questionnaire surveys in workshop and conference. Regarding the received responses, the expert panel can be specified. As it was replied on workshop and conferences to gather opinions, the consequence was insufficient time to conduct more questionnaire surveys to verify the results, so as to go forward to the step of

iteration as mentioned in Delphi method and further investigate the consistency. From the first survey, it was recognized that the design of questionnaires sheets leaded to serious deviations with the expectation. Thus, invalid results were received and the opportunity of conducting iteration in second surveys was sacrificed to remedy the deviations occurred in first survey. It is anticipated that the iteration procedure can advance the whole idea of assessment framework and obtain more reliable results.

The third limitation is how to ensure the data reliability while conducting questionnaires survey. Learning the experiences from first survey, it is not easy to control the data reliability unless the clear indication is provided on the survey sheets as well as filling the survey sheet under a proper supervision, which can be able to minimize the occurrence of unreliability. Apparently, the respondents in the second survey were filling the survey sheets under supervision, thus the number of invalid sample was relatively lesser.

The forth limitation is the comparison of the weight values between the first and second surveys. Since there were substantial amount of invalid samples in the first surveys, the comparison of the weight value between the two surveys can be able to examine. It is anticipated that conducting more rounds of surveys allow refining the weight value to more reliable results.

The fifth limitation is without the benefit of knowing the larger political and institutional contexts, the respondents would probably refer to some unstated assumptions in stating their opinions regarding some generic categories. However,

the fact that each respondent might have referenced some unstated assumptions in answering the questions could result in a major validity problem with the data gathered. Thus, this assessment exercise did not complete with all respondents results. Though the Chi Square test, it was anticipated to specific the expert panels from the questionnaire surveys and ensure the quality of the expert panel and its reliability. Such test aided in working out the qualified respondents to form the expert panel. This test checked the significance among their experiences in vehicle emission control. It was found that over five years of experiences are separation point, thus the respondent with over 5 years of experiences in vehicle emission control was defined as expert. Though this step, it was anticipated that the validity problem with the data gathered could be reduced.

# CHAPTER 5.0 SUMMARY, IMPLICATIONS AND FURTHER STUDIES

## 5.1 Findings of the Dissertation

There are various kinds of evaluation methods being commonly used for policy analysis, but they are time-consuming, complicated and incomprehensive. It was questioned whether any time-saving yet unsophisticated assessment methods in assisting the policy determinations in a comprehensive manner. This study was an attempt to construct a assessment framework for vehicle emission control strategies. It helps speeding up the decision-making process as well as drawing a clear picture on the priority of implementation so as to minimize the probability of adopting improper control strategies. The concept of proposed assessment framework is simple, i.e. define the framework elements that are criteria and strategies, then assess the performance of strategies regarding the criteria and finally obtain the policy option(s). First, two key framework elements have been identified, comprising six policy evaluation criteria and seventeen common vehicle emission control strategies under four major categories. The importance of those framework elements has been examined through the questionnaire surveys. The surveys were conducted in vehicle emission control workshop and conference. The findings obtained suggest that the

ascending order of the importance of the evaluation criteria is the effectiveness (F), political acceptability (C), cost of implementation (E), administer-ability (D), effect time (B) and degree of deviations from existing system (A) in general speaking. The data provide evidence that the six evaluation criteria can be considered as three levels regarding the background of respondents. The first level contains the effectiveness (F) and political acceptability (C), the second level comprises the cost of implementation (E) and administer-ability (D), the third level includes the effect time (B) and degree of deviations of existing system (F).The ascending order of the favorite of the control strategies is the modification of existing transportation system (I), introduction of alternative fuels (II), land use planning and control (IV) and restriction on drivers (I) under all circumstances. Regarding the ascending order of importance/favorite, the weight values for the framework elements were established. The evidences show that the background of respondents influenced the weight value. To enhance the accuracy of the performance assessment for the control strategies, a particular group of data from experts was selected. On the basis of the data availability, the group of experts from Hong Kong and China were selected. It was recommended that the prior policy options for Hong Kong are under the control category of the modification of existing transportation system (II) while the prior policy options for China are under the control category of the land use planning and control (IV). The recommended policy options fairly satisfied with the current situation in Hong Kong and China regarding the empirical evidence in controlling vehicle emission.

## 5.2 Implications of the Findings

One of the key implications from this study is the selection of the group of experts. The data provide evidence that five years of experience in vehicle emissions is the separation point of the group. While forming a proper expert panel or selecting an expert group from surveys, it is suggested that the respondents with over five years of experience in vehicle emission would be a proper selection for the expert panel. This information would be useful while conducting another round of questionnaire survey. It could be targeted at the respondents who have over 5 years of experience in vehicle emission. The respondents came from which income class is another concern in selecting the expert group. It is related to cultural and financial context of the country. In fact, the findings obtained suggest that there were significant differences between the respondents from governmental and non-governmental organizations. Yet to cover the aspects from non-governmental experts, it can help enhancing the acceptability of community. Such obtains a wider spectrum of surveyed subjects and provides a more completed picture for vehicles emission control strategies. In addition, the findings of performance assessment of control strategies suggest approximate scores among the control strategies. This implies the design of the questionnaire survey would possibly influence the accuracy of results, like the scale of the rating value. It is proposed that the scale of the rating value can adopt 5 instead of 3, such can maintain the scale of the rating value not being too difficult to determine and diminish the duplicate of performance scores.

## 5.3 Further Studies Needs

Additional research is recommended to confirm the findings of this study. It would be suggested that a proper expert panel to be formed in order to obtain a more accurate and reliable policy option for controlling vehicle emission. The experts, who will be invited, should have at least five years of experiences in vehicle emission control. If the expert panel can be formed, the policy option can be reviewed and updated in an annual basis.

It was mentioned that it is subjective on defining evaluation criteria. Additional work could be done on defining proper evaluation criteria is to conduct qualitative survey with experts, for instance, face-to-face interview with professional experts is good method. It means having discussion with the experts individually to gather their aspects in the selection of evaluation criteria while selecting vehicle emission control strategies.

Perhaps further studies can be conducted in reviewing the policy instrumentation. This can allow the whole idea of the proposed assessment framework become more comprehensive. The aim of reviewing the use of policy instrumentation is to suggest the proper way in implementation after the best policy options are obtain.

# APPENDIX

Examples of measures implemented in the 14 Asian cities.

Table A1 Examples of implemented control measures/strategies in China, Beijing

| Levels | Measures | References |
|---|---|---|
| I-2 | Old vehicles are enforced to have retirement.<br>Pass inspecting stations have been set up to inspect all non-local vehicles. | (Beijing Environmental Protection Bureau, 2003) |
| II-6 | Beijing has conducted a large campaign to retrofit older vehicles with three-way catalyst. | (Shao & Zhang, 2001) |
| III-9 | CNG filling stations have been established to promote CNG vehicles. | (Yang, 2002) |
| III-10 | In-use vehicles have been retrofitted to use LPG or CNG.<br>About one third of the bus fleet was run by CNG engines in Beijing of 2001. | (Beijing Environmental Protection Bureau, 2003)<br>(Yang, 2002) |
| IV-14 | The subway in Beijing has been expanded since 1965. | (Beijing Subway, 2004) |

Table A2 Examples of implemented control measures/strategies in China, Guangzhou

| Levels | Measures | References |
|---|---|---|
| I-1 | The licenses of motorcycle in urban area have been restricted to reduce traffic accident and emissions. | (Zhang, 2001) |
| I-2 | A regulation that accelerates the scrap page and replacement of older vehicles has been in effect since 1986. Passenger cars and minivans are limited to 12 years of service and motorcycles must be removed from the road after 15 years. | (Shao & Zhang, 2001) |
| II-6 | Motorcycles are enforced to be installed with the low pollution carburetor or catalyst converter.<br>Certain in-use vehicles have been required to be retrofitted with catalytic converters. | (Zhang, 2001)<br>(Shao & Zhang, 2001) |
| III-9 | The government has established LPG stations for the use of LPG public transports. | (He & Zhang, 2000) |
| III-10 | Over 3000 buses and taxies have been retrofitted to use LPG. | (He & Zhang, 2000) |
| IV-14 | The Guangzhou metro rail system has been expanded since 1993. | (Guangzhou Metro Light Rail System, China, 2004) |

Table A3 Examples of implemented control measures/strategies in China, Hong Kong

| Levels | Measures | References |
|---|---|---|
| I-1 | The government has imposed first registration taxes to restrict the vehicle ownership. | (Rusco & Walls, 1995) |
| I-2 | Regulatory controls on idling vehicles and enforcement on "switching off engine while waiting" have been executed. | (Environmental Protection Department, 2004) |
| I-3 | The Environmental Protection Department has been offering training sessions for vehicle mechanics on proper engine repair and maintenance to reduce smoke emissions from diesel vehicles. "Switching off engines while waiting" campaign has been promoted and guidelines have been issued to the transport trade. | (Environmental Protection Department, 2004) |
| II-5 | Ultra low sulfur diesel (ULSD) is the only motor diesel fuel available at petrol filling stations after the Government introduced a concessionary duty on ULSD in July 2000. | (Environmental Protection Department, 2004) |
| II-6 | Pre-Euro light diesel vehicles are enforced to be retrofitted with particulate traps or catalytic converters. | (Environmental Protection Department, 2004) |
| II-8 | Intelligent Transport Systems have been developed for efficient traffic management. | (Intelligent Transportation Systems Hong Kong, 2005) |
| III-9 | LPG filling stations have been built for the LPG vehicles. | (Environmental Protection Department, 2004) |
| III-11 | Diesel taxis have switched to LPG and diesel light buses have been replaced with LPG or electric ones. | (Environmental Protection Department, 2004) |
| IV-12 | Bus routes and stops have been rationalized to enhance bus efficiency. Bus-bus interchange schemes and better bus-rail coordination are introduced to improve the bus network and relieve congestion problem. | (Li, 2000) |
| IV-13 | Pedestrian scheme are introduced to improve the overall pedestrian environment and to promote walking as a transport mode | (Li, 2000) |
| IV-14 | There are three rail systems in Hong Kong. | (Transport Department, HKSARG, 2005) |

Table A4 Examples of implemented control measures/strategies in India, Delhi

| Levels | Measures | References |
|---|---|---|
| I-2 | Strict enforcement has been imposed on restricting on plying of goods vehicles during the day time. Old commercial/transport vehicles have been phased out, only non-commercial vehicle complying with EURO-II Norms have been registered. | (Transport Department, Government of Delhi 2004) |
| I-3 | It is mandatory for all vehicle owners to have their vehicles with Pollution Under Control Certification. | (Transport Department, Government of Delhi 2004) |
| II-5 | Leaded gasoline and unleaded gasoline have been sold at the same price during the switchover period. | (Gupta, 2001) |
| II-6 | Post-1990 autos and taxis have been replaced with new vehicles on clean fuel with financial incentives. Since 1995, only 4-wheeled petrol driven vehicles have been registered on first sale in Delhi with catalytic converters. | (Transport Department, Government of Delhi 2004) |
| II-8 | Traffic signals have been synchronized with the establishment of area traffic control and central control room for diversion of traffic based on air quality monitoring data. Halting time at major traffic intersections is displayed for better traffic control. Road bye-pass and express ways have been constructed. | (Ministry of Environment & Forests, 2003) |
| III-9 | CNG supply outlets have been expanded to meet the demand. | (Transport Department, Government of Delhi 2004) |
| III-11 | Entire city bus fleet has been converted to single fuel mode on CNG | (Transport Department, Government of Delhi 2004) |
| IV-12 | The government has augmented public transport with buses. | (Transport Department, Government of Delhi 2004) |
| IV-13 | Bicycle tracks have been provided to promote cycling. | (Ministry of Environment & Forests, 2003) |
| IV-14 | Mass rapid transport system is being constructed. | (Ministry of Environment & Forests, 2003) |

Table A5 Examples of implemented control measures/strategies in Indonesia, Jakarta

| Levels | Measures | References |
|---|---|---|
| I-2 | Since 1990, restricted areas for private cars with a minimum of three passengers during morning peak hours have been implemented. | (The Partnership for Clean Emission, 2002) |
| I-3 | A publicity campaign has been used to encourage people awareness and increase public participation on the Clean Air Programme. The activities are emission test for private cars under the I&M Programme and dissemination information through all media. | (Aboeprajitno, 2001) |
| II-5 | The government excluded unleaded gasoline from any increase in the price of fuel to increase the attractiveness of unleaded gasoline.. | (Aboeprajitno, 2001) |
| III-9 | There are limited fueling stations for alternative fuels which restrain the increase in the use of LPG and CNG vehicles.. | (The Partnership for Clean Emission, 2002) |
| III-10 | Buses use gas fuel, taxis and official car of local governments are equipped with liquid natural gas or compressed natural gas fuel converters. | (Aboeprajitno, 2001) |
| IV-12 | The government has promoted the use of public transportation by expanding and improving public transport and parking facilities | (The Partnership for Clean Emission, 2002) |
| IV-13 | The use of non-motorized transport has been encouraged by designing non-motorized transport facilities along the bus rapid transit route and formulating policies. | (The Partnership for Clean Emission, 2002) |

Table A6 Examples of implemented control measures/strategies in Japan, Tokyo

| Levels | Measures | References |
|---|---|---|
| I-1 | The government has imposed various motor vehicle taxes and high gasoline taxes to minimize the car ownership. | (The World Bank, 2000) |
| I-2 | The government has limited the automobile use through imposing strict parking-space requirement, promoting of parking lot management and road pricing system. | (The World Bank, 2000; Tokyo Metropolitan Government, 2003) |
| I-3 | Direct mails are sent to individuals to ensure awareness of the diesel vehicle emissions control regulations. Stickers are affixed to vehicles with PM reduction system for easy supervision. | (Tokyo Metropolitan Government, 2003) |
| II-5 | Preferential car tax and discount parking fee system for low-emission vehicles have been established. | (Tokyo Metropolitan Government, 2003) |
| II-6 | The government has solicited cooperation of diesel vehicle makers for the promotion of diesel vehicle replacement purchases and increase in the supply of oxidation catalysts. Loan program was provided to vehicle owners for the replacement of vehicles. | (Tokyo Metropolitan Government, 2003) |
| | The government has requested automobile makers and control device manufacturers for the increase in supply of PM devices. Subsidies were provided for installation of PM devices in business and private sectors. | (Hirabayashi, 2002) |
| II-8 | The government has made intelligent transportation systems even more sophisticated for the control of traffic volume. | (Tokyo Metropolitan Government, 2003) |
| III-9 | Financial support was provided from the government for installation of CNG fueling stations. A hydrogen pumping station was set up in 2002 as the base for fuel cell vehicle driving tests. | (Tokyo Metropolitan Government, 2003) |
| III-11 | Assistance was provided to regular route bus operators to cover their expense for CNG vehicles. Businesses using 200 vehicles or more are restricted to use low-pollution vehicles accounting for more than 5%. | (Tokyo Metropolitan Government, 2003) |
| IV-12 | Park and ride program and convenience transfer have been enhanced for the promotion of a shift from use of vehicles. | (Tokyo Metropolitan Government, 2003) |
| IV-13 | The use of bicycles has been widely spread for the shift from use of vehicles. Non-motorized vehicles have been extensively used for short trips. | (The World Bank, 2000; Tokyo Metropolitan Government, 2003) |
| IV-14 | Rails have been 41% of the trips made in Tokyo. | (The World Bank, 2000) |
| IV-15 | The rail system in Tokyo has been improved with various kinds of development and redevelopment activities around rail stations including land readjustment and urban redevelopment. | (The World Bank, 2000) |

Table A7 Examples of implemented control measures/strategies in Korea, Seoul

| Levels | Measures | References |
|---|---|---|
| I-1 | The government has imposed a number of car ownership and user taxes to alleviate congestion and encourage saving and restricting luxury imtems in the country. | (The World Bank, 2000) |
| I-2 | The government has promoted "Stop Idling" at the special area including parking, terminal stations. | (Park, 2002) |
| | Limited access roads and parking restrictions have been enforced. A system in use is one where the use of private vehicles is discouraged on certain days of the month based on the license plate number. | (Hwang, 2001) |
| I-3 | The public-private coalition campaign has successfully reduced the automobile usage. Green car certification has been introduced to both used-vehicles and new-models meeting emission standards which bring a reduction in vehicle emissions. | (Hwang, 2001) |
| II-5 | The government has implemented energy tax reform to discourage the use of diesel fuel. | (Park, 2002) |
| II-6 | The government has provided fiscal support for the installation of PM reduction devices. | (Park, 2002) |
| II-8 | The government focuses on building more urban freeways and bridges. Local streets and arterial will be redesigned for both access traffic-friendly and pedestrian-friendly streets. | (Hwang, 2001) |
| III-9 | CNG stations were established in parallel with the promotion of CNGVs. | (Park, 2002) |
| III-11 | Seoul introduced 2000 CNG buses by 2003 and subsidized trucks (above 8 ton) to be operated with CNG (60 million won per truck) and trucks (under 8 ton) to be operated with LPG (6 million won per truck). | (Park, 2002) |
| IV-12 | The public bus system has been reformed and bus lanes have been designed. | (Hwang, 2001) |
| IV-13 | Pedestrian-friendly streets and bicycle-only streets were designed to improve pedestrian environment and reduce traffic accidents. | (Hwang, 2001) |
| IV-14 | There are two urban rail systems in Seoul: subways and urban rails. | (Hwang, 2001) |

Table A8 Examples of implemented control measures/strategies in Malaysia, Kuala Lumpur

| Levels | Measures | References |
|---|---|---|
| I-2 | Car-pooling is implemented in Kuala Lumpur, which is defined as those who drive to work with at least 1 passenger. | (Ab Rahman, 1997) |
| II-6 | Catalytic converters were installed on new vehicles to meet the stipulated emission limits in Malaysia. | (Ishak, 2001a) |
| II-8 | Broad arteries in Kuala Lumpur tempt drivers into driving fast between intersections. | (Fjellstrom, 2002) |
| III-9 | NGV refueling outlets have been set up to serve the vehicles. | (Ishak, 2001a) |
| III-10 | The government provides exemption on the import duty and sales tax on the conversion kits | (Ishak, 2001a) |
| III-11 | Road tax reduction scheme for mono-gas vehicles and bi-fuel or dual-fuel vehicles | (Ishak, 2001a) |
| | Vehicles (mostly taxis) have been converted to run on-bi-fuel mode and mono-gas. | |
| IV-14 | Light rail metro system has been established in Kuala Lumpur to alleviate the heavy traffic since 1999. | (Kuala Lumpur Light Tail Driverless Metro System, Malaysia, 2004) |

Table A9 Examples of implemented control measures/strategies in Nepal, Kathmandu

| Levels | Measures | References |
|---|---|---|
| I-2 | In 1991, the government stopped the import of three-wheelers into the valley. | (Shrestha & Raut, 2002) |
| | The government has banned the registration of new two stroke engine vehicles. Parking fee system has been introduced since 1995. The movements of trucks and tractors during peak traffic time have been prohibited on congested roads. The government has banned the movement of vehicles older than twenty years and all three wheelers and two stroke engines since 2001. | (Jha, 2001) |
| I-3 | The government has its own FM station and TV programme for the general public to create awareness on urban environment and other issues of concern. | (Shrestha & Raut, 2002) |
| II-8 | The government is involved in the construction of overhead crossing bridge, subway, traffic intersections and road widening. | (Shrestha & Raut, 2002) |
| | Automatic signaling at several crossroads and one-way traffic have been introduced. | (Jha, 2001) |
| III-9 | Electric charging stations have been established for the industry of electric vehicles in Nepal. | (Clean Energy Nepal, 2003) |
| III-10 | Conversion diesel operated three wheeler vehicles into electric battery or LPG operated vehicles was introduced since 1994. | (Jha, 2001) |
| III-11 | Electric vehicles were introduced in Kathmandu in 1975. | (Clean Energy Nepal, 2003) |
| IV-12 | The main public transport organization (Sajha Yatayat) for passenger movement was established in 1961 under the Japanese grant. A 13 km Trolley bus service (through Nepal Transport Corporation) was developed in 1975 in Kathmandu valley with the Chinese assistance. | (Jha, 2001) |
| IV-13 | The government has prepared a separate bicycle lane inline with its aim to prepare a large bicycle lane network in the city. | (Shrestha & Raut, 2002) |

Table A10 Examples of implemented control measures/strategies in Philippines, Manila

| Levels | Measures | References |
|---|---|---|
| I-2 | A traffic regulation that prohibits vehicles from being used on specific policy days depending on the last digit of their license plates. | (Metropolitan Manila (Philippines, 2002) |
| I-3 | Anti-smoke belching program was set up for law (Clean Air Act) enforcement. | (Philippines Land Transportation Office, 2002) |
| II-5 | Unleaded gasoline was sold at a price lower than leaded gasoline. | (Larssen et al., 1997) |
| III-9 | LPG/CNG filling stations are available in Manila. | (LPG-CNG Workshop, 2002) |
| III-11 | CNG buses were supplied from China. | (Environmental News Network, 2005) |
| IV-12 | With the assistance of World Bank, interchanges between and among buses, jeepneys. LRT lines have been improved to manage traffic congestion. | (The World Bank, 2000) |
| IV-13 | Pedestrian and bicycle paths have been constructed for low-income class. | (The World Bank, 2000) |
| IV-14 | Light transit system has been operated since 1984. | (The World Bank, 2000) |

Table A11 Examples of implemented control measures/strategies in Singapore

| Levels | Measures | References |
|---|---|---|
| I-1 | In 1972, the government restrained the vehicle growth by increasing import duties, annual road tax and additional registration fee. Since 1990, the Government has imposed vehicle quota system to further tighten the vehicle growth. | (The World Bank, 2000), (Tan, 2001) |
| I-2 | The use of private motor vehicles in Singapore has been restrained by the Area License Scheme and Electronic Road Pricing. | (The World Bank, 2000) |
| I-3 | The government educates the vehicle owners on proper vehicle maintenance and holds meetings with vehicle fleet owners, association and school and bus owners. | (Tan, 2001) |
| II-6 | All petrol driven vehicles registered between 1994 -2001 were required to be fitted with catalytic converters. | (National Environment Agency, 2003) |
| II-8 | An Automatic Network Travel Time System and closed circuit television system at critical junctions have been introduced to monitor traffic flow. A computerized traffic signal system has been operated to monitor traffic volume at intersections and coordinate lights. | (Kahaner, 1996) |
| III-9 | CNG refilling stations will be set up on the main island in Singapore to facilitate the promotion of green vehicles. | (Ministry of the Environment and Water Resources, 2006) |
| III-11 | The government will conduct a pilot project to convert in-use commercial diesel vehicles to run on CNG and to encourage and facilitate the government agencies to use green vehicles. | (Ministry of the Environment and Water Resources, 2006) |
| IV-12 | The number of covered linkways from bus stops and interchanges to housing estates is increasing for the promotion of public transports.<br>In 1973, the bus groups merged into a single national company for better management. | (Ministry of the Environment and Water Resources, 2006)<br>(The World Bank, 2000) |
| IV-13 | Singapore has implemented a range of mobility management measures, including pederstrianized streets, widened and attractive newly-paved walkways, tree-planting for shade and a “smart bike” program providing free bicycle use. | (Breithauph, 2003) |
| IV-14 | Mass Rapid Transit System was completed in 1990 for the urban renewal programs. | (The World Bank, 2000) |
| IV-15 | The 1971 Ring Plan established the basis for new towns containing high-density housing, industrial sites, and urban centers in a ring around the urban core and interconnected by an efficient MRT network. | (The World Bank, 2000) |

Table A12 Examples of implemented control measures/strategies in Taiwan, Taipei

| Levels | Measures | References |
|---|---|---|
| I-2 | Prohibited large trucks and tractor-trailers from certain routes and areas at certain times. Motorcycle-only lanes or motorcycle prohibition areas are implemented on special sections. | (Wang, 2004) |
| I-3 | The government has organized campaigns to promote strategies controlling diesel-fuelled car exhaust emission and to promote the examination system for vehicle inspections. | (Wang, 2004) |
| II-5 | Unleaded gasoline has been supplied since 1988, which is sold at price lower than leaded gasoline to encourage the use. | (Fang & Chen, ,1996) |
| II-6 | With the support of the air pollution prevention and control fund, buses in Taipei have installed smoke filters and catalytic converters. | (Wang, 2004) |
| II-8 | The computer signal system facilitates efficient traffic flow by regulating intersections via signal optimization. | (Wang, 2004) |
| III-9 | Electric charging stations were established for the electric motorcycles | (Wang, 2004) |
| III-11 | In 1996, the EPA promoted LPG vehicles by granting an allowance to LPG taxi drivers. Bureau of Transportation has been implementing the natural gas buses with the support of the air pollution prevention and control fee. The government has promoted low-pollution vehicles including electric motorcycles, electric bicycles, LPG cars, CNG buses and those automobiles powered by alternative fuels. | (Wang, 2004) |
| IV-12 | Bus lanes and preference lanes have been introduced in Taipei. Transfer and shuttle between MRT system and buses have been implemented. | (Wang, 2004) |
| IV-13 | Pedestrian-only lanes are implemented on partial sections | (Wang, 2004) |
| IV-14 | The existing metro lines largely relieve pressure on the highways, in which the first line was opened at 1992. | (The World Bank, 2000) |
| IV-15 | Government of Taipei city will strive to create a quality system of public transport with comprehensive network of roads, parking space and pedestrian walkways. It also aims at redevelopment city sub-centers with multifunctional urban space. | (The World Bank, 2000) |

Table A13 Examples of implemented control measures/strategies in Thailand, Bangkok

| Levels | Measures | References |
|---|---|---|
| I-2 | The government has imposed Parking restriction on major streets and automatic area traffic control. | (Srisurapanon & Wanichapun, 2001) |
| II-5 | To promote the use of unleaded gasoline, it has been made to be less expensive than leaded gasoline. | (Wangwongwatana & Warapetcharayut, 2001) |
| II-6 | Controls of CO and NOx from gasoline vehicles are performed through the use of catalytic converters | (Srisurapanon & Wanichapun, 2001) |
| II-8 | Extension of road network and expressway | (Srisurapanon & Wanichapun, 2001) |
| III-9 | NGV refueling stations have been expanded along the existing gas pipeline routes. | (Eamrungroj 2000) |
| III-10 | NGV has been introduced with the financial support from New Zealand Government in converting 5 public buses to be dual-fuel mode together with providing 6 sets of conversion kits and cylinders. | (Eamrungroj 2000) |
| III-11 | NGV buses have been purchased and operated in Bangkok. Petroleum authority of Thailand has been using its efforts to intensively promote the expansion of natural gas engine to use natural gas as an alternative fuel in transportation sector in forms of dedicated NGVs, bi-fuel vehicles and diesel dual fuel vehicles. | (Eamrungroj 2000) |
| IV-12 | Bus system has been reformed with bus lanes and reversible lanes. | (Srisurapanon & Wanichapun, 2001) |
| IV-14 | There are two mass rapid transit systems in Bangkok: elevated sky-train system and a subway system | (Srisurapanon & Wanichapun, 2001) |

Table A14 Examples of implemented control measures/strategies in Vietnam, Ho Chi Minh City

| Levels | Measures | References |
|---|---|---|
| I-2 | All new vehicles manufactured locally or imported should be required to conform to the emission control regulation. | (Duc, 1999) |
| I-3 | Public awareness through mass media and holding seminars and conference would be carried out. | (Multi-sectoral Action Plan Group, 2002) |
| II-5 | Petrol companies have received subsidies from government. | (Multi-sectoral Action Plan Group, 2002) |
| II-8 | Road widening and private build-operate-transfer schemes have been taken to reduce congestion and improve traffic flow. | (Duc, 1999) |
| III-9 | LPG filling stations will be established in Ho Chi Minh City. | (Multi-sectoral Action Plan Group, 2002) |
| III-11 | The taxis in Ho Chi Minh City will run on the LPG. | (Multi-sectoral Action Plan Group, 2002) |
| IV-12 | The taxiing services have been increased and the bus services have been expanded to encourage the use of public transport. | (Duc, 1999) |

Table A15 Chi Square test of Criteria A to F between groups of experiences (0 year) and (>0 year)

| Criteria | A | B | C | D | E | F | |
|---|---|---|---|---|---|---|---|
| Degree of freedom (df) | | 5 | 5 | 5 | 5 | 5 | 5 |
| Chi Square ($\chi^2$) | | 2.80 | 5.50 | 1.37 | 5.90 | 1.82 | 3.68 |
| t-value (t) | | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 |
| p-value (P) | | 0.73 | 0.36 | 0.93 | 0.32 | 0.87 | 0.60 |

Table A16 Chi Square test of Criteria A to F between groups of experiences (0 year) and (>0-5 years)

| Criteria | A | B | C | D | E | F | |
|---|---|---|---|---|---|---|---|
| Degree of freedom (df) | | 5 | 5 | 5 | 5 | 5 | 5 |
| Chi Square ($\chi^2$) | | 3.57 | 3.61 | 0.67 | 3.70 | 1.29 | 5.20 |
| t-value (t) | | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 |
| p-value (P) | | 0.61 | 0.61 | 0.98 | 0.59 | 0.94 | 0.39 |

Table A17 Chi Square test of Criteria A to F between groups of experiences (0 year) and (>5 years)

| Criteria | A | B | C | D | E | F | |
|---|---|---|---|---|---|---|---|
| Degree of freedom (df) | | 5 | 5 | 5 | 5 | 5 | 5 |
| Chi Square ($\chi^2$) | | 3.18 | 4.81 | 4.03 | 6.96 | 4.73 | 5.86 |
| t-value (t) | | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 |
| p-value (P) | | 0.67 | 0.44 | 0.54 | 0.22 | 0.45 | 0.32 |

Table A18 Chi Square test of Criteria A to F between groups of experiences (>0-5) and (>5) years

| Criteria | A | B | C | D | E | F | |
|---|---|---|---|---|---|---|---|
| Degree of freedom (df) | | 5 | 5 | 5 | 5 | 5 | 5 |
| Chi Square ($\chi^2$) | | 5.13 | 1.69 | 4.02 | 1.45 | 5.01 | 10.49 |
| t-value (t) | | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 |
| p-value (P) | | 0.40 | 0.89 | 0.55 | 0.92 | 0.41 | 0.06 |

Table A19 Chi Square test of Criteria A to F between groups of experiences (>0-2) and (>2-5) years

| Criteria | A | B | C | D | E | F | |
|---|---|---|---|---|---|---|---|
| Degree of freedom (df) | | 5 | 5 | 5 | 5 | 5 | 5 |
| Chi Square ($X^2$) | | 11.13 | 6.19 | 4.53 | 3.87 | 2.58 | 5.81 |
| t-value (t) | | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 |
| p-value (P) | | 0.05 | 0.29 | 0.48 | 0.57 | 0.76 | 0.32 |

Table A20 Chi Square test of Criteria A to F between groups of experiences (>5-10) and (>10) years

| Criteria | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Degree of freedom (df) | 5 | 5 | 5 | 5 | 5 | 5 |
| Chi Square ($\chi^2$) | 2.24 | 4.92 | 3.56 | 6.61 | 10.81 | 1.87 |
| t-value (t) | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 |
| p-value (P) | 0.82 | 0.43 | 0.61 | 0.25 | 0.06 | 0.87 |

Table A21 Chi Square test of Criteria A to F between groups of experiences (>2-5) and (>5-10) years

| Criteria | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Degree of freedom (df) | 5 | 5 | 5 | 5 | 5 | 5 |
| Chi Square ($X^2$) | 12.37 | 4.02 | 2.91 | 3.57 | 4.12 | 6.86 |
| t-value (t) | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 |
| p-value (P) | 0.03 | 0.55 | 0.71 | 0.61 | 0.53 | 0.23 |

Table A22 Chi Square test of Criteria A to F between groups of experiences (0 year) and (>10 years)

| Criteria | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Degree of freedom (df) | 5 | 5 | 5 | 5 | 5 | 5 |
| Chi Square ($X^2$) | 2.62 | 1.98 | 4.53 | 7.86 | 8.01 | 5.26 |
| t-value (t) | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 |
| p-value (P) | 0.76 | 0.85 | 0.48 | 0.16 | 0.16 | 0.38 |

Table A23 Chi Square test of Criteria A to F between groups of experiences (>2-5) and (>10) years

| Criteria | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Degree of freedom (df) | 5 | 5 | 5 | 5 | 5 | 5 |
| Chi Square ($\chi^2$) | 6.03 | 1.91 | 4.56 | 5.14 | 6.79 | 12.49 |
| t-value (t) | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 |
| p-value (P) | 0.30 | 0.86 | 0.47 | 0.40 | 0.24 | 0.03 |

Table A24 Chi Square test of Criteria A to F between government and non-government group

| Criteria | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Degree of freedom (df) | 5 | 5 | 5 | 5 | 5 | 5 |
| Chi Square ($X^2$) | 6.58 | 4.41 | 5.51 | 6.45 | 8.97 | 8.39 |
| t-value (t) | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 |
| p-value (P) | 0.25 | 0.49 | 0.36 | 0.26 | 0.11 | 0.14 |

Table A25 Chi Square test of Criteria A to F between cities of lower and middle income class

| Criteria | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Degree of freedom (df) | 5 | 5 | 5 | 5 | 5 | 5 |
| Chi Square ($X^2$) | 8.11 | 4.17 | 2.67 | 3.65 | 4.01 | 9.97 |
| t-value (t) | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 |
| p-value (P) | 0.15 | 0.53 | 0.75 | 0.60 | 0.55 | 0.08 |

Table A26 Chi Square test of Criteria A to F between cities of lower and upper income class

| Criteria | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Degree of freedom (df) | 5 | 5 | 5 | 5 | 5 | 5 |
| Chi Square ($X^2$) | 6.21 | 6.55 | 4.45 | 5.91 | 6.67 | 16.84 |
| t-value (t) | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 |
| p-value (P) | 0.29 | 0.26 | 0.49 | 0.31 | 0.25 | 0.00 |

Table A27 Chi Square test of Criteria A to F between cities of middle and upper income class

| Criteria | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Degree of freedom (df) | 5 | 5 | 5 | 5 | 5 | 5 |
| Chi Square ($X^2$) | 7.10 | 2.22 | 3.15 | 5.21 | 6.21 | 2.86 |
| t-value (t) | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 |
| p-value (P) | 0.21 | 0.82 | 0.68 | 0.39 | 0.29 | 0.72 |

Table A28 Chi Square test of Control Measures I to IV between groups of experiences (0 year) and (>0 year)

| Control Measures | I | II | III | IV |
|---|---|---|---|---|
| Degree of freedom (df) | 3 | 3 | 3 | 3 |
| Chi Square ($\chi^2$) | 2.91 | 2.42 | 4.21 | 0.64 |
| t-value (t) | 7.8 | 7.8 | 7.8 | 7.8 |
| p-value (P) | 0.41 | 0.49 | 0.24 | 0.89 |

Table A29 Chi Square test of Control Measures I to IV between groups of experiences (0 year) and (>0-5 years)

| Control Measures | I | II | III | IV |
|---|---|---|---|---|
| Degree of freedom (df) | 3 | 3 | 3 | 3 |
| Chi Square ($\chi^2$) | 3.11 | 2.60 | 4.20 | 0.30 |
| t-value (t) | 7.8 | 7.8 | 7.8 | 7.8 |
| p-value (P) | 0.38 | 0.46 | 0.24 | 0.96 |

Table A30 Chi Square test of Control Measures I to IV between groups of experiences (0 year) and (>5 years)

| Control Measures | I | II | III | IV |
|---|---|---|---|---|
| Degree of freedom (df) | 3 | 3 | 3 | 3 |
| Chi Square ($\chi^2$) | 1.08 | 0.88 | 1.30 | 0.83 |
| t-value (t) | 7.8 | 7.8 | 7.8 | 7.8 |
| p-value (P) | 0.78 | 0.83 | 0.73 | 0.84 |

Table A31 Chi Square test of Control Measures I to IV between groups of experiences (>0-5) and (>5) years

| Control Measures | I | II | III | IV |
|---|---|---|---|---|
| Degree of freedom (df) | 3 | 3 | 3 | 3 |
| Chi Square ($\chi^2$) | 1.00 | 0.44 | 0.36 | 0.32 |
| t-value (t) | 7.82 | 7.82 | 7.82 | 7.82 |
| p-value (P) | 0.80 | 0.93 | 0.95 | 0.96 |

Table A32 Chi Square test of Control Measures I to IV between groups of experiences (>0-2) and (>2-5) years

| Control Measures | I | II | III | IV |
|---|---|---|---|---|
| Degree of freedom (df) | 3 | 3 | 3 | 3 |
| Chi Square ($X^2$) | 4.43 | 0.01 | 3.96 | 0.77 |
| t-value (t) | 7.8 | 7.8 | 7.8 | 7.8 |
| p-value (P) | 0.22 | 1.00 | 0.27 | 0.86 |

Table A33 Chi Square test of Control Measures I to IV between groups of experiences (>5-10) and (>10) years

| Control Measures | I | II | III | IV |
|---|---|---|---|---|
| Degree of freedom (df) | 3 | 3 | 3 | 3 |
| Chi Square ($X^2$) | 3.52 | 9.27 | 3.31 | 1.52 |
| t-value (t) | 7.8 | 7.8 | 7.8 | 7.8 |
| p-value (P) | 0.32 | 0.03 | 0.35 | 0.68 |

Table A34 Chi Square test of Control Measures I to IV between groups of experiences (>2-5) and (>5-10) years

| Control Measures | I | II | III | IV |
|---|---|---|---|---|
| Degree of freedom (df) | 3 | 3 | 3 | 3 |
| Chi Square ($X^2$) | 1.56 | 3.50 | 2.80 | 0.89 |
| t-value (t) | 7.8 | 7.8 | 7.8 | 7.8 |
| p-value (P) | 0.67 | 0.32 | 0.42 | 0.83 |

Table A35 Chi Square test of Control Measures I to IV between groups of experiences (0 year) and (>10 years)

| Control Measures | I | II | III | IV |
|---|---|---|---|---|
| Degree of freedom (df) | 3 | 3 | 3 | 3 |
| Chi Square ($X^2$) | 1.45 | 2.55 | 2.46 | 0.55 |
| t-value (t) | 7.8 | 7.8 | 7.8 | 7.8 |
| p-value (P) | 0.69 | 0.47 | 0.48 | 0.91 |

Table A36 Chi Square test of Control Measures I to IV between groups of experiences (>2-5) and (>10) years

| Control Measures | I | II | III | IV |
|---|---|---|---|---|
| Degree of freedom (df) | 3 | 3 | 3 | 3 |
| Chi Square ($X^2$) | 0.92 | 0.21 | 0.93 | 0.81 |
| t-value (t) | 7.8 | 7.8 | 7.8 | 7.8 |
| p-value (P) | 0.82 | 0.98 | 0.82 | 0.85 |

Table A37 Chi Square test of Control Measures I to IV between government and non-government group

| Control Measures | I | II | III | IV |
|---|---|---|---|---|
| Degree of freedom (df) | 3 | 3 | 3 | 3 |
| Chi Square ($X^2$) | 4.07 | 6.21 | 11.90 | 0.84 |
| t-value (t) | 7.8 | 7.8 | 7.8 | 7.8 |
| p-value (P) | 0.25 | 0.10 | 0.01 | 0.84 |

Table A38 Chi Square test of Control Measures I to IV between cities of lower and middle income class

| Control Measures | I | II | III | IV |
|---|---|---|---|---|
| Degree of freedom (df) | 3 | 3 | 3 | 3 |
| Chi Square ($X^2$) | 0.06 | 3.38 | 2.13 | 0.59 |
| t-value (t) | 7.8 | 7.8 | 7.8 | 7.8 |
| p-value (P) | 1.00 | 0.34 | 0.54 | 0.90 |

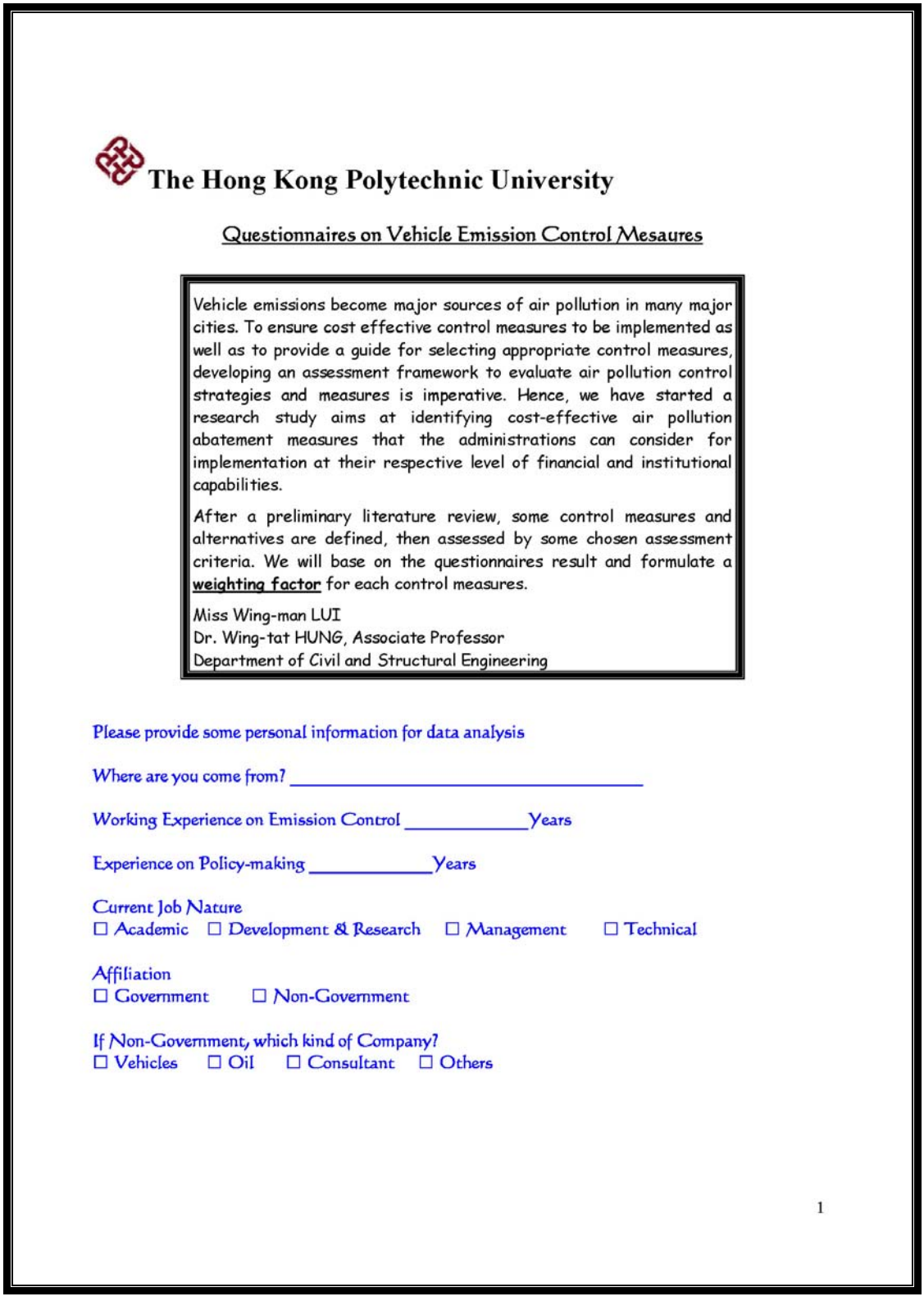
Table A39 Chi Square test of Control Measures I to IV between cities of lower and upper income class

| Control Measures | I | II | III | IV |
|---|---|---|---|---|
| Degree of freedom (df) | 3 | 3 | 3 | 3 |
| Chi Square ($X^2$) | 3.34 | 2.23 | 3.14 | 0.94 |
| t-value (t) | 7.8 | 7.8 | 7.8 | 7.8 |
| p-value (P) | 0.34 | 0.53 | 0.37 | 0.82 |

Table A40 Chi Square test of Control I to IV between cities of middle and upper income class

| Control Measures | I | II | III | IV |
|---|---|---|---|---|
| Degree of freedom (df) | 3 | 3 | 3 | 3 |
| Chi Square ($X^2$) | 6.23 | 6.74 | 2.62 | 4.01 |
| t-value (t) | 7.8 | 7.8 | 7.8 | 7.8 |
| p-value (P) | 0.10 | 0.08 | 0.45 | 0.26 |

Questionnaire 1 Sample of questionnaires sheets for the first survey



**The Hong Kong Polytechnic University**

Questionnaires on Vehicle Emission Control Mesaures

Vehicle emissions become major sources of air pollution in many major cities. To ensure cost effective control measures to be implemented as well as to provide a guide for selecting appropriate control measures, developing an assessment framework to evaluate air pollution control strategies and measures is imperative. Hence, we have started a research study aims at identifying cost-effective air pollution abatement measures that the administrations can consider for implementation at their respective level of financial and institutional capabilities.

After a preliminary literature review, some control measures and alternatives are defined, then assessed by some chosen assessment criteria. We will base on the questionnaires result and formulate a **weighting factor** for each control measures.

Miss Wing-man LUI
Dr. Wing-tat HUNG, Associate Professor
Department of Civil and Structural Engineering

Please provide some personal information for data analysis

Where are you come from? _____

Working Experience on Emission Control _____Years

Experience on Policy-making _____Years

Current Job Nature
☐ Academic ☐ Development & Research ☐ Management ☐ Technical

Affiliation
☐ Government ☐ Non-Government

If Non-Government, which kind of Company?
☐ Vehicles ☐ Oil ☐ Consultant ☐ Others

1

Please complete all the questions.

**Part One: Ranking Questions**

**6 assessment criteria** have been set. These performance criteria are:

A. **Degree of deviations to existing system** refers to the intensity of alterations to the community during the implementation of the measures, such as changes in vehicles and fuels used and urban planning.

B. **Effect time** refers to the period of implementation when the measure could reach its full effectiveness.

C. **Political acceptability** refers to the willingness of the government and public to accept the policy.

D. **Administer-ability** refers to the level of involvement of different parties, such as government, automobile manufacturers, fuel producers and public transport operators, to manage the measures.

E. **Cost of implementation** refers to the investments, including capitals, resources and technology, required to establish the measures.

F. **Effectiveness** refers to the level of attainment in emissions control after the execution of the measures.

1) Criteria – Rank criterion A to F base on the importance

*Please circle your selection

| Criterion | Criteria Ranking* | | | | | |
|---|---|---|---|---|---|---|
| | Most Important | | | | | Least Important |
| A | 1 | 2 | 3 | 4 | 5 | 6 |
| B | 1 | 2 | 3 | 4 | 5 | 6 |
| C | 1 | 2 | 3 | 4 | 5 | 6 |
| D | 1 | 2 | 3 | 4 | 5 | 6 |
| E | 1 | 2 | 3 | 4 | 5 | 6 |
| F | 1 | 2 | 3 | 4 | 5 | 6 |

Also, 17 control measures were summarized and group into **4 categories**. These categories are:

I. **Restriction on Drivers**

II. **Modification of Existing Transportation System**

III. **Introduction of Alternative Fuels**

IV. **Land Use Planning and Control**

2) Categories – Rank category I to IV base on the priority of consideration

| Category | Categories Ranking* | | | |
|---|---|---|---|---|
| | High Priority | | | Less Priority |
| I | 1 | 2 | 3 | 4 |
| II | 1 | 2 | 3 | 4 |
| III | 1 | 2 | 3 | 4 |
| IV | 1 | 2 | 3 | 4 |

**Part Two: Rating – Questions**

3) Please circle your selection.

| A. Deviations from existing system | Little | | Large |
|---|---|---|---|
| I. Restriction on Drivers | | | |
| 1. Limitation on car ownership | 1 | 2 | 3 |
| 2. Control of car use | 1 | 2 | 3 |
| 3. Educate the drivers | 1 | 2 | 3 |
| II. Modification of Existing Transportation System | | | |
| 4. Improvement of fuel quality | 1 | 2 | 3 |
| 5. Promotion of cleaner fuel | 1 | 2 | 3 |
| 6. Vehicle technology advances | 1 | 2 | 3 |
| 7. Inspection and maintenance program | 1 | 2 | 3 |
| 8. Traffic management | 1 | 2 | 3 |
| 9. Strengthen regulations and enforcements | 1 | 2 | 3 |
| III. Introduction of Alternative Fuels (AFs) | | | |
| 10. Infrastructure for AFs | 1 | 2 | 3 |
| 11. Retrofit vehicles with AFs kits | 1 | 2 | 3 |
| 12. Promotion of AFs | 1 | 2 | 3 |
| 13. Purchasing AF vehicles | 1 | 2 | 3 |
| IV. Land Use Planning and Control | | | |
| 14. Reformation of public transports | 1 | 2 | 3 |
| 15. Use of non-motorized vehicles | 1 | 2 | 3 |
| 16. Rail System | 1 | 2 | 3 |
| 17. Re-conceptualization of town plan | 1 | 2 | 3 |

| B. Effect Time | Short | | Long |
|---|---|---|---|
| I. Restriction on Drivers | | | |
| 1. Limitation on car ownership | 1 | 2 | 3 |
| 2. Control of car use | 1 | 2 | 3 |
| 3. Educate the drivers | 1 | 2 | 3 |
| II. Modification of Existing Transportation System | | | |
| 4. Improvement of fuel quality | 1 | 2 | 3 |
| 5. Promotion of cleaner fuel | 1 | 2 | 3 |
| 6. Vehicle technology advances | 1 | 2 | 3 |
| 7. Inspection and maintenance program | 1 | 2 | 3 |
| 8. Traffic management | 1 | 2 | 3 |
| 9. Strengthen regulations and enforcements | 1 | 2 | 3 |
| III. Introduction of Alternative Fuels (AFs) | | | |
| 10. Infrastructure for AFs | 1 | 2 | 3 |
| 11. Retrofit vehicles with AFs kits | 1 | 2 | 3 |
| 12. Promotion of AFs | 1 | 2 | 3 |
| 13. Purchasing AF vehicles | 1 | 2 | 3 |
| IV. Land Use Planning and Control | | | |
| 14. Reformation of public transports | 1 | 2 | 3 |
| 15. Use of non-motorized vehicles | 1 | 2 | 3 |
| 16. Rail System | 1 | 2 | 3 |
| 17. Re-conceptualization of town plan | 1 | 2 | 3 |

| C. Political Acceptability | Easy | | Hard |
|---|---|---|---|
| I. Restriction on Drivers | | | |
| 1. Limitation on car ownership | 1 | 2 | 3 |
| 2. Control of car use | 1 | 2 | 3 |
| 3. Educate the drivers | 1 | 2 | 3 |
| II. Modification of Existing Transportation System | | | |
| 4. Improvement of fuel quality | 1 | 2 | 3 |
| 5. Promotion of cleaner fuel | 1 | 2 | 3 |
| 6. Vehicle technology advances | 1 | 2 | 3 |
| 7. Inspection and maintenance program | 1 | 2 | 3 |
| 8. Traffic management | 1 | 2 | 3 |
| 9. Strengthen regulations and enforcements | 1 | 2 | 3 |
| III. Introduction of Alternative Fuels (AFs) | | | |
| 10. Infrastructure for AFs | 1 | 2 | 3 |
| 11. Retrofit vehicles with AFs kits | 1 | 2 | 3 |
| 12. Promotion of AFs | 1 | 2 | 3 |
| 13. Purchasing AF vehicles | 1 | 2 | 3 |
| IV. Land Use Planning and Control | | | |
| 14. Reformation of public transports | 1 | 2 | 3 |
| 15. Use of non-motorized vehicles | 1 | 2 | 3 |
| 16. Rail System | 1 | 2 | 3 |
| 17. Re-conceptualization of town plan | 1 | 2 | 3 |

| D. Administer-ability | Easy | | Hard |
|---|---|---|---|
| I. Restriction on Drivers | | | |
| 1. Limitation on car ownership | 1 | 2 | 3 |
| 2. Control of car use | 1 | 2 | 3 |
| 3. Educate the drivers | 1 | 2 | 3 |
| II. Modification of Existing Transportation System | | | |
| 4. Improvement of fuel quality | 1 | 2 | 3 |
| 5. Promotion of cleaner fuel | 1 | 2 | 3 |
| 6. Vehicle technology advances | 1 | 2 | 3 |
| 7. Inspection and maintenance program | 1 | 2 | 3 |
| 8. Traffic management | 1 | 2 | 3 |
| 9. Strengthen regulations and enforcements | 1 | 2 | 3 |
| III. Introduction of Alternative Fuels (AFs) | | | |
| 10. Infrastructure for AFs | 1 | 2 | 3 |
| 11. Retrofit vehicles with AFs kits | 1 | 2 | 3 |
| 12. Promotion of AFs | 1 | 2 | 3 |
| 13. Purchasing AF vehicles | 1 | 2 | 3 |
| IV. Land Use Planning and Control | | | |
| 14. Reformation of public transports | 1 | 2 | 3 |
| 15. Use of non-motorized vehicles | 1 | 2 | 3 |
| 16. Rail System | 1 | 2 | 3 |
| 17. Re-conceptualization of town plan | 1 | 2 | 3 |

| E. Cost of Implementation | Low | | High |
|---|---|---|---|
| I. Restriction on Drivers | | | |
| 1. Limitation on car ownership | 1 | 2 | 3 |
| 2. Control of car use | 1 | 2 | 3 |
| 3. Educate the drivers | 1 | 2 | 3 |
| II. Modification of Existing Transportation System | | | |
| 4. Improvement of fuel quality | 1 | 2 | 3 |
| 5. Promotion of cleaner fuel | 1 | 2 | 3 |
| 6. Vehicle technology advances | 1 | 2 | 3 |
| 7. Inspection and maintenance program | 1 | 2 | 3 |
| 8. Traffic management | 1 | 2 | 3 |
| 9. Strengthen regulations and enforcements | 1 | 2 | 3 |
| III. Introduction of Alternative Fuels (AFs) | | | |
| 10. Infrastructure for AFs | 1 | 2 | 3 |
| 11. Retrofit vehicles with AFs kits | 1 | 2 | 3 |
| 12. Promotion of AFs | 1 | 2 | 3 |
| 13. Purchasing AF vehicles | 1 | 2 | 3 |
| IV. Land Use Planning and Control | | | |
| 14. Reformation of public transports | 1 | 2 | 3 |
| 15. Use of non-motorized vehicles | 1 | 2 | 3 |
| 16. Rail System | 1 | 2 | 3 |
| 17. Re-conceptualization of town plan | 1 | 2 | 3 |

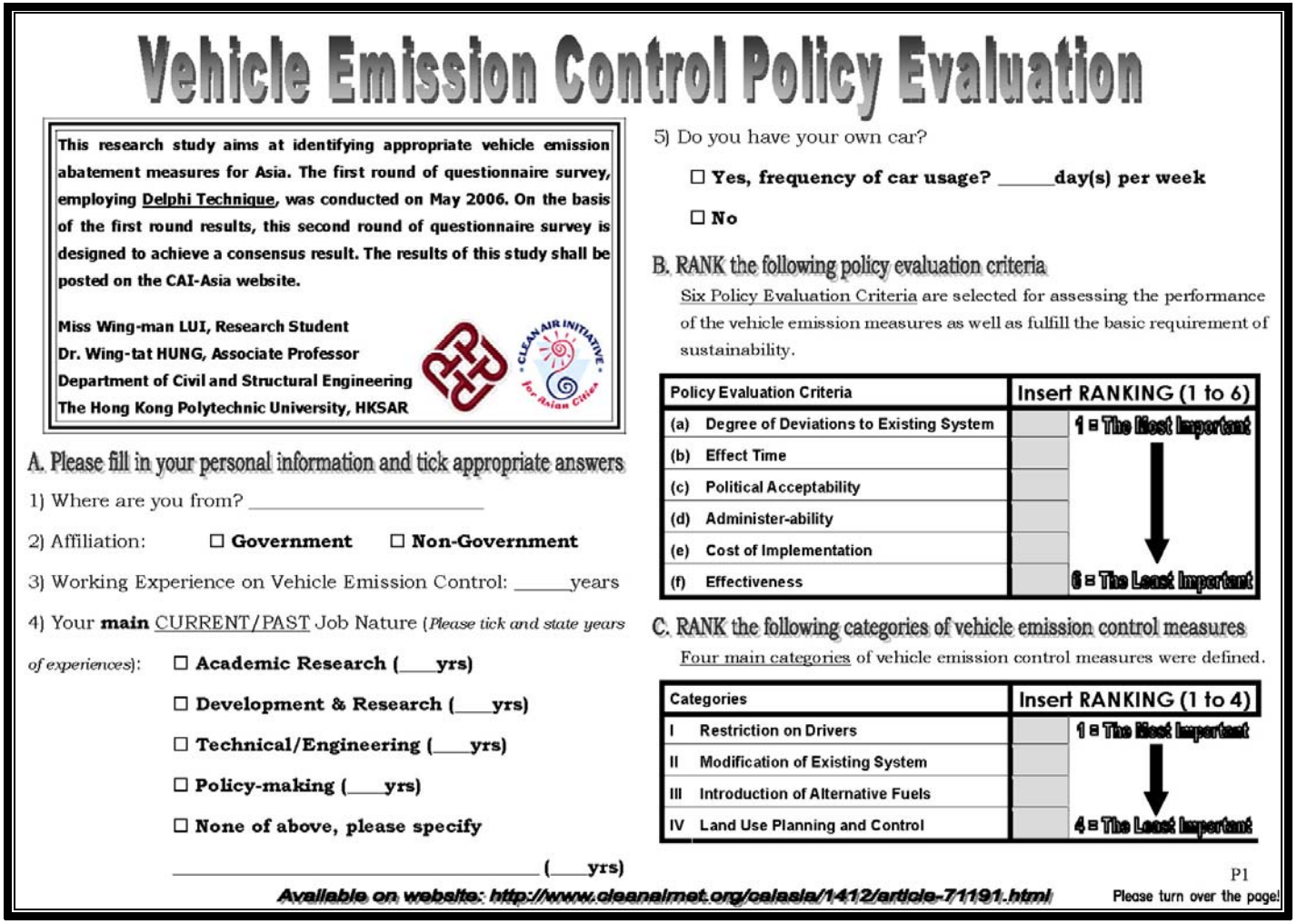
| F. Effectiveness | Low | | High |
|---|---|---|---|
| I. Restriction on Drivers | | | |
| 1. Limitation on car ownership | 1 | 2 | 3 |
| 2. Control of car use | 1 | 2 | 3 |
| 3. Educate the drivers | 1 | 2 | 3 |
| II. Modification of Existing Transportation System | | | |
| 4. Improvement of fuel quality | 1 | 2 | 3 |
| 5. Promotion of cleaner fuel | 1 | 2 | 3 |
| 6. Vehicle technology advances | 1 | 2 | 3 |
| 7. Inspection and maintenance program | 1 | 2 | 3 |
| 8. Traffic management | 1 | 2 | 3 |
| 9. Strengthen regulations and enforcements | 1 | 2 | 3 |
| III. Introduction of Alternative Fuels (AFs) | | | |
| 10. Infrastructure for AFs | 1 | 2 | 3 |
| 11. Retrofit vehicles with AFs kits | 1 | 2 | 3 |
| 12. Promotion of AFs | 1 | 2 | 3 |
| 13. Purchasing AF vehicles | 1 | 2 | 3 |
| IV. Land Use Planning and Control | | | |
| 14. Reformation of public transports | 1 | 2 | 3 |
| 15. Use of non-motorized vehicles | 1 | 2 | 3 |
| 16. Rail System | 1 | 2 | 3 |
| 17. Re-conceptualization of town plan | 1 | 2 | 3 |

*Thank you for your kind help!*

*Please return the complete questionnaire to the Workshop Secretariat.*

4

Questionnaire 2 Sample of questionnaires sheets for the second survey



# Vehicle Emission Control Policy Evaluation

This research study aims at identifying appropriate vehicle emission abatement measures for Asia. The first round of questionnaire survey, employing Delphi Technique, was conducted on May 2006. On the basis of the first round results, this second round of questionnaire survey is designed to achieve a consensus result. The results of this study shall be posted on the CAI-Asia website.

Miss Wing-man LUI, Research Student
Dr. Wing-tat HUNG, Associate Professor
Department of Civil and Structural Engineering
The Hong Kong Polytechnic University, HKSAR

## A. Please fill in your personal information and tick appropriate answers

1) Where are you from? _____

2) Affiliation: ☐ **Government** ☐ **Non-Government**

3) Working Experience on Vehicle Emission Control: _____years

4) Your **main** CURRENT/PAST Job Nature (*Please tick and state years of experiences*):

☐ **Academic Research (____yrs)**

☐ **Development & Research (____yrs)**

☐ **Technical/Engineering (____yrs)**

☐ **Policy-making (____yrs)**

☐ **None of above, please specify**

_____ **(____yrs)**

5) Do you have your own car?

☐ **Yes, frequency of car usage? _____day(s) per week**

☐ **No**

## B. RANK the following policy evaluation criteria

Six Policy Evaluation Criteria are selected for assessing the performance of the vehicle emission measures as well as fulfill the basic requirement of sustainability.

| Policy Evaluation Criteria | Insert RANKING (1 to 6) |
|---|---|
| (a) Degree of Deviations to Existing System | 1 = The Most Important |
| (b) Effect Time | |
| (c) Political Acceptability | |
| (d) Administer-ability | |
| (e) Cost of Implementation | |
| (f) Effectiveness | 6 = The Least Important |

## C. RANK the following categories of vehicle emission control measures

Four main categories of vehicle emission control measures were defined.

| Categories | Insert RANKING (1 to 4) |
|---|---|
| I Restriction on Drivers | 1 = The Most Important |
| II Modification of Existing System | |
| III Introduction of Alternative Fuels | |
| IV Land Use Planning and Control | 4 = The Least Important |

P1

Available on website: http://www.cleanairnet.org/caiasia/1412/article-71191.html

Please turn over the page!

D. On the basis of above categories, some common control measures were defined. RANK the corresponding control measures in EACH CATEGORY, and recommend additional control measures if you wish

| Category | | Vehicle Emission Control Measures *(Recommend your additional control measures on the blanks)* | | Insert RANKING | "✓" the measures that implemented in your country if you know? | State the Starting Year if you know |
|---|---|---|---|---|---|---|
| I | Restriction on Drivers | I-1 | Limitation on Car Ownership | 1 = The Most Favorable | | |
| | | I-2 | Control of Car Use | | | |
| | | I-3 | Educate the Drivers | | | |
| | | I-4 | | 4 = The Least Favorable | | |
| II | Modification of Existing System | II-1 | Improvement of Fuel Quality | 1 = The Most Favorable | | |
| | | II-2 | Promotion of Cleaner Fuel | | | |
| | | II-3 | Vehicle Technology Advances | | | |
| | | II-4 | Inspection and Maintenance Program | | | |
| | | II-5 | Traffic Management | | | |
| | | II-6 | Strengthen Regulations and Enforcements | | | |
| | | II-7 | | 7 = The Least Favorable | | |
| III | Introduction of Alternative Fuels | III-1 | Infrastructure for Alternative Fuels | 1 = The Most Favorable | | |
| | | III-2 | Retrofit Vehicles with Alternative Fuels Kits | | | |
| | | III-3 | Promotion of Alternative Fuels | | | |
| | | III-4 | Purchasing Alternative Fuel Vehicles | | | |
| | | III-5 | | 5 = The Least Favorable | | |
| IV | Land Use Planning and Control | IV-1 | Reformation of Public Transports | 1 = The Most Favorable | | |
| | | IV-2 | Use of Non-motorized Vehicles | | | |
| | | IV-3 | Rail System | | | |
| | | IV-4 | Re-conceptualization of Town Plan | | | |
| | | IV-5 | | 5 = The Least Favorable | | |

Please RETURN the completed questionnaire to
1) Booth No. 38: "The Hong Kong Polytechnic University", BAQ2006: Best Practices Exhibit;
2) Fax: (852)2334-6389 or 3) E-mail: wingman.lui@

Thank you for your valuable opinions!

P2

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