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**A Delphi Study of the Vehicular Emissions Control Strategies for the Capital City Delhi**

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**ABSTRACT**

*In present work a Delphi study was commissioned to obtain the feedback and suggestions of the experts, having technical backgrounds, such as industrial, scientific, transport administration, engineering academics and engineering studies. The questionnaire was designed including a wide spectrum of different modes of transportation, beginning with bicycles and cycle rickshaws, encompassing all the prevalent modes of automobiles being used and including up to electric and solar powered vehicles. The collected data was analysed using the MATLAB software and the results have been used to estimate and then propose future emission modification factors. It is found that a large majority of experts were in favour of improving and subsidizing the public transportation system, enhancing the traffic management and accelerating the infrastructure projects. The preferences of the experts were given due consideration while proposing the future emission control strategies and making the estimates of the vehicle emissions in the next chapter.*

**Keywords:** Emissions Control Traffic Management Delphi Study.

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**1.0 Introduction**

Today, the capital of India, Delhi is one of the most polluted cities in the world, which has been caused by phenomenal vehicular growth primarily during the past two-three decades.

Incidentally, only a few decades earlier Delhi was acclaimed as one of the greenest capitals in the world. In order to restore the air quality and refurbish its image, a number of plans have been prepared and implemented in Delhi during the past few years. The related externalities like traffic congestion, quality of available fuel quality, extent of overloading or over speeding, and maintenance, have a definite impact on the environmental degradation.

Although the statistical data for the vehicular pollution of Delhi is available, a comprehensive planning and optimization strategy to overcome the above problem is yet to be formulated. Controlling the vehicular emissions of a metro city public transportation system need an honest approach to incorporate the judgment, critical comments and suggestions by the people who use these systems and who also know the technical aspects of these systems. The Delphi methodology enables one to incorporate the opinions of a large number of experts/participants, about the present public transportation system and

their preferences, without creating any conflict or wide disagreements.

Delphi is one of the most widely used techniques for creative exploration of ideas for the production of suitable information for the decision making or future planning applications.

The Delphi study or technique was used to determine if there are emerging patterns or consensus on leadership practices and information technologies used in leading virtual teams. The purpose of the Delphi technique is to elicit information and judgments from participants to facilitate problem-solving, planning, and decision-making. Why Delphi was used in this study is explained in the chapter 3 on the selection of the research methodology.

**2.0 The History of Delphi**

The Delphi technique was developed during the 1950s by the workers at the RAND Corporation while operating on a U.S. Air Force sponsored project. The aim of the project was the application of expert opinion to the selection – from the point of view of a Soviet strategic planner – of an optimal U.S. industrial target system, with a corresponding estimation of the number of atomic bombs required to reduce armaments output by a prescribed amount. More generally, the technique is seen as a procedure

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to obtain the most reliable consensus of opinion of a group of experts by a series of intensive questionnaires interspersed with controlled opinion feedback"" (Dalkey & Helmer, 1963). In particular, the structure of the technique is intended to allow access to the positive attributes of interacting groups (knowledge from a variety of sources, creative synthesis, etc.), while pre-empting their negative aspects (attributable to social, personal and political conflicts etc.), from a practical perspective, the method allows input from a larger number of participants that could feasibly be included in a group or committee meeting and from members who are geographically dispersed.

Delphi is not a procedure intended to challenge statistical or model-based procedures, against which human judgment is generally shown to be inferior. It is intended for use in judgment and forecasting situations in which pure model-based statistical methods are not practical or possible because of the lack of appropriate historical / economic / technical data, and thus where some form of human judgmental input is necessary (Wright et al., 1996). Such input needs to be used as efficiently as possible, and for this purpose the Delphi technique might serve a role.

Four key features may be regarded as necessary for defining a procedure as a „Delphi“. These are: Anonymity, Iteration, Controlled feedback, and Statistical aggregation of group response.

**Anonymity** is achieved through the use of questionnaires. By allowing the individual group members an opportunity to express their opinions and judgments privately, undue social pressures – as from dominant or dogmatic individuals or from a majority – should be avoided. Ideally, this should allow the individual group members to consider each idea on the basis of merit alone, rather than on the basis of potentially invalid criteria (such as the status of an idea's proponent).

Furthermore, with the **iteration** of the questionnaire over a number of rounds, the individuals are given the opportunity to change their opinions and judgments without fear of losing face in the eyes of the others in the group.

Between questionnaire iterations, **controlled feedback** is provided, through which the group members are informed of the opinions of their anonymous colleagues. Often feedback is presented as a simple statistical summary of the group response,

usually comprising a mean or median value, such as the average „group“ estimate of the date by when an event is forecast to occur.

Occasionally, additional information may also be provided, such as arguments from individuals whose judgments fall outside certain pre specified limits. In this manner, feedback comprises the opinions and judgments of all group members and not just the most vocal. At the end of the polling of participants (i.e., after several rounds of questionnaire iteration), the group judgment is taken as the **statistical average** (mean / median) of the panelists' estimates on the final round.

The above four characteristics are necessary defining attributes of a Delphi procedure, although there are numerous ways in which they may be applied. The first round of the classical Delphi procedure (Martino, 1983) is unstructured, allowing the individual experts relatively free scope to identify, and elaborate on, those issues they see as important. These individual factors are then consolidated into a single set by the monitor team, who produce a structured questionnaire from which the views, opinions and judgments of the Delphi panelists may be elicited in a quantitative manner on subsequent rounds.

After each of these rounds, responses are analyzed and statistically summarized (usually into medians plus upper and lower quartiles), which are then presented to the panelists for further consideration, if panelists' assessments fall outside the upper or lower quartiles, they may be asked to give reasons, why they believe their selections are correct against the majority opinion? This procedure continues until stability in panelists' responses is achieved. The forecast or assessment for each item in the questionnaire is typically represented by the median on the final round. An important point to note here is that variations from the above Delphi model do exist (Martino, 1983). Most commonly round one is structured in order to make the application of the procedure simpler for the monitor team and panelists; the number of rounds is variable, though seldom goes beyond one or two iterations (during which time most change in panelists' responses generally occurs).

Often, panelists may be asked for just a single statistic – such as the date by when an event has a 50% likelihood of occurring – rather than for multiple figures or dates representing degrees of confidence or likelihood (e.g., the 10% and 90% likelihood dates),

or for written justifications of extreme opinions or judgments. These simplifications are particularly common in laboratory studies and have important consequences for the generalize ability of research endings.

One of the aims of using Delphi is to achieve greater consensus amongst panelists. Empirically, consensus has been determined by measuring the variance in responses of Delphi panelists over rounds, with a reduction in variance being taken to indicate that greater consensus has been achieved.

Results from empirical studies seem to suggest that variance reduction is typical, although claims tend to be simply reported unanalyzed (Dalkey & Helmer, 1963), rather than supported by analysis (Jolson & Rossow, 1971). Indeed, the trend of reduced variance is so typical that the phenomenon of increased „consensus“, per se, no longer appears to be an issue of experimental interest. Where some controversy does exist, however, it is in whether a reduction in variance over rounds reflects true consensus (reasoned acceptance of a position).

Delphi has, after all, been advocated as a method of reducing group pressures to conform (Martino, 1983) and both increased consensus and increased conformity will be evident as a convergence of panelist's estimates over rounds (i.e., these factors are confounded). It is seen in the literature that reduced variance has been interpreted according to the position on Delphi held by the particular author/s, with proponents of Delphi arguing that results demonstrate consensus, while critics have argued that the „consensus“ is often only „apparent“, and that the convergence of responses is mainly attributable to other social-psychological factors leading to conformity (Stewart, 1987).

Clearly, if panelists are being drawn towards a central value for reasons other than a genuine acceptance of the rationale behind that position, then inefficient process-loss factors are still present in the technique. Alternative measures of consensus have been taken, such as „post-group consensus. This concerns the extent to which individuals – after the Delphi process has been completed – individually agree with the final group aggregate, their own final round estimates, or the estimates of other panelists. Rohrbaugh (1979) compared individuals“ post-group responses to their aggregate group responses, and seemed to show that reduction in „disagreement“ in Delphi groups was significantly less than the

reduction achieved with an alternative technique (Social Judgment Analysis). Furthermore, he found that there was little increase in agreement in the Delphi groups. This latter finding seems to suggest that panelists were simply altering their estimates in order to conform to the group without actually changing their opinions (i.e., implying conformity rather than genuine consensus).

An alternative slant on this issue has been provided by Bardecki (1984), who reported – in a study not fully described – experts with more extreme views were more likely to drop out of a Delphi procedure than those with more moderate views (i.e., nearer to the group average).

This suggests that consensus may be due – at least in part – to attrition. Further empirical work is needed to determine the extent to which the convergence of those who do not (or cannot) drop out of a Delphi procedure are due to either true consensus or to conformity pressures.

### **3.0 The Delphi Versus Other Statistical Procedures**

The average estimate of Delphi panelists on the first round – prior to iteration or feedback – is equivalent to that from a statistical sized group. Comparing a final round Delphi aggregate to that of the first round is thus, effectively, a within-subjects comparison of techniques (Delphi versus statistical sized group).

Although the comparison of round averages should be possible in every study considering Delphi accuracy/quality, a number of evaluative studies have omitted to report round differences [Fischer (1981) and Riggs (1983)].

Many studies have reported significant increase in accuracy over Delphi rounds [Erffmeyer et al. (1986), and Rowe & Wright (1996)]. Some other studies have reported Delphi to be better than statistical or first round aggregates more often than not, or to a degree that does not reach.

### **4.0 Application of Delphi to the Public Transportation System of Delhi**

Although evidence suggests that Delphi does generally lead to improved judgments over statistical sized groups and unstructured interacting groups, it is clearly of interest to see how Delphi performs in

comparison to groups using other structured procedures.

The Delphi survey conducted in this research work included the people chosen mainly from technical background such as:

Transportation Planning related Departments like Delhi Transport Corporation (DTC), Department of Science and Technology (DST), Defense Research and Development Organization (DRDO), State Transport Authority (STA), Central Road Research Institute (CRRI), Delhi Metro Rail Corporation (DMRC) etc.

**Automobile manufacturers** like Maruti Udyoog Limited, Hyundai Motors, Ashok Leyland, Honda and their vendors.

**Indian fuel refinery personals** from Indian Oil Corporation (IOCL), Bharat Petroleum Corporation Limited (BPCL), Hindustan Petroleum Corporation Limited (HPCL), Indraprastha Gas India Limited (IGIL)

**Engineering academicians** from Delhi College of Engineering (DCE), Indian Institute of Technology Delhi (IITD), Maharaja Agrasen Institute of Technology (MAIT), Delhi, Directorate of Training and Technical education (DTTE) Delhi and Engineering students from DCE, NSIT, MAIT etc.

The Delphi questionnaire was designed using guidelines of Sharma (2000) and Pal (2004), included a wide spectrum of different modes of transportation, beginning with bicycles and cycle rickshaws, encompassing all the prevalent modes being used of automobiles, and extending up to electric and solar powered vehicles, including advanced forms of fuel cells, hybrid vehicles etc.

for planning an appropriate strategy to optimize the vehicular emissions of the capital city of Delhi. The experts have been asked to rate the suggested strategies for the reduction of the vehicular emissions from the transport system of the city of Delhi on a scale of 10 and they were also been asked to give their narrative suggestion and remarks to control the vehicular emissions.

In the first round of Delphi, about 300 participants were approached, roughly fifty plus from each category i.e. Automobile industry, Petroleum oil industry, Transport Department, Engineering Academia's and Engineering Students, out of which 138 responded, spending on an average of 30 to 45 minutes of their precious and rationed time.

## 5.0 Investigations of the Delphi Study

Various methods were used to contact the experts for the survey, maximum experts were contacted personally. A sizable number of experts were contacted through various other means of communications such as internet, post/courier, phone calls etc. The respondent's work experience average is more than 8 years which is reasonably good (Assigning the experience of one year to all the students as most of them were already graduate i.e. Post Graduate students), whereas the group's average for experts stay in Delhi is about 10 years. The group's average annual income is more than rupees two lakh, here for students their family income is considered and only final year engineering students (both full time and part time) are approached for the study. The survey experts stay duration in Delhi is also considered and ensured that the experts have reasonable stay duration in Delhi, so as to ensure that they are fully aware of the transportation problem of Delhi. The groups average stay duration in Delhi is more than 8 years.

The responses of above questionnaire were analyzed using statistical tools and processed with MATLAB program me. The STATISTICALLY ACCEPTABLE RANGE followed here to ascertain the agreement of majority of the group, for Delphi first and second round are as following:

RANGE (Higher /Lower) = AVERAGE  $\pm$  1.5 STDV, IF STDV  $d < 2.0$ ,

RANGE (Higher /Lower) = AVERAGE  $\pm$  2.0 STDV, IF STDV  $> 2.0$

The responses of 36 experts were found to be out of acceptable range; they were again contacted and requested to participate in the second round, with a view to arrive at a consensus worthy of framing a feasible solution/policy framework. All the responses of second round were within statistical limits. Further their replies to some specific questions on how to control the vehicular emissions, suitability of the alternative fuels, how to improve the Public Transportation System, steps to control the number of vehicles and their awareness level on alternative propulsion systems are presented in the form of bar chart in Figure 1 to 5.

It is worth to mention that all the experts have rated our suggested measures more than 6. The opinion of the participants is given due consideration in proposing the future emission control strategies.

It is observed that they have given a very high rating (i.e. about 8-10) to the practically feasible options like improvement in fuel quality, augmentation of Delhi metro, promoting CNG as fuel, augmentation of PTS, enforcement of strict emission norms etc., while control actions such as removing the encroachment from roads, improving the infrastructure, adding the hydrogen in CNG fuel, strengthening the ring rail, restructuring the tax on vehicles taxes, among others were rated low because their implementation is not practically easy.

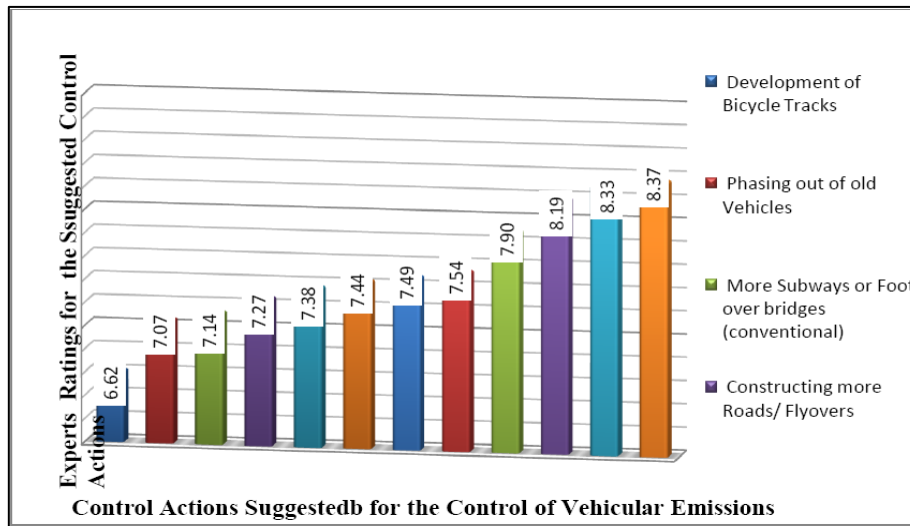
Experts reply were also analyzed with MATLAB software, various statistical parameters like average, coefficient of variance, standard deviation etc were determined and they are

represented in graphical images in Figure 6 to 8. Different colored lines are used for different experts groups (such as Engg. Acamadiations-ACAD-dark blue. Engg.

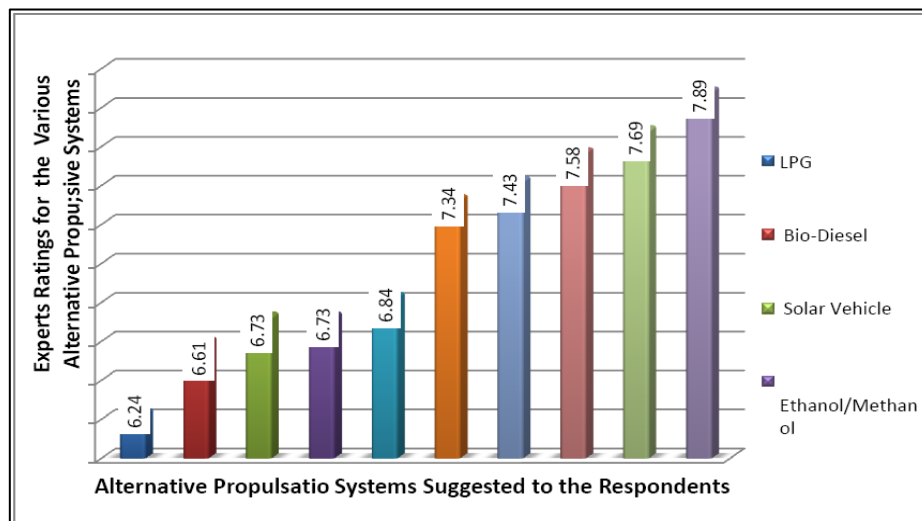
Students-STUD-blue, Automobile engineers-AIE-green, Transport officials- TRPS-orange, Oil industry personals-OIE-red, group averages are also shown in different column heights.

These graphs show the various statistical parameters for the survey data such as standard deviation (SD), mean, coefficient of variance (CV), inter quartile range (IQR) etc. with different types and colored lines with the reply of the different expert groups for various questionnaire entries.

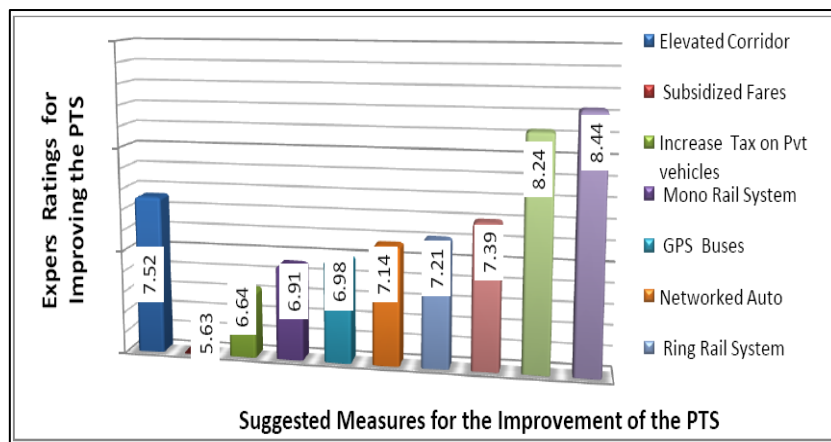
**Fig 1: Experts Preferences to Control Vehicle Emissions**



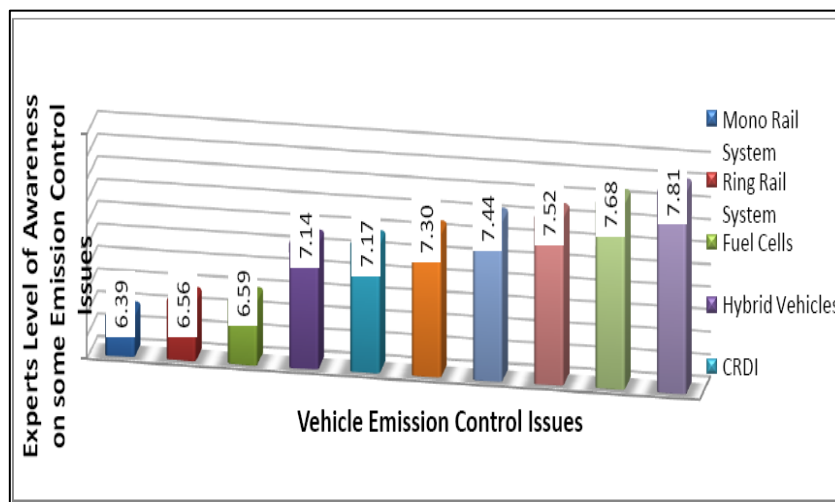
**Fig 2: Experts Preferences for the Alternative Fuels**



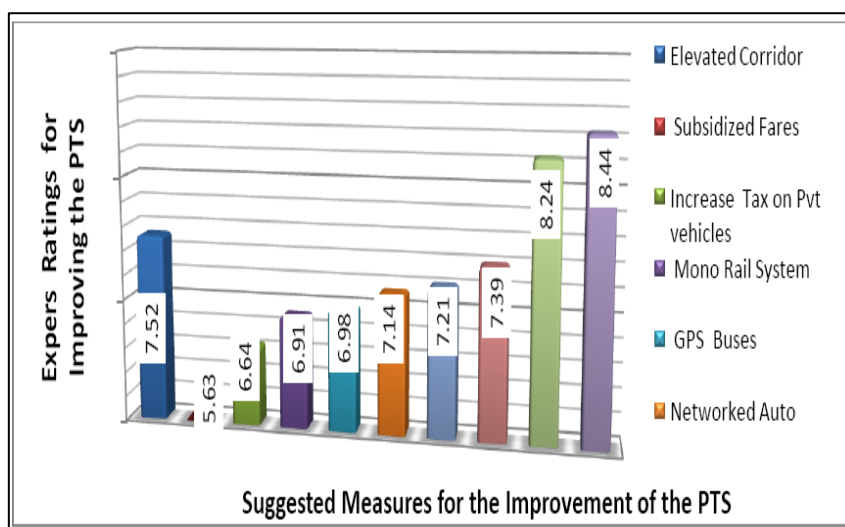
**Fig 3: Experts Suggestions to Improve Public Transport**



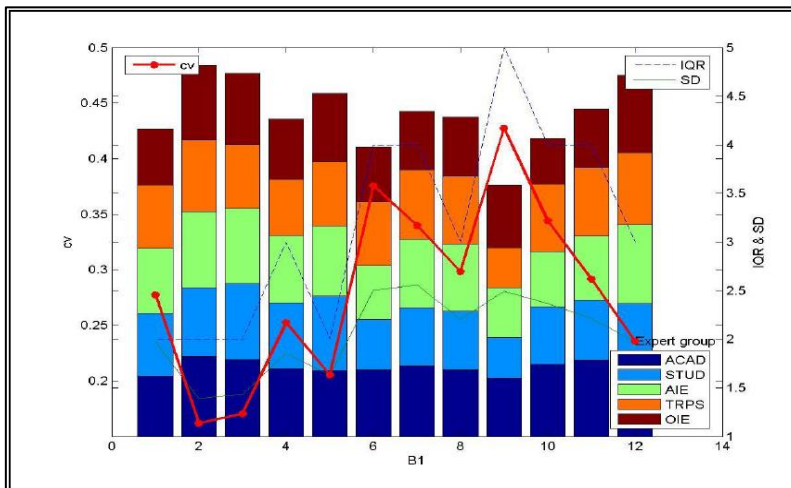
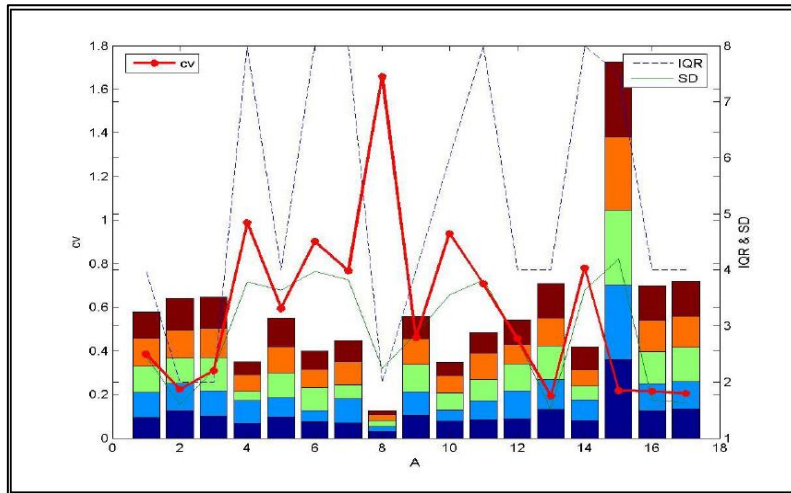
**Fig 4: Experts' Level of Awareness About Alternative Propulsion Systems**



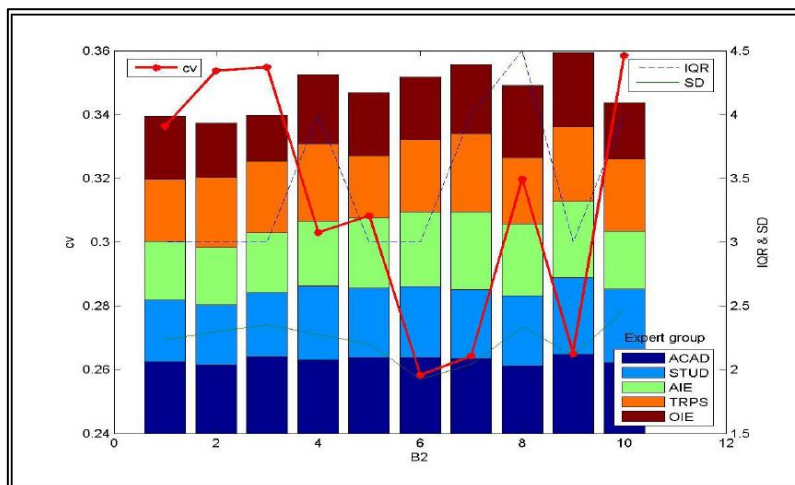
**Fig 5: Experts' Suggestions to Control the Number of Vehicles**

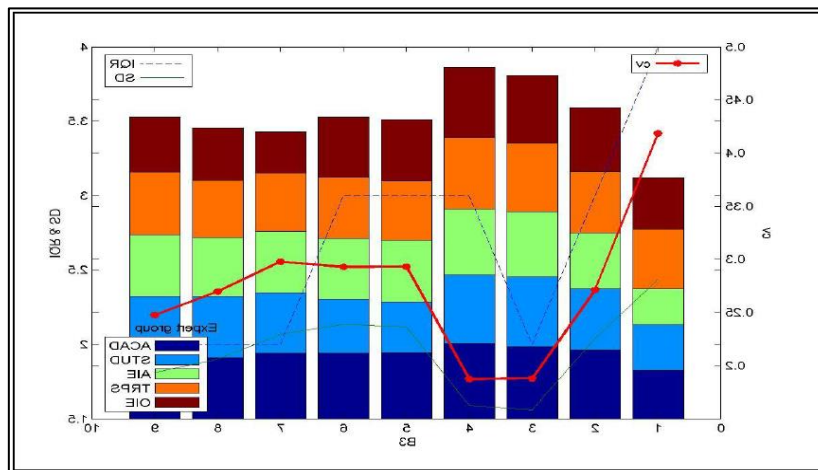


**Fig 6: MATLAB Statistical Results for the Survey Section A & B1**

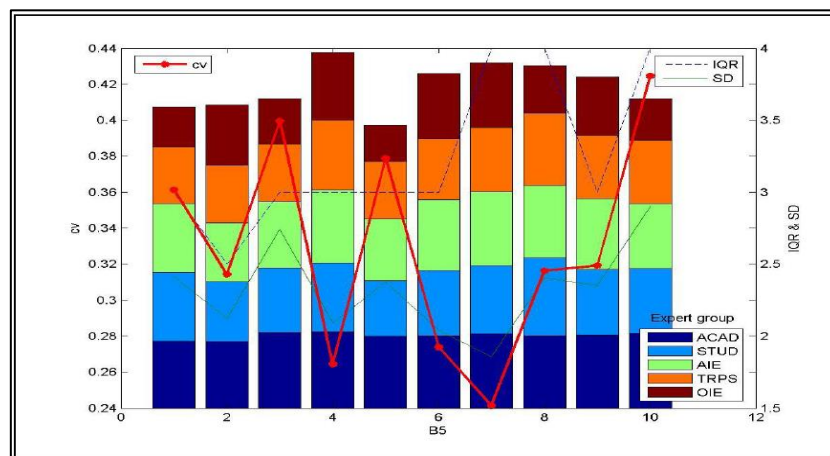
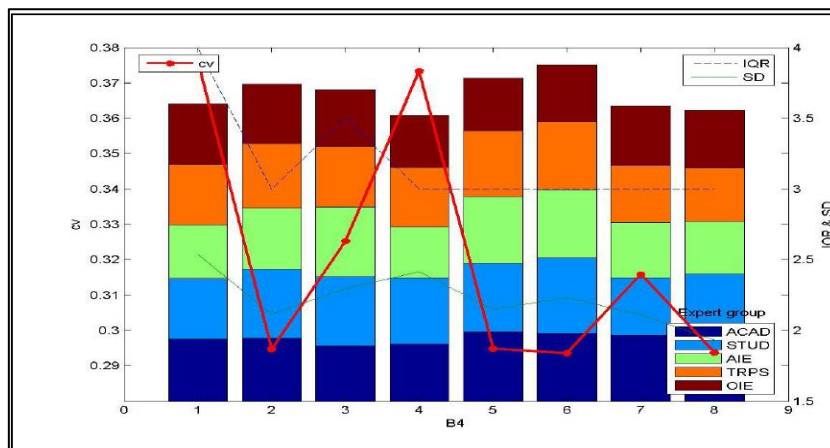


**Fig 7: MATLAB Statistical Results for the Survey Section B2 (Experts' Level of Awareness on Related Topics) and B3 (Experts' Preferences to Control the Growth of Private Vehicles)**





**Fig 8: MATLAB Statistical Results for the Survey Section B4 (Experts’ Opinion on Vehicle Taxation) and B5 (Experts’ Opinion on Various Alternative Fuels/Technology)**



**6.0 Conclusions**

The survey results shown above are an indication that though people are well aware about the advanced alternatives like Hydrogen, Hybrid, Solar and Fuel Cell etc. but as their success history is

not proven thus they are ranked, marginally lower than that of well established and familiar alternative fuels like CNG/LPG/Ethanol and Bio-diesel etc. We noticed some very much important and interesting suggestion from the experts. Some of them valuable to be referred are:



- There should be a system in which or a method has to be developed so that only a particular lot of vehicle (like odd or even numbered) can operate on some decided day of work.
- Strict rule for no use of private vehicles, for at least one day /week
- Advanced and classified PTS for different section of people
- Campaign on public awareness for lane driving to avoid traffic jams
- Endorse employee car pool as a part of corporate social responsibility
- To control higher fuel consumption and aldehyde emission
- Hydrogen technology is in nascent stage.
- For CNG safety aspects need to be taken care of.
- Motor vehicle licensing system should be strict and linked to awareness for emission control and driving training, and advance driver licensing system like graduated licensing system must be promoted.
- Create a phool (ideates) lane for fast movers, let live others.
- Reliable integration of different modes of public transport.
- Tax Free, State owned buses, to subsidize public transport.
- Making turbocharger mandatory in standard design in diesel engine.
- Delhi metro should be linked possibly by small PTS vehicle under one ticket scheme.
- Amendment should be made in Central Motor Vehicle Rule (CMVR) to restrict entry of other state private vehicle in Delhi. Otherwise due to heavy tax in Delhi people are lured top get their vehicles registered outside Delhi and use in Delhi.
- Substantially subsidized fare passes of PTS for the School/College/Office goers.
- Incentive for accident /challenge free vehicle
- Public walk way (footpath to be made encroachment free) elevated, made to cater up to 1km walk
- Limiting the number of vehicle per family, and enforcing higher tax for the subsequent vehicles.
- Tax to the number of vehicle per floor of a house.
- Heavy duty vehicle should not be allowed from 6AM to 11PM.

- Public Transport Systems routes should be increased connecting residential and industrial area.
- High penalty for environment enemy vehicle.

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