A comprehensive integrated framework linking vehicle emissions and traffic simulation complemented with social-institutional analysis

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Abstract— The transport sector in the Indian Megacity of Hyderabad contributes extensively to climate change through greenhouse gases emitted by vehicles. Though recent research shows that traffic congestion is one of the major contributors to the vehicle emission in the city, they do not provide any concrete methods or primary data to measure and derive the relation between vehicle emission and traffic congestion. Hence, Urban planners use outdated records and statistics, for traffic simulation to forecast the travel demand in order to propose development action plans. These include mostly infrastructure projects like construction of flyovers, expansion of the existing roads, laying new roads, improvement of vehicle technology etc. Nevertheless these solutions do not sufficiently address the problem of congestion or vehicle emission in the city, as these developmental plans are only based on physical aspects like roads or vehicles. However, there is always a human behaviour factor, which is influenced by culture, attitudes, emotions, and values that tends to make decision either individually or collectively, during the travel on road. This novel thought has provided an insight for the author to advance the discourses on sustainable traffic solutions by sparking a discussion on the value of a comprehensive integrated framework that is capable of depicting a 'near to real' social interaction in the form of a vehicle emission estimation based on a social-institutional analysis. This framework could then be used in combination with traffic simulation tools for analyzing the results to an actual scenario in order to derive an efficient analysis based solution. Results for the vehicle emission estimation of four representative stretches to be used for the social-institutional analysis in Hyderabad are discussed in this paper. The author also provides an overview of the transport route-mode choice game that is currently being developed as a tool for this social-institutional analysis.

***Keywords* -** Comprehensive integrated framework, driver behavior, social-institutional analysis, transport route-mode choice game, vehicle driving pattern, vehicle emission.

I. Introduction

A recent study on the air quality conducted in Hyderabad, the capital city of the state Andhra Pradesh and the fifth largest Indian city, has found that the exponential growth of vehicular fleets contribute nearly 58% to deteriorating air quality [1]. The city has total 2.6 million vehicles, with every year 0.2 million new vehicles and each day 600 new vehicles being added. This leads to the phenomenon where the traffic is growing four times faster than the population [2]. According to Hyderabad City Development Plan [3] the main roads are congested with a vehicle density of 720 vehicles per kilometer. This is due to the excessive traffic volume than the designed capacity (area) of the roads, and hence a reduction of the average journey speed (12 km/h), than the designed speed of the road. Given this scenario the urban transport planners to believe or presume that road improvement projects are the effective methods to combat the problem of congestion. Based on this thought, the city has now sixteen existing elevated corridors (flyovers) and fifteen proposed road widening projects [4]. In contrast, these road based projects in the long run will only increase the number of vehicles compared to the total length of roads available, as per theory of induced travel demand [5]. The theory states that road improvements encourage latent demand where it tends to invites more new people to travel [6]. This process of latent demand occurs due to a behavioral shift in each individual road users that are greatly influenced by the social-psychological factors like culture, attitude, emotions and values during their travel. Each individual driver tends to interact with other road user based on four factors. They are formal institutions, informal institutions, nature of the road (which often leads to the creation of informal rules), and other driver's behavior [7]. Formal institutions are the rules and conventions of society that are legitimized and officially entered in to regulations [8], e.g., laid legal traffic rules like vehicles must stop when the signal is red. Informal institutions are the unsaid rules, practices and conventions that are created, communicated, enforced and applied under certain conditions, when drivers tend to interact [9]. These rules might either supplement or contradict formal rules, e.g. vehicles may not stop on a red light, if there is no traffic police. As a result of these behavioral shifts, some might switch between vehicle modes, routes and times of travel to exploit the newly available capacity and leads to an increased travel demand. This increased travel demand has an effect upon Vehicle Kilometer Travelled (VKT) [10]. VKT is the product of total number of vehicles on the road and the length of the road they travel. It is the determining indicator for vehicle emission in terms of grams emitted per kilometer [11]. Though various research activities are being carried out to integrate vehicle emission estimation tools in traffic planning, most of them fail to

The German Federal Ministry of Education and Research (BMBF) sponsor this work in the funding programme "Research for the Sustainable Development of the Megacities of Tomorrow". The particular research is also supported by the German Academic Exchange Service (DAAD).

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address the above mentioned driver behavioral perception based on social-institutional analysis. Hence there arises a need where the traffic planning through traffic simulation software has to directly integrate the vehicle emission estimation together with a tool for social-institutional analysis. By this way, the pollution impact supplemented with behavioral based analysis could be included during the planning phase itself. This behavioral approach might shed light on those unseen but crucial elements that we name informal institutions in the transport setting, providing insights for an efficient analysis and forecasting. This is the research work carried under the research project "Sustainable Hyderabad: Climate and Energy in a complex Transition Process towards Sustainable Hyderabad - Mitigation and Adaptation Strategies by changing Institutions, Governance Structures, Lifestyles and Consumption Patterns" This paper intends to discuss the concept of the comprehensive integrated framework and present the initial findings of vehicle emission estimation for representative road stretches on the basis of the International Vehicle Emission (IVE) model. Finally the author argue how the calculated parameters from the vehicle emission model will serve as an input to transport route-mode choice game, a tool for social-institutional analysis, that is currently being developed to explore behavioural aspects of transportation in the future.

II. Concept of Comprehensive Integrated Framework

The development of a comprehensive integrated framework (Fig.1) aims to integrate vehicle emission, driver behaviour and road traffic. Most of the recent researches have focused on the integration of vehicle emission with road traffic. Some of the models based on this relationship (link 1 in Fig.1) are HBEFA (Handbook of Emission Factors) with VISUM (macro scale traffic simulation software), CMEM (Comprehensive Modal Emission) with VISSIM (micro scale traffic simulation software) [12]. The emission model estimates the vehicle emission for a given road traffic forecast from traffic simulation software. The calculations between these models are based on road characteristics, traffic flow, vehicle operation and vehicle classification. This way of conventional approach lead to proposing road improvement projects the resulting heavy traffic or high emission stretches. As already discussed this approach for addressing the problem of congestion will not be a sustainable solution until it provides a platform for behavioural analysis of driver interaction. This necessitates incorporating driver behaviour into the comprehensive integrated framework. The proposed framework (Fig. 1) begins with an Estimation phase. In this phase, estimation of vehicle emission for four representative stretches in Hyderabad is carried out using the International Vehicle Emission (IVE) model. This enables to analyse the impact of the existing traffic on vehicle emission and result in determining the vehicle emission quantity for each stretch. This forms the basis for the Analysis phase where the impact of behavioural pattern of drivers on the vehicle emission is analysed. This analysis phase uses the social-institutional analysis as the needed tool. The key element of this analysis would be vehicle drivers. Their interaction on road is made possible with the help of formal or informal rules. The result of this interaction makes them to take a decision individually or collectively. This is often reflected in selection of their vehicle modes or routes or travel time. Hence their behaviour on road will be unpredictable. A transport route mode choice game is being currently developed as a supplementary tool for studying the behavioural analysis of vehicle drivers. The transport parameters from the estimation phase would be input to this game in order to determine the impact of pollution due to the behavioural aspects of the driver under a given constraint. The game will be based on the Common Pool Resource (CPR) theory [13], where roads are the man-made resource system and its space acts as urban commons (The urban commons is the terminology referring to resources that are collectively owned or shared between or among populations [14]. The main objective of this game is to study the typical social dilemma among vehicle drivers, that arises when they are bound to share the limited space of roads with heterogeneous groups of people varied by culture, attitude, emotions and values etc., where individual optimum might clashes with the group's optimum and to identify the trade-off between them, under different institutional set up (formal or informal rules). The key findings of this behavioural analysis from the transport game would act as an input for the policy recommendation to transport planners for the road traffic simulation.

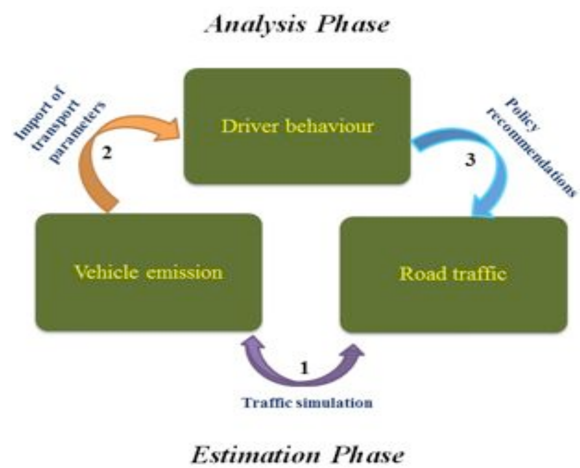


Fig. 1 Development of a comprehensive integrated framework

The estimation phase of this integrated framework has been completed and their process and results are discussed in the following sections. These results act as an input to the social-institutional analysis as stated above. As such only a sketchy image of the Analysis phase is provided in this paper.

III. Vehicle Emission Estimation

A. Vehicle Emission model

International Vehicle Emission model is used here as a tool to estimate vehicle emission in this study. The primary inputs to this model are geometric design elements, traffic characteristics, roadside environmental characteristics, and driving pattern. In Hyderabad, the driving behavior is greatly varied due to the heterogeneous traffic network and transport modes. This variation is ultimately reflected in vehicle speed.

However accounting the average vehicle speed alone for on-road vehicle emission calculation would not provide accurate results. Moreover, even same classes of vehicles in the city vastly differ in their technology (model year, engine displacement, air/fuel ratio, exhaust and evaporative control provisions). It was found from initial analysis of the existing vehicle models that the International Vehicle Emission (IVE) was the most suitable model to address all these heterogeneous factors of Indian vehicles and traffic situation [15]. This model considers three main components in developing emissions' inventories namely, i) the vehicle engine technology ii) driving behavior of various types of on-road vehicles traveling on local roadways and iii) vehicle emission factors specific to the local vehicles [16]. Vehicle Specific Power (VSP) binning measured from instantaneous speed, acceleration and gradient is used to calculate the emission quantity. It is a key indicator of driving pattern and is directly related to vehicle emissions [17]. It also calculates two types of pollutants like criteria pollutants and global warming pollutants [18]. Criteria pollutants are the pollutants classified under Clean Air Act, that are based on health and environmental criteria like Carbon Monoxide, Volatile Organic Compounds and Particulate Matter. Global warming pollutant like Carbon dioxide, Nitrous oxide and Methane are grouped together, as their persistence of distribution have a global impact on air quality [19]. In both the type of pollutants, it calculates the two types of exhaust emission namely start emissions and running emissions. In start emissions the pollutant are emitted during the start of a vehicle and continues for the first few minutes of driving, until the emissions-control equipment has reached its optimal operating temperature. In running emissions, pollutants are during driving and idling after the vehicle is warmed up [20].

B. Representative stretch characteristics in Hyderabad

The city has radial and orbital form of road network development. The recent urban growth expands towards west and south directions of the city. Hence, selection of stretches (Fig.2) along these directions assumes greater significance in order to reflect the true driving patterns in the city. The stretches also differ on the basis of their location, road type and usage as per the standards of Indian road classification [21] are shown in Table I. The stretches are numbered here based on the order of their road type

No.	Stretch Name	Indian Road Classification
1	Jawaharlal Nehru	Arterial Road
2	Panjagutta	Primary Collector
3	Mahaboob Gunj	Secondary Collector road
4	MLA Colony	Residential road

Table I Representative stretches in Hyderabad

The first stretch, Jawaharlal Nehru (JN) Road, is located in the southern part of Hyderabad and is the main corridor connecting the old with the new city. It is also a prime access to the landmarks Charminar and Afzalganj Mosque. The second stretch, Panjagutta Road, is located along the west direction of the city. This corridor is the central access to governmental institutions and numerous shopping malls. The third stretch, Mahaboob Gunj Road, is located again in the southern end and is the secondary collector road. The fourth stretch, MLA Colony Road, is located again in the west. It is a residential road located in Banjara Hills also consisting of Hospitals and Hotels. Data for Vehicle emission estimation were collected on these four stretches.

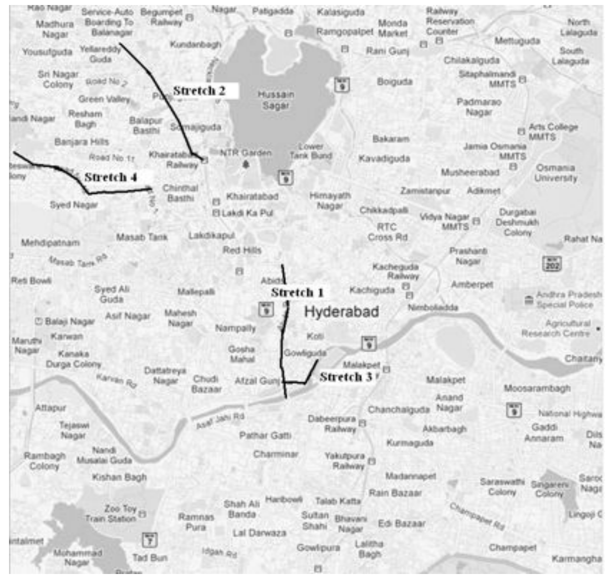


Fig. 2 Representative stretch for vehicle emission estimation

C. Data collection

Driving pattern, vehicle technology distribution, vehicle start pattern and traffic volume are the required input for the vehicle emission estimation. Survey was performed to collect these required inputs for all vehicle types that include passenger car, two wheelers, three wheelers, bus, trucks and LCV (Light Commercial Vehicles). Interviews with vehicle drivers along the roadside, at public location like shopping malls, gas stations (Fig.3) and parking lot survey were conducted with the support from School of Planning department of JNAFAU University, Hyderabad.

Fig. 3 Vehicle Interview Survey

Fig. 4 Driving Pattern and Parking survey

The driving pattern of each vehicle in the urban traffic highly depends on the traffic nature, road quality, fuel, weather and driver's physical condition [22]. The driving pattern of the vehicle (Fig.4) was recorded by means of Global Positioning Satellite (GPS) device placed in the different vehicle types and various traffic situations for peak (17-19h) and non-peak (14-16h) period.

D. Methodology

The methodology for vehicle emission estimation (Fig.5) using the IVE model starts with the calculation of VKT. It is followed by the estimation of vehicle starts for the given on-road vehicle volume, average driving and average vehicle starts per day. Then the driving pattern of each vehicle are analysed with respect to their corresponding speed profile, altitude and gradient of each stretch. The vehicle technology distribution of each vehicle category is determined with respect to vehicle make, model, year and their engine type on each stretch. Finally the vehicle emission with respect to travel demand, start pattern, driving behavior and vehicle technology are calculated.

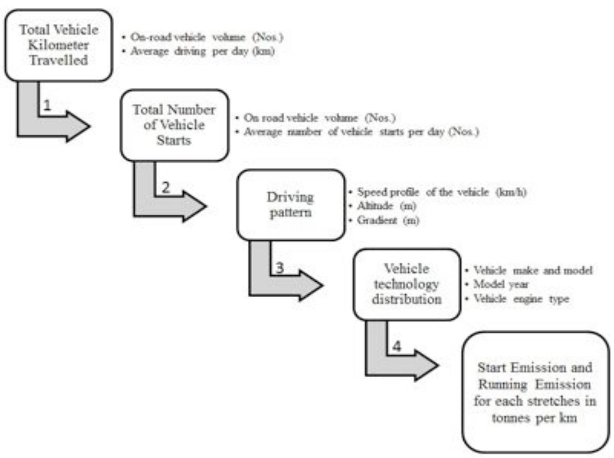


Fig. 5 Methodology for vehicle emission estimation

- *Vehicle Kilometer Travelled*

The Vehicle Kilometer Traveled (VKT) is used to determine the travel demand of total driving by accounting the traffic volume of each vehicle type for a given stretch. PTV Planung Transport Verkehr AG in Germany has undertaken a comprehensive traffic management project for Hyderabad city. Travel demand analysis using VISUM software for the city was carried out in 20 identified locations [23]. The representative stretches are also among the 20 locations. The traffic volumes were obtained from traffic volume survey conducted by PTV in 2009. This data was used to calculate the VKT.

- *Start pattern estimation*

A considerable amount of vehicle emission is contributed from vehicle's engine starts. Hence the number of vehicle engine starts assumes significance in the estimation of vehicle emission. The overall starts for each vehicle type for a stretch is calculated by multiplying the total number of starts of vehicle type with the number of that type plying on road [24].

- *Driving pattern estimation*

Driving pattern analysis is an important process in vehicle emission estimation using IVE. The peak and non-peak hours driving data is extrapolated into 24h to facilitate the calculation of vehicle emission per day. For trucks and LCV, the driving pattern of cars is accounted as it has similar driving pattern in urban road [10]. IVE model, accounts this driving behavior in terms of Vehicle Specific Power (VSP) and engine stress to calculate the vehicle emission. The percentage of time spent in driving is calculated by means of VSP and Engine stress [15]. There are three engine stress categories and 20 VSP categories, making a total of 60 bins (1-20 bins –Low engine stress, 20-40 bins: Medium engine stress, 40-60 bins: High engine stress). This forms the basis for the proposed social-institutional analysis.

- *Vehicle technology distribution*

The vehicle technology also plays a significant role in contributing to the emission. Hence determining the technology distribution assumes greater significance. The specific vehicle technology was collected for 500 samples in each stretches. On the whole, 45% of two wheelers, 27% of passenger cars, 16% of three wheelers, 5% of LCV, 4% of bus and 3% trucks were collected. These data were given as input to the fleet and technology distribution in IVE. The air/fuel ratio, the exhaust and evaporative emission control type were obtained from the respective make, model and year of the each vehicle type collected.

E. Vehicle emission estimation analysis

The input data collected helps to analyse the existing nature of the stretches. From the determined VKT and vehicle start pattern, it is observed from Fig. 6 and 7, that all vehicles, san Buses, have the highest VKT and number of vehicle starts in the first stretch when compared to other three stretches. Buses have the highest VKT and vehicle starts in the second stretch. It is also seen that in all the stretches, two wheelers' share is exactly half the proportion of total vehicles, followed by three wheelers and passenger cars. On the other hand, Buses, Trucks and LCV share only a lower proportion of total vehicles in both VKT and vehicle start.

The temporal driving pattern (Fig.8 to Fig.11), indicates the speed profile of four vehicle types, (passenger car, two wheeler, three wheeler and bus) over a 24h period on all stretches. The orders of vehicle type based on the average velocity (high to low) are:

1) Two wheeler, three wheeler, passenger car and bus in the first stretch (Fig.8).
2) Two wheeler, bus, passenger car and three wheeler in the second stretch (Fig.9).
3) Two wheeler, three wheeler and passenger car in the third stretch (Fig.10).
4) Two wheeler, three wheeler, bus and passenger car in the fourth stretch (Fig.11).

The minimum and the maximum velocity among all the vehicle types between 8-18h is 5 km/h and 27 km/h in the first stretch, 7 km/h and 30 km/h in the second stretch, 8 km/h and 33 km/h in the third stretch and 11 km/h and 32 km/h in the fourth stretch respectively The rate of velocity for all given vehicle type was observed to be high during the period between 10h-11h and 15h-16h; and was low during the period between 8h-9h, 12h-13h and 17h-19h.

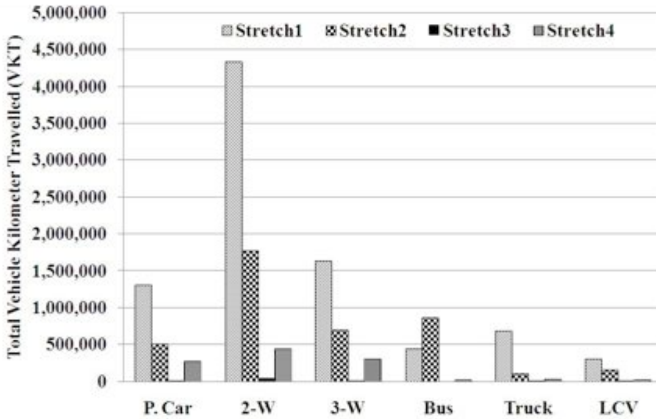


Fig. 6 Total Vehicle Kilometer Travelled

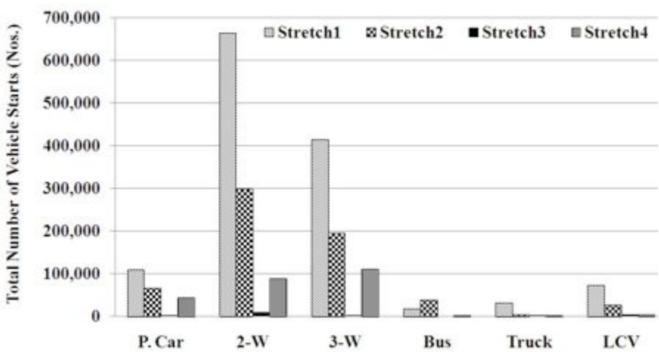


Fig. 7 Total number of vehicle starts

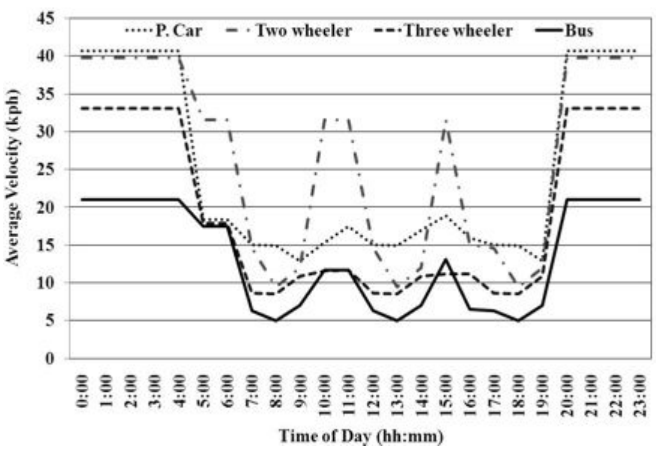


Fig. 8 Temporal speed profile of first stretch

The driving pattern was analyzed by the percentage distribution of driving into specific bins for all the vehicle types. It is calculated on an hourly basis in order to determine hourly quantity of vehicle emission on the stretch.

The driving pattern of the first stretch at early morning non-peak hour (05.30h) is compared here with late morning peak hour (09.30h) (Fig. 12 and Fig.13). It could be observed from the graph that at 5.30h, the percentage of driving for all vehicle types are widely distributed along 5-19 low stress VSP bins, but at 9.30h, it is concentrated over 9-15 low stress VSP bins. The order of driving pattern (from highest to lowest) at 5.30h were observed to be three wheeler, bus, passenger car and two wheeler respectively, while at 9.30h, they were bus, three wheeler, passenger car and two wheeler. In both the cases, passenger car and two-wheeler have similar driving pattern. Three wheeler and two wheeler reaches high stress bin levels at negligible percentage of driving at 5.30h when compared to 9.30h.

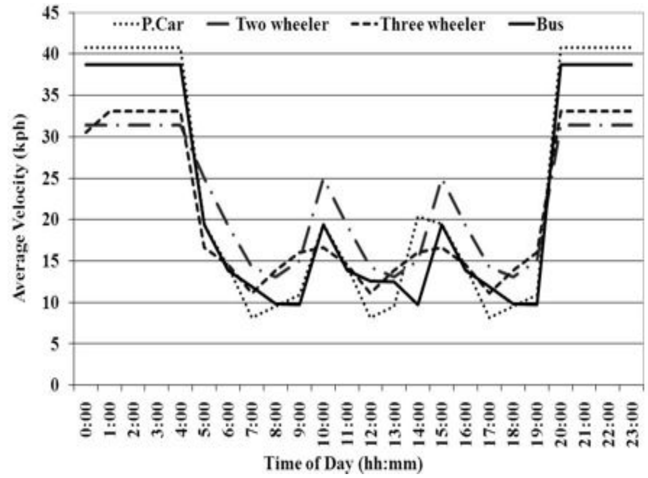


Fig. 9 Temporal speed profile of second stretch

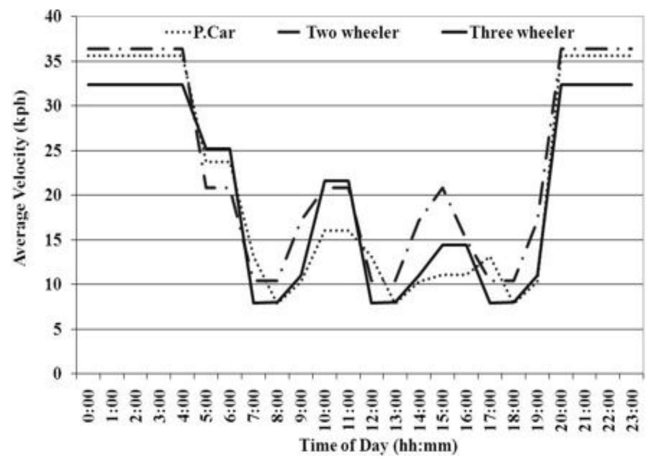


Fig. 10 Temporal speed profile of third stretch

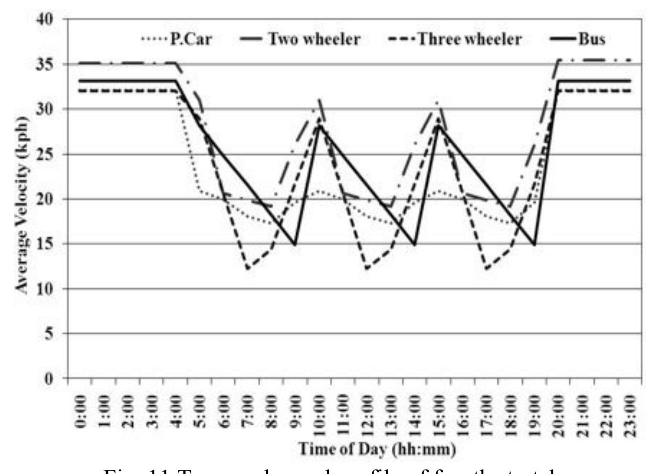


Fig. 11 Temporal speed profile of fourth stretch

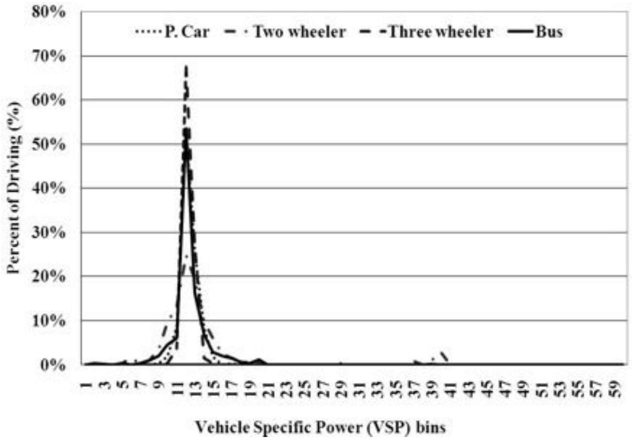


Fig. 12 Driving pattern of first stretch (5.30h)

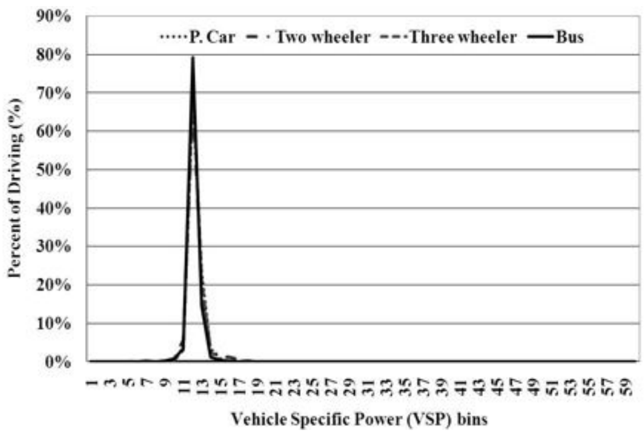


Fig. 13 Driving pattern of first stretch (9.30h)

To summarise, the driving pattern of all vehicle types at 9.30h has the highest percent of driving and narrow distribution of bins in comparison to the driving pattern of all vehicle types at 5.30h. The graphs shows that the easy maneuverability of the vehicles at 5.30h, is due to less traffic, whereas the idling condition of vehicle at 9.30h is due to heavy traffic.

The vehicle technology distribution for two wheelers, passenger cars and three wheelers are shown from Fig. 14 to Fig 16. It can be seen that distribution of vehicles according to the year of make ranges from 1996 to 2011.

In two wheeler year distributions, the third stretch shares the highest percentage over the years. In passenger car year distribution, the first and third stretch share almost equally over the years and in three wheeler year distributions, almost all the stretches share their fraction over the years.

It is concluded from the figures (Fig.14 to Fig.16), that vehicles that are more than ten years are still in existence and ply on all stretches.

Based on these parameters, the vehicle emission quantities for each stretch was determined and the results are presented in the next section

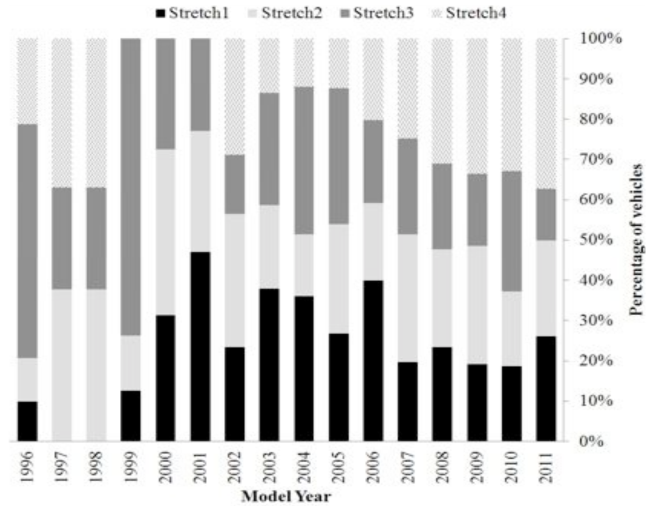


Fig. 14 Two wheeler vehicle model year distribution

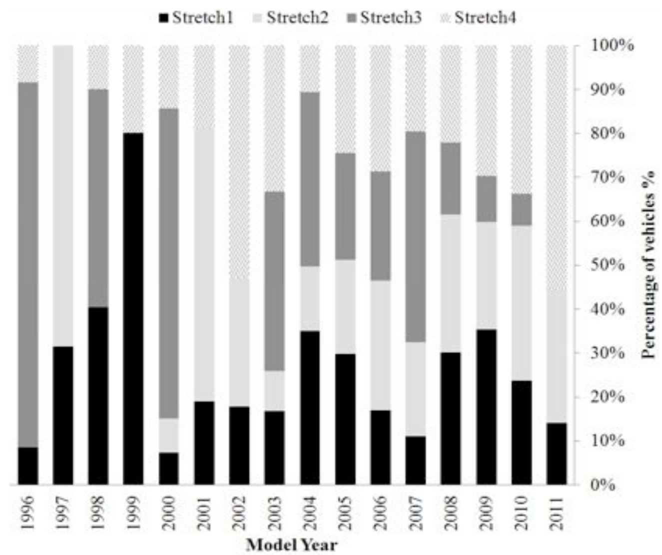


Fig. 15 Passenger car vehicle model year distribution

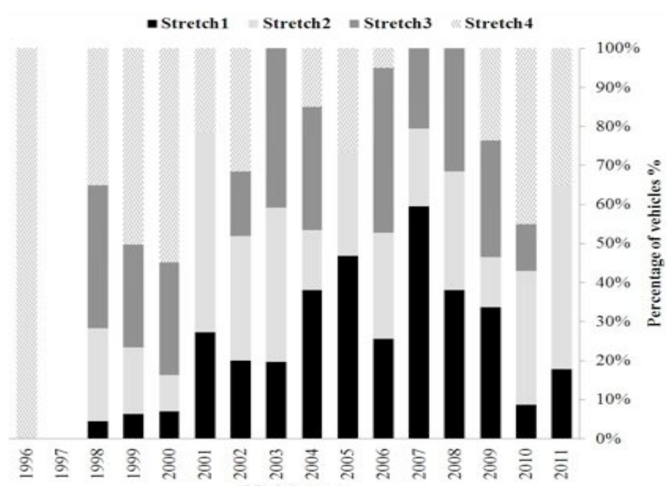
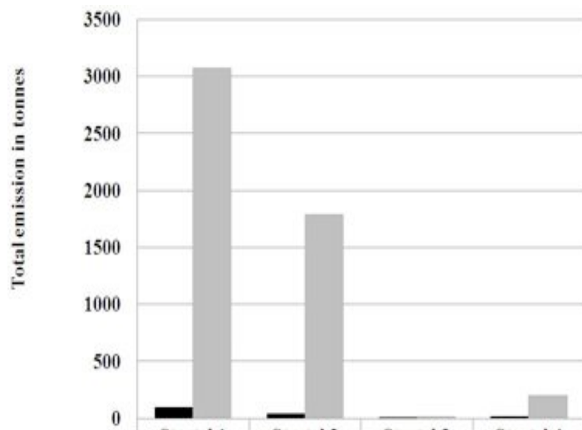


Fig. 16 Three wheeler vehicle model year distribution

F. Results and discussions

The overall vehicle emission (start and running) (Fig.17) of all pollutants for all stretches was calculated in Tonnes. Start emissions contribute to 3% of emissions in first stretch, 2% of emissions in second stretch, 12% of emissions in third stretch and 8% of emissions in fourth stretch. It is observed that the first stretch is the highest contributor to both start and running emission, succeeded by the second fourth and third stretches. This trend was also already reflected in the VKT and start pattern data. The average minimum and maximum velocity observed in the driving pattern of the first stretch is also less than the other three stretches. This shows that the VKT, start pattern, driving pattern and technology have greater influence on vehicle emission. Figures 18 to 21 show the pollutant composition for start and running emissions in all stretches.



	Stretch1	Stretch2	Stretch3	Stretch4
Start Emission	96.96354898	39.0052239	1.980769401	17.30615928
Running Emission	3070.863607	1786.063935	16.88169642	201.6327343

Fig. 17 Overall start and running emissions

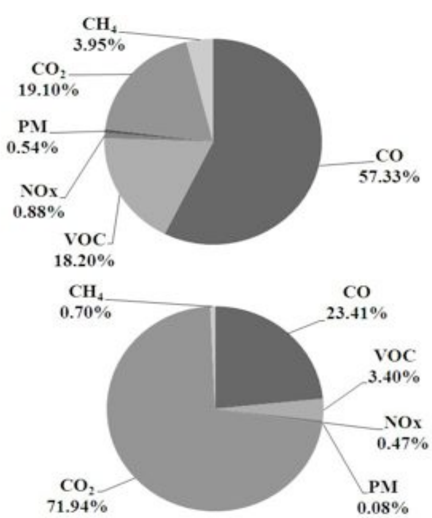


Fig. 18 Pollutant composition for start and running emissions First stretch

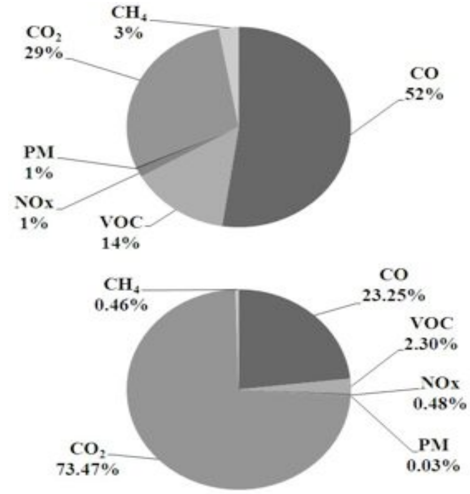


Fig. 19 Pollutant composition for start and running emissions Second stretch

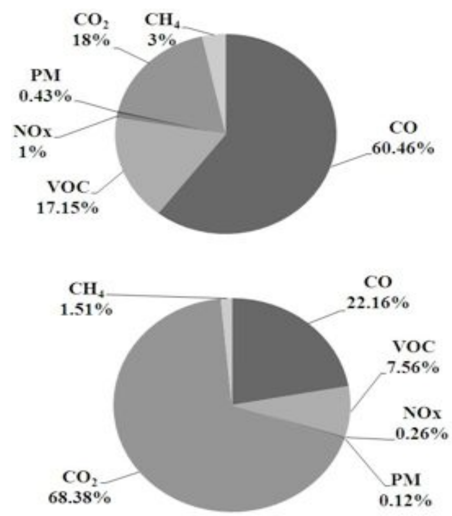


Fig. 20 Pollutant composition for start and running emissions Third stretch

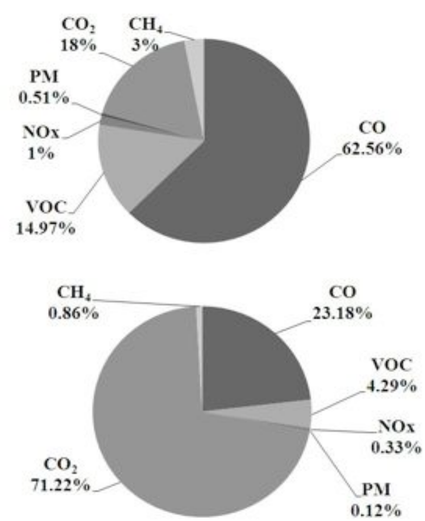


Fig. 21 Pollutant composition for start and running emissions Fourth stretch

On the one hand, criteria pollutants like CO, VOC and PM, are of immediate concern for urban air quality due to their significant impact on health, while on the other hand, global pollutants like CO_2, (N_2O) and (CH_4) have impact on environment in the form of global warming like Green House Gas and ozone depletion. It can be seen that for all the stretches (Fig.18 to Fig. 21) CO contributes more than the half proportion in total start emission while CO2 is the highest contributor in total running emission.

The results of vehicle emission could be viewed from two perspectives. On the basis of normal existing approach it is perceived through what current researchers tend to do for pollution abatement or for transport planning. As seen from the Fig.17 the first stretch and second stretch are the most polluted of all stretches. Hence some control strategies like advancement in vehicle technology or alternate fuel system, road infrastructure development are suggested for controlling vehicle emission. The recommendation of these strategies is finally decided based on benefit-cost analysis of each strategy.

However with a detailed analysis, these control measures cannot be successful in the long run [25] without sufficient behavioral analysis. Referring to a sample case, suggestion of control strategies or road improvement projects in the first stretch might decrease intensity of pollution or congestion for first few years but in parallel it tends to invite more new people to travel on this stretch, due to improved road facilities and thus result in increase of travel demand. Since the available road space is limited and cannot cater to the increased demand, in the later years, this stretch is again highly polluted or heavily congested. The problem turns into a vicious cycle and has to be addressed in an iterative process approach. Hence this methodology is not sustainable and sufficient. The reason behind this non-sustainable condition is that only vehicles and roads are the two key elements analyzed in this approach for reducing congestion and emission. It neglects the fact that the problems like congestion and emission become seemingly complex as it is involved by the third key element, the behavioural aspect of the driver, who controls vehicle and makes decision on road.

Analyzing the behavioural aspects of driver would be the core research interest in the social-institutional analysis. Details on the social-institutional analysis and the initial concept mechanism and implementation of the experimental game are discussed in the following section.

IV. Social-Institutional Analysis

A What is Social-Institutional Analysis

Social-Institutional analysis aims to study behavioral aspects of vehicle driver under different institutional arrangements. The behaviour of driver on road is not predictable and they tend to exhibit either collective behaviour (behaviour that tends to make decision that complies with other road user behaviour either by communicating or imitating) or rational behavior (behaviour that tends to make decision at the cost of maximizing the benefit or utility of individual) [26]. When both these behaviour clash each other, then there arises a situation called social dilemma. This could be explained with a sample scenario. Individuals with rational behaviour, who prefer to maximize their comfort and convenience, commute by car and, face the negative effects of traffic congestion and vehicle emission. On the contrary, if the individual joins the other road users and pose a collective behavior by deciding to travel by bus, then negative effects like congestion or emission could be greatly avoided or minimized. This transition of interpersonal interest to intergroup interest might leads to the situation called social dilemma. An experimental game called Transport route-mode choice game is therefore being developed. The main objective of this experimental tool is to study the typical social dilemma in an urban transport setting, where individual optimum clashes with the group's optimum and to identify the tradeoff [27] between them. This clash might finally result in a tragedy of the urban commons not because of technical constraints but due to institutions (or the lack there of) shaping the choices of the commuters. The concept and theory behind this development of experimental game is discussed in the following section.

B. Game Concept

The game is about the mode and route choice of the employee given the condition that he/she needs to go to his/her office in morning peak time. The players' preferences of transport modes and routes are controlled by transport parameters namely vehicle and travel cost, road capacity, travel time, speed and air pollution. Three sets of rounds are played under three different concepts. Namely: a) an open access situation where all players freely choose their modes and routes without communicating with each other, b) restricted/regulated access by imposing traffic and transport rules/sanctions without communication and finally c) the introduction of communication and the possibility for players to craft their own rules or improve the existing ones. The overall goal of this game is to explore equilibrium on how to balance the individual and group profit avoiding a tragedy of urban commons. These context-dependent games also act as complementary tools to the currently employed transportation models. Such a holistic approach may include effects of rules in transportation by addressing institutional constraints in traffic solutions not captured by current practices and set up an integrated supportive tool for a sustainable traffic solution.

The concept of transport game (Fig.22) is based on the Common Pool Resource (CPR) theory [13], which defines CPR as a natural or human-made resource system, whose size or characteristics of which makes it costly, but not impossible, to exclude potential beneficiaries from obtaining benefits from its use. Here the roads are the man-made resource system, where its space acts as urban commons shared by heterogeneous groups of vehicles varied by shape, size, speed, and age. Based on PIEV theory (Perception, Intellection, Emotion and Volition) [28], the drivers exhibit travel behavior, which is different from each other, which get reflected in their varied decision over the available choice of routes and vehicle modes. When these drivers with varied decisions decided to travel on road, then there might be two chances of occurrences. One is the occurrence of 'tragedy

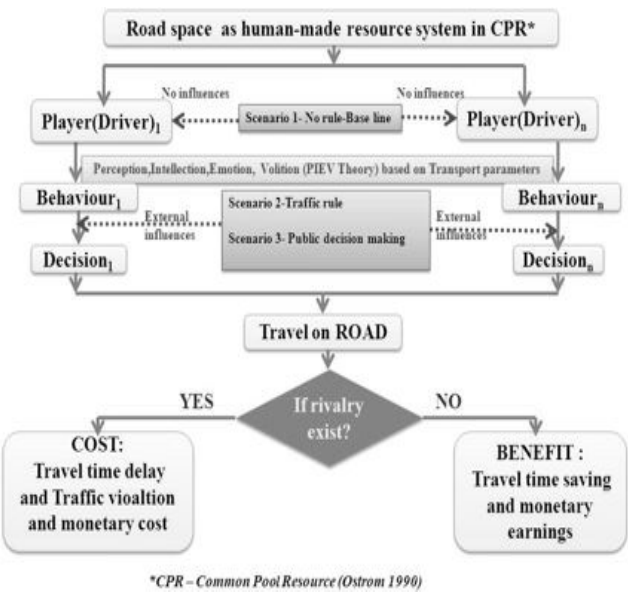


Fig. 22 Route-Mode choice game concept

of Commons' stated by Hardins (1968) [29], who defines it as a class of phenomena that involve a conflict for resources between individual interests and the common good. This might result in rivalry between vehicle drivers, further leading to traffic congestion, travel time delay, traffic violation and monetary cost involved in it. Other possibility is that there might not be a problem of rivalry, then there is no traffic congestion and hence every drivers whoever travel, save their travel time and earn monetary benefits. The main objective of this game is to show how the individual vehicle user choice of route and mode is affected by the group's choice. In the real world, vehicle users decide upon mode and route in order to reach any place in time, as none of them prefers to stay longer in roads. So the travel time is one of the important transport parameter from the demand-side perspective (vehicle user), in selecting their choices. This could be best depicted in Home-Work based travel trips [30], where each employee from different firms would tend to select the route and mode favoring him to reach his office on time.

With this background, the transport game is structured under three scenarios where three games are played with the given three sets of choices. The first game is played under no traffic rules or measures as base case scenario, where there is no restriction on given choices and players are allowed to select any choice to reach their office (free access situation). The second game is played under the introduction of traffic rule and traffic measure in to the game, where there is a restriction on the choices to players. In the first two games, communication between the players is strictly not permitted. The third game is played same as second game except involving players in to decision making of rules, by allowing them to communicate. Hence, the transport route-mode choice game, which is the part of the integrated framework, is currently being developed to test the hypothesis of how the behavior of driver results in, when they decided to travel.

C. Game Mechanism

The mechanism for the transport game is designed based on the given choices of routes and modes of transport. The routes to be selected for this game are the primary and secondary roads in Hyderabad and the given modes are the passenger car and public transport bus. From the traffic volume survey carried out in the selected stretches for vehicle emission calculation, it could be seen that the passenger car contributes a substantial share in overall vehicle composition and invade large amount of the road space. Hence the road capacity and the game mechanism are designed based on passenger cars. The following are the three choices, given for all the players to reach their office.

1) Use of passenger car and take primary road (Short route but more easily congested).
2) Use of passenger car and take secondary road (long route but less affected by congestion).
3) Take public transport bus that goes only on secondary road (long route but unaffected by congestion).

Transport parameters - namely travel time, road capacity, vehicle emission and speed are the controlling parameters in the first two choices and it is assumed that there is no controlling parameter for the third choice, as in reality the public (here the game players) act as passengers in public transport bus and they are given services and are not allowed to make decisions on route. Moreover, when all players opt for traveling by bus then there will be no problem of traffic congestion or vehicle emission and the average speed would also be high, so they can reach in time [31]. The mechanism is designed in such a way so that the controlling parameters are influenced by the percentage of choice of players.

According to the game mechanisms, the most attractive option for the players is the first one, where players drive through the shortest route, thus increasing their possibility of reaching their office on time. At the same time, this option involves high risk, since when 50% or more of the players follow the shortest route; it will become congested, thus resulting in a delayed arrival at office and subsequently to a sum of money subtracted from their salary. The choice 1 is compared with the primary short road in reality, where it influence the vehicle drivers, as it saves travel time but also associates high risk of congestion. In case of choice 2, the players do not earn more and at the same time they do not lose more, when the percentage exceeds 40%. Hence the intensity of risk is very less in case of choice 2. It represents the secondary road in reality, where it has longer travel time and lesser congestion. In choice 3, there is no mechanism, which involves no earnings and no delay cost and hence no risk. In reality, the public transport bus provided by Government has fixed time- table schedule and routes; hence passengers are only given services to travel but not to select the time and route of travel of their choice.

D. Game Implementation

The game is to be implemented by playing with different groups of social community like students, public transport drivers etc. The robustness and novelty of the framework could be significantly tested on the basis of the results obtained and their analysis. It is also intended to subsequently improve and modify the game based on these results.

V. Conclusions and Further Research

The author attempts a very simple yet novel innovation in the sector of urban planning in Hyderabad: integrating aspects of institutional analysis in an arena dominated by technical responses in an attempt of providing sustainable traffic solutions. If the actors in the urban arena respond to a mix of formal and informal constraints an institutional analysis is required to examine both sets of rules. By broadening the scope of institutional analysis to include informal rules, researchers and policy makers alike can gain a better understanding of the incentives shaping driving behavior and consequently determining the success or failure of urban planning. The advance of such understanding should result in both better research and better planning.

A transport route-mode choice game is proposed as entry point to explore the informal rules of transport in Hyderabad. Transportation is perceived as an urban common. As such the focus lies on the typical social dilemma in an urban transport setting, where individual optimum clashes with the group's optimum and might finally result in a tragedy of the urban commons. It is also assumed that this tragedy is not only because of technical constraints but also due to institutions (or the lack thereof) influencing the choices of the commuters among the given routes and modes. It is planned to use the ground data from the emission calculation discussed in this paper, namely the driving pattern and vehicle emission quantity for the design of vehicle speed, travel time and air pollution parameter in developing the transport game mechanism. This would help in simulating the real traffic situation in the game. As an example, the total running emission of passenger car of tonnes per hour calculated for this stretch would be converted into gram per hour as an air pollution parameter and the driving pattern of instantaneous speed and travel time of passenger car in this stretch would be converted to average speed and travel time for the given routes and game mechanism based on these transport parameter would be designed for given choice based on the capacity of passenger car, i.e., if the capacity of passenger car exceeds the limit, then the probability of congestion also increases resulting in decrease of speed and increase in travel time and thereby increasing the overall emission emitted in g/hr for particular selection of route. Having repeated this game in an adequate number of rounds, the decision of players (real drivers) influenced by the effect of their choice, would be taken as the simulation of the social interaction in the real world. This simulation could be then compared and analyzed with the result from traffic simulation software.

The linkage of a comprehensive integrated framework deriving from the combination of a vehicle emission estimation of the selected stretches in Hyderabad and the transport route-mode choice game presents few major challenges requiring further research. Namely,

1) As the existing emission factor derived from Indian driving conditions is inaccurate, the emission factor based on driving condition of US is used here for the calculation. Hence, the challenge of assuming an emission factor that reflects realistically Indian driving conditions emerges.
2) The impact of current policies, norms and measures on vehicle emissions should be further analysed to get realistic transport parameters necessary for the development of the transport game.
3) Importing parameters from the vehicle emission estimation to the development of transport game mechanism should be made dynamic, thus reflecting constantly changing conditions instead of providing a static picture like most models do.
4) The trade-off between players namely Social optimum (group optimum) and Nash equilibrium (individual optimum) condition of the game has to be finely tuned and adjusted to realistic values, so as to supplement the game.
5) The available players' choices and rule sets need to be further simplified.
6) The developed prototype of the game would be then extensively tested with drivers in Hyderabad and the feedback loop between the estimated data and the role of social interactions on emissions must be reinforced and proved with the end target to show case how travel behaviour affects the vehicle emission.

Acknowledgment

The author would like to thank the School of Planning department of JNAFAU University, Hyderabad, India and PTV AG, Karlsruhe, Germany for providing assistance in the data collection for this research and her research advisor Dr. Dimitrios Zikos, and her colleague Ms. Wiebke Hampel in her department, at the Humboldt University who had helped her in providing their valuable comments on this paper.

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