Survey Paper on Methodology Development for Estimation of Air Pollution near Road

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Abstract
The objective of this survey paper is finding methodology for estimation of air pollution that comes from road traffic. A detailed study has been done for estimation of air pollution. In this paper, we have studied relevant papers and designed a methodology for estimation near road air pollution that is relevant to the movement of on-road vehicles. This research is important for verification of national ambient air quality standards (NAAQS), especially at and near living places. Because NAAQ standards should follow at any place where people live in consideration of health effects related to traffic-related air pollution.

Keywords: Air Pollution, Road Emissions, NAAQS, Health Hazards.

1. Introduction

Road emission is a major source of air pollution that contributes health hazards. Emissions from road traffic are carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbons (HC), nitrogen oxides (NO_x), and particulate matter (PM). Among major sources of emissions, CO_2 and its equivalents are responsible for greenhouse gas (GHG) emissions, whereas others are treated as criteria pollutants. GHG emission is a global issue with long-term effects. However, criteria pollutants cause complications for those living near major urban roads.

This survey paper illuminates the available methodologies for estimation of roadside emissions and corresponding air pollution levels. Near-road air pollution levels are important for human health. Health problems from road traffic include the development of asthma in infants and children, worsening asthma symptoms for adults and the elderly, reduced lung function, lung cancer, heart disease, and increased risk of death due to heart diseases, reducing the average lifespan, and more.

Although the correlation between traffic-related air pollution and corresponding health effects is challenging, some tools have been developed by health scientists. The basic indication for protecting human health is that air pollution levels should not exceed the national ambient air quality standards (NAAQS). The sources of air pollution in residential areas near roads include road traffic and other sources. However, the major source of air pollution in these areas is road traffic.

The estimation of air pollution concentrations from road traffic is a complex phenomenon. It is easy to collect samples using pollution measuring devices, but this process is time-consuming and expensive. However, it does not solve the real-world problem, which involves estimating pollution concentrations

at the policy level. The only way to estimate air pollution levels for urban land use planning is simulation methods.
Some of researchers are limited their research with emission estimator, but some of are interested in air quality models. There are some models focused on chemistry of pollution, whereas few models are implemented to express pollution movement in spatially. The objective of this study is to methodology development at near road air pollution. To finalize the methodology, we used some keywords in search engine that helps to understand the available techniques in market. Among other key words in this survey paper, traffic-related exposures to primary emissions from motor vehicles were used. However, health related reports were taken consideration. The Health Effect Institute (HEI, 2010) reported specific scenarios with high densities of motor vehicles and people in urban settings. Studies examined gradients in pollutant concentration as a function of distance from busy roadways. These indicated exposure zones for traffic-related air pollution from major urban roads depending on the pollutants and the meteorological conditions. Therefore, estimation of air pollution levels surrounding to major urban roads through simulation for policy analysis are considered the main purpose of this paper.

2. Research on Transportation to Control Emissions and Environment

The emissions from motor vehicles dramatically vary with driving character. It is increases vividly during stop-and-go driving mission (Jayaratne, Wang, Heuff, Morawska, & Ferreira, 2009). In literature, driving mission implies that the motor vehicle was travelling at a steady speed; a stop was made at a crossing and then accelerated from the stopped position. Emissions were approximately 13 times higher at a crossing and then accelerated from the stopped position. Emissions were approximately 13 times higher for this stop-and-start mission than the condition where vehicles do not need to stop and they passed at their cruising speed without stopping. The authors also mentioned that the highest emissions occurred near the crossing in either side of the crossing, and the value was approximately 80 times higher than that at the cruising speed.
(Nijkamp, 1994) explored roads in terms of environmental sustainability, with particular emphasis on removing bottlenecks that prevent the achievement of policy objectives of reconciling the economic interests of the transport sector and environmental quality. Several arguments that were supported by empirical evidences from various countries are put forward to show current megatrends in transportation that are at odds with sustainable development and lead to high social costs. This research discussed a variety of policy strategies to improve the current situation.
Mobile Emission Assessment System for Urban and Regional Evaluation (MEASURE) approach reported to researchers and planners with a means of assessing motor vehicle emission reduction strategies (Bachman, Sarasua, Hallmark, & Guensler, 2000). They also compared MEASURE and MOBILE-5a software in terms of differences in their emission rates. In this comparison, the regional fleet distribution was used to estimate emissions for Interstate Highway Level of Service LOS-A to F. Mean emission rates in g/s were within 20% of each software for LOS A. They reported that MEASURE emission rates were 50% higher than for MOBILE for LOS B and C, and twice as high for LOS D and E. However, emission rates were back to within 20% for LOS F.
The authors explained the reasons for differences as follows. Since MEASURE's functions take into account the effect of accelerations at high speed, its emission rates were much higher for moderate congestion levels where high speeds and variable acceleration are experienced due to increased vehicle interaction. MEASURE has already shown to be capable of analyzing policies, because of the realistic

scenarios adopted in this model. As an example mentioned by the authors, MEASURE was already applied in Atlanta by the Georgia Department of Transportation to evaluate the emission impacts of proposed intelligent transportation systems (ITS) projects. As for emission studies, the authors noted that progress has been made in reduction of mobile emissions.

The multidisciplinary research was done recently that facilitated on characterizing ultrafine particles and other air pollutants in and around school buses. Their aim was to characterize UFP, PM2.5 (particulate matter ≤ 2.5 μm in aerodynamic diameter), and other vehicular-emitted pollutants in and around school buses on Interstate Highway (Freeway) 405 in Los Angeles, CA, USA (Zhu & Zhang, 2014). A total of 24 school buses were employed to identify particle number concentration (PNC), fine and UFP size distribution in the size range 7.6-289 nm, PM2.5 mass concentration, black carbon (BC) concentration, and carbon monoxide (CO) concentrations. Four sub-studies were conducted. These are noted below.

1. On-road measurement of in-cabin air pollutant levels;
2. Idling tests to quantify the contributions of tailpipe emissions from idling school buses to air pollutant levels in and around school buses under different conditions;
3. Evaluation of the performance of two retrofit systems, a diesel oxidation catalyst (DOC) muffler and a crankcase filtration system (CFS), on reducing tailpipe emissions and in-cabin air pollutant concentrations under idling and driving conditions; and
4. Test of high efficiency particulate air (HEPA) filter air purifier in order to evaluate the effectiveness of in-cabin filtration.

The characterization of pollutants and other observations drawn from the study were useful contribution to literature.

3. Methodologies for Estimation of Near-Road Air Pollution

A study by (Batterman, et al., 2014) developed and evaluated several metrics for characterizing exposure to traffic-related air pollutants for 218 residential locations that participated in the NEXUS epidemiology study conducted in Detroit. Exposure metrics included proximity to major roads, traffic volume, vehicle mix, traffic density, vehicle exhaust emissions density, and pollutant concentrations predicted by dispersion models. Information provided by the metric of kilometers traveled (VKT) per day within a 300 m buffer around each home, was reasonably consistent with the more sophisticated metrics. Dispersion model provided spatially and temporally resolved concentrations and the study method used separated concentrations attributable to traffic and other sources. The results suggested the potential for exposure misclassification and the need for refined and validated exposure metrics.

(Pandian, Gokhale, & Ghosal, 2009) researched urban air quality by emphasizing that composition of vehicles in the traffic stream among other factors affects vehicular emissions. They suggested that renewal of fleets, exclusive separate lane for buses, land use and traffic planning regulations might improve the air quality in urban areas. It can be appreciated that emission and flow models can be combined together for better estimates of emissions and may further be integrated with urban transportation and air quality planning system.

(Brown & Affum, 2002) assessed the environmental effects of road traffic plans. A travel demand model, often called TRAEMS (TRAnsport planning Add-on Environmental Modelling System), was used with the intent to obtain information for the design of transport networks that allow optimum and efficient movement of traffic. This paper reported the effect of constructing a bypass on the existing network. Results showed about 14.7% increase in vehicle kilometers traveled (VKT) between 1995 and

2011 with the construction of the bypass, whereas without bypass the VKT increased only 10.5%. The NOx emission increased due to an increase of VKT. However, the bypass scenario improved noise emission.

The air pollution and health impact in Malaysia is reviewed that attracted attention of the government regarding the growing environmental concerns (Afroz, Hassan, & Ibrahim, 2003). This is basically a review paper and it concentrated on several big cities in Malaysia and monitored most of the pollutants. It confirmed that about 82 percent of air emission sources were motor vehicles, so land transportation was noted as a big threat for health impact. The results show that restricted activity days accounted for about 79.3% of health damage cost while asthma attack contributed 10.7% to total health damage cost. Consequently, production opportunities were idled during workdays as workers were in the hospital and on sick leave. The total health damage cost was assessed to be significantly high and losses were estimated to be RM 4.3 million (approx. 1.02 million U.S. dollars).

Exposure models were studied by (Isakov, et al., 2009) with the capability to predict the distribution of personal exposures to pollutants of outdoor origin. A variety of inputs were used including air pollution concentrations, human activity patterns, such as the amount of time spent outdoors versus indoors, commuting, walking, and indoors time at home; micro-environmental infiltration rates; and pollutant removal rates in indoor environments. They presented a methodology for combining multiple types of air quality models and linked the resulting hourly concentrations to population exposure models in order to enhance estimates of air pollution exposures.

4. Involvement of Geo-Spatial Technology for Understanding the Propagation of Air Pollution Levels

The literature review indicates that most references are on traffic-related pollution. However, there is an evidence of application of GIS-based methodology to spatial distribution of emissions from a broader level inventory to gridded small area level (Dalvi, et al., 2006). The authors point out that their methodology makes it possible to distinguish between high and low emission regions at a finer scale than was possible with conventional methods. The results provide detailed information on emission "hot spots" and the relative contribution of various sources.

A GIS-based modeling approach MEASURE has reported that provides an idea to planners in respect of assessing motor vehicle emission reduction strategies (Bachman, Sarasua, Hallmark, & Guensler, 2000). MEASURE has shown its capability for analyzing policies, so that it is implemented by the United States Transportation Departments for reduction of mobile emissions. Authors expressed their view that there will be a need to gather comprehensive spatial and temporal distributions of emissions, especially for urban areas. For this purpose, they emphasized the role of GIS-based emissions modeling framework.

The effects of planning related to road traffic movements on environments were expressed using TREAMS model (Brown & Affum, 2002). This model is capable of enabling planners to test transport-related environmental impacts at the same time as they are testing the traffic carrying efficiencies of network plans. The results were demonstrated on the road networks of inner Brisbane City using GIS environment.

A research by (Wang, van den Bosch, & Kuffer, 2008) produced information in support of decision-making process, such as air quality impact analysis, and human health assessment. Their research study required spatial modeling of traffic-induced air pollution dispersion in urban areas at street level. The 3D

GIS environment enabled the visualization of pollution levels in the form of maps, in both planar and non-planar view. The visualization facility for better understanding by the planner improved interpretability. Hot spots, where the highest pollution occurs, were shown on a colour map. In non-planar view, variation in pollution was presented along building facades. Furthermore, researchers emphasised the incorporation of vertical dimension of an impact area, including the number of floors affected. The authors presented the variation of vertical pollution concentration using GIS environment in an Asian mega city.

The up-to-date vehicular emissions information provides to the decision makers in an easily understandable form by using GIS (Rebolj & Sturm, 1999). After the emissions were calculated, the dispersion of emitted substances was evaluated according to the dispersion model. The methodology produced results from crosswind distances away from the road. Based on the specific concentration of a specific substance, the visualization procedure interpolated the concentration buffer and generated a new polygon on the geographic map. This research suggests that overlay of relevant geographic themes with concentration buffer can be applied for evaluation of impacts of specific concentrations of specific substances on sensitive areas.

5. Overview of Available Air Pollution Models

The available air pollution exposure models that are used to study health effects are reviewed in this section. These models have their strengths and weaknesses in terms of technical, financial and temporal features. Most of the models are intended for use within cities. Surrogate measures, such as distance to roads, have been related to major health effects (Hoek, Brunekreef, Goldbohm, Fischer, & van den Brant, 2002). In the last part of this section, empirical comparisons are presented and future directions of research are noted.

5.1 Proximity Models

Proximity models usually enable a quick assessment of air pollution's health effect based on the closeness to the source of pollution. (Jerrett, et al., 2005) used buffers at different distances from major roads to assess distance decay of concentration (i.e. 0-50, 51-100, and 101-150 m). (English, et al., 1999) implemented a traffic emissions model and combined this with circular buffers around the subjects' home. A study on adult asthma in Hamilton by (Jerrett, et al., 2001b) found that women, aged 20-44 years, within 50 m of a major road were associated with a 50% increased risk of reporting asthma symptoms. Although the proximity model is popular within the research community, the main disadvantage of such models is that parameters affecting the dispersion and physicochemical activity of pollutants are not considered. These models are limited to the statistical association of traffic activity and possible risk of health effect.

5.2 Interpolation Models

Interpolation models based on deterministic as well as stochastic geo-statistical techniques are used to estimate the concentration of pollutants at sites other than the location of monitoring stations. The most common geo-statistical techniques used in the air pollution field are 'kriging' methods (Jerrett, et al., 2001a). These methods are known as optimal interpolators because of their best linear unbiased estimate (BLUE). (Mulholland, Butler, Wilkinson, Russell, & Tolbert, 1998) analysed the spatial and temporal distributions of ozone in the 20th-century. Atlanta metropolitan area used this technique to generate concentration levels over the study area. (Jerrett, et al., 2001a) modelled total suspended particulates (TSP) in Hamilton, Canada by using this technique. (Ritz, Yu, Chapa, & Fruin, 2000) applied a modified

Theissen triangulation for a number of pollutants to assess the health effects of pollution on pre-term birth in Southern California. They assigned pollution values to zip code locations within 3.2 km (2 miles) of the air quality monitor.

Interpolation techniques have an advantage over proximity models due to their use of real pollution measurements in their computation of exposure estimates. If implemented correctly, they can provide credibility to the analysis by quantifying the level of exposure difference between subjects and in computing dose-response relationships (Jerrett, et al., 2001b; Mulholland, Butler, Wilkinson, Russell, & Tolbert, 1998). These models are beneficial for estimating pollution concentration over several time intervals, subject to the availability of a number of measurement periods. For the implementation of a geospatial model, improved hardware, spatial statistics software, and appropriate expertise are mandatory. These requirements have cost implications and render these models to be most expensive among proximity models.

5.3 Land Use Regression Models

The land-use regression methodology provides an empirical approach for explaining and predicting pollution concentrations at a given site based on surrounding land use and traffic characteristics. Regression mapping is a practical approach for an assessment of exposure to traffic-related pollution (Briggs, et al., 1997; Lebret, et al., 2000). A calibrated least-squares regression model can predict pollution surfaces. For calibrating such a model, pollution monitoring data and existing exogenous independent variables are essential. Two studies (Briggs, et al., 1997; Lebret, et al., 2000) were carried out as a part of the Small Area Variation in Air pollution Health (SAVIAH) Project that examined traffic-related air pollution in four European cities (Amsterdam, Huddersfield, Prague, Poznan). A revised model described by (Briggs, et al., 1997) was employed to investigate traffic-related air pollution in four UK urban areas (Huddersfield, Hammersmith and Ealing, Northampton, and Sheffield).

The cost of developing land-use regression models is higher than for other models reviewed earlier. Once calibrated, these are relatively inexpensive to implement and can provide reliable estimates of traffic-related air pollution when adequate land use, transportation, and pollution monitoring data are available. The limitation of the regression model arises from its area-specificity. Moreover, (Briggs, et al., 1997) have argued that it is possible to pool effects into a random effects framework within areas of relative homogeneity of land use, meteorology, and vehicle mix.

5.4 Dispersion Models

Literature sources serve as good practice guide for atmospheric dispersion modelling (MoNZ, 2004). Likewise, on the related subject of air pollution exposure models, literature sources are available on model review and evaluation (Jerrett, et al., 2005).

In this research study, it was considered essential to decide on the use of a Gaussian plume model or a street canyon model or a Computational Fluid Dynamics (CFD) model for the dispersion part of the study. The strengths and weaknesses of each approach were studied and it was decided that due to the worst-case condition philosophy which in part is based on very calm wind speed, the canyon and CFD models were not applicable. Therefore, software containing the Gaussian plume model was selected for use in this research study.

Most dispersion models are based on Gaussian plume equations (Bellander, et al., 2001). In their formulation, the following are the variables: deterministic processes making use of data on emissions, meteorological conditions, and topography. Their outputs are spatial exposure estimates of air pollution concentrations. In recent research and applications, dispersion models are popular due to their conjunction with GIS. When these models use the topography of the study area, an abstraction of the road network and its traffic is formed, which is a more realistic representation of the area. Available sources indicate that these models have been used for different kinds of pollutants such as TSP (Bartonova, et al., 1999), nitrogen oxides (NO_2) (Bellander, et al., 2001; Bartonova, et al., 1999) and CO (Benson, 1989).

The Integrated Model of Urban Land-use and Transportation for Environmental analysis (IMULATE) was used to estimate CO, NO_2, and hydrocarbon (HC) emissions from passenger cars for all the links of the transportation network of Hamilton, Ontario (Anderson, Ponce de Leon, Bland, Bower, & Strachan, 1996). This study estimated traffic volumes at the link level and then used MOBILE5C through an automatic interface to transform traffic volumes into emissions. The MOBILE5C is the Canadian equivalent of MOBILE5 that was developed by US Environmental Protection Agency. (Potoglou & Kanaroglou, 2002) applied the emissions outputs of IMULATE model in the California Line Source Dispersion model (CALINE) and displayed the results using GIS software.

The resulting receptor locations, derived from the (Anderson, Ponce de Leon, Bland, Bower, & Strachan, 1996) study's emission estimates were displayed by applying a weighted kernel estimate to the CALINE output to show a density of emissions in part per billion per square kilometre. A follow-up study of 16,209 men reported by (Nafstad, et al., 2003) found an increased risk of lung cancer for a 10 $\mu g/m^3$ increase in NO_2 at the home address. Based on results, they concluded that urban air pollution might increase the risk of developing lung cancer.

In a 2015 paper, Shekarrizfard and Hatzopoulou presented an application of fine-scaled dispersion modelling method. Their study used a site in Montreal to model NOx by using a transportation and emissions model. They found a reasonable performance of the dispersion model with 0.77 correlations between simulated and observed concentrations in January.

Although the canyon model and the CFD mode are not used in this research, a brief introduction is provided for the information of the reader. These models calculate emissions per street section. An approach is developed that links the multi-agent based transport model (MATSim) with the calculation of air pollution using the Operational Street Pollution Model (OSPM). CALPUFF calculates emissions per street section based on dispersion modelling with consideration of spatial resolution of land uses. It considers complex building structures in urban areas and therefore air circulation effects due to urban land uses are taken into account. However, in this research, due to worst-case condition of very calm wind, this model is not of assistance (Hulsmann, Gerike, & Ketzel, 2014).

The Computational Fluid Dynamics (CFD) model can represent canyon effects. The choice of CFD approach (mainly the Reynold-Averaged Navier-Stokes (RANS) and Large-Eddy Simulation (LES) model) depends on the computational cost, the accuracy required and hence the application context (Cai, 2012). However, given the very calm wind conditions to be modelled in this research, the use of the CFD model cannot be justified.

A review of modelling air quality in street canyons is presented by (Vardoulakis, Fisher, & Gonzalez-Flesca, 2014). Their approach is applicable to high pollution levels that can be experienced in conditions of reduced natural ventilation due to very high-density land uses and high traffic conditions. Since these conditions do not fully apply to this research, this modelling approach is not of immediate interest.

5.5 Integrated Meteorological-Emission Model

In integrated meteorological-emission (IME) models, meteorological data can be applied to the chemistry modules at every time step of a simulation. However, due to their high implementation cost, data requirements, and complexity, IME models have not been used for studies attempting to link air quality to health in spite of their considerable potential, especially for highly populated areas. An example of IME modelling framework is United States' CALPUFF (Scire, Robe, Fernau, Insley, & Yamartino, 1997). The advantages of integrated meteorological-emission model over dispersion model have been recognized as the capability to incorporate chemical transport of pollutants and the ability to represent complex pollutant pathways that lead to secondary pollutants, such as ozone and secondary particles.

Dispersion models and IME models are considered more sophisticated and reliable than other models. These models can be used at the regional and the intra-urban scale. Their applications call for substantial amount of data on emissions and meteorology. In addition, these models require improved management tools, specialized software (i.e., GIS, dispersion software, and their integration) and computer hardware that are capable of handling, storing and processing these data. Furthermore, there is a need for specialized personnel trained in GIS, statistics, mathematics, and computer science. Given these requirements, their cost of implementation is significantly higher than for other models.

5.6 Hybrid Models

Hybrid models combine personal/household or regional level exposure monitoring with other air pollution exposure models. At the detailed level, personal monitoring enables a direct measurement of exposure subjects to air pollutants. This is a very useful attribute. However, the drawback of such models is the high cost of implementation. For this reason, personal monitoring is often used within a "hybrid framework" as a complement to one of the other model types. Most studies that used these models were conducted at intra-urban scale (Liu, Delfino, & Koutrakis, 1997). Some studies have used personal monitoring methods in conjunction with fixed outdoor stations to compare their difference in derived health outcomes (Liu, Delfino, & Koutrakis, 1997; Kramer, Koch, Ranft, Ring, & Behrendt, 2000; Mukala, et al., 2000).

As for methodology, these empirical models employed a mixture of multiple linear (Liu, Delfino, & Koutrakis, 1997; Mukala, et al., 2000) and logistic regressions (Kramer, Koch, Ranft, Ring, & Behrendt, 2000) to link exposure estimates to health outcomes. Schoolchildren are the primary receptor groups with the exception of the work done by (Liu, Delfino, & Koutrakis, 1997), which treated children and adults as a collective group.

6. Comparison of Methods and Conclusion

Source-activity indicators based modelling approaches are commonly used on traffic and road characteristics those compared for estimation of PM_{10} and NO_2 concentrations (de Hoogh, Gulliver, Briggs, & Mitchell, 2002). In the case of proximity measure and regression approach, 30% were classified in the same quintile, while 26% of the sites were similarly classified for proximity and dispersion approaches. Only 30% of the postal codes were classified within the same quintile when comparing regression and disruption approaches. The highest comparability was found at 68% for dispersion modelled NO_2 and PM_{10}.

(Collins, 1998) calculated an annual mean of NO_2 at eight monitoring locations and then calculated mean pollution values from 80 monitoring sites, but excluded those eight permanent locations. The data enabled comparisons of the NO_2 pollution surfaces estimated using kriging, hybrid and land-use regression techniques. Her analysis revealed that land-use regression techniques predicted NO_2 levels most accurately with an R^2 of 0.82, compared to kriging and a hybrid approach yielded R^2 of 0.44 and

0.63, respectively.

On the basis of the current state of knowledge of intra-urban (i.e., within city scale) air pollution assessment, (Jerrett, et al., 2005) evaluated models and found a growing emphasis on increasingly sophisticated land use, dispersion, and integrated meteorological models. Beyond refinements in these models, researchers suggested the need for more research in three areas: (1) remote sensing models, (2) mobility or activity-space analysis, and (3) personal monitoring to cross validate estimates and improve understanding of the role that measurement errors play in risk assessment models.

If accuracy and cost factors are favorable, remote sensing for exposure assessment appears to be a promising avenue to implement extensive ground monitoring programs. This method relies on high-resolution satellite observations in combination with existing fixed-site monitoring stations. Mobility or activity-space analysis is an interesting area of research. Time–activity studies have found that individuals spend an average of about 66% of their time at their residential location (Leech, Nelson, Burnett, Aaron, & Raizenne, 2002). However, an important question remains, "where" individuals spend the rest of the time? A related question is that who is likely to be impacted during temporal peaks in air pollution (e.g., during p.m. peak travel period). Potentially, a detailed study of "spatial and temporal" facets of human activities may lead to answers to some of these concerns. Although the daily averages correlate highly with central monitor estimates, site-specific comparisons are desirable (Mage, Wilson, Hasselblad, & Grant, 1999).

A study of air quality assessment, namely CO pollutant, was carried out in 2003 for Lisbon at the local scale. The analysis interlinked two numerical tools (i) the Transportation Emission Model for Line Sources (TREM) and (ii) the Local Scale Dispersion Model (VADIS) (Borrego, Tchepel, Costa, Amorim, & Miranda, 2003). Another Lisbon air quality management study applied integrated modelling approach to road traffic emissions. The integrated models include VISUM (applied to private and public transport), TREM and Variable Dispersion (VADIS) model for characterizing the traffic fluxes, to quantify the emission amounts, and finally to evaluate the air quality (Borrego, et al., 2010).

The review of literature suggests that the state of knowledge in modelling pollution dispersion and population exposure within GIS environment has advanced to a sufficient degree. An introductory research study to integrate traffic, emissions, and dispersion processes was reported by (Ma, Huang, & Koutsopoulos, 2014). They describe a common distributed computational framework that makes it efficient to quantify and analyze correlations among dynamic traffic conditions, emission impacts, and air quality consequences. A model calibration approach is proposed in this paper. (Amirjamshidi, Mostafa, Misra, & Roorda, 2013) have reported an integrated model for micro-simulating vehicle emissions, pollution dispersion and population exposure. The above literature reviews helped in defining the research framework and methodology development.

REFERENCES

2. Afroz, R., Hassan, M. N., & Ibrahim, N. A. (2003). Review of air pollution and health impacts in Malaysia. *Environmental Research, 92,* 71-77.
3. Amirjamshidi, G., Mostafa, T., Misra, A., & Roorda, M. J. (2013). Integrated Model for Microsimulating Vehicle Emissions, Pollutant Dispersion and Population Exposure. *Transportation Research Part D: Transport and Environment, 18(1),* 16-24.
4. Anderson, H. R., Ponce de Leon, A., Bland, J. M., Bower, J. S., & Strachan, D. (1996). Air pollution and the daily mortality in London. *BMJ Journals, 312,* 665-669.

5. Axhausen, K., Scott, D., Konig, A., & Jurgens, C. (2001). *Locations, Commitments and Activity Spaces.* Swiss Federal Institute of Technology: Bonn.
6. Bachman, W., Sarasua, W., Hallmark, S., & Guensler, R. (2000). Modeling regional mobile source emissions in a geographic information system framework. *Transportation Research Part C: Emerging Technologies, 8(1-6),* 205-229.
7. Bartonova, A., Clench-Aas, J., Gram, F., Gronskei, K. E., Guerreiro, C., & Larssen, S. (1999). Air pollution exposure monitoring and estimation traffic exposure in adults. *Journal of Environ. Monit., 1(V),* 337-340.
8. Batterman, S., Burke, J., Isakov, V., Lewis, T., Mukherjee, B., & Robins, T. (2004). A Comparison of Exposure Metrics for Traffic-Related Air Pollutants: Application to Epidemiology Studies in Detroit, Michigan. *Int. J. Environ. Res. Public Health, 11(9),* 9553-9577.
9. Bellander, T., Berglind, N., Gustavsson, P., Jonson, T., Nyberg, F., & Pershagen, G. (2001). Using geographic information systems to assess individual historical exposure to air pollution from traffic and house heating in Stockholm. *Environ Health Perspective, 109(6),* 633-639.
10. Benson, P. (1989). *CALINE4 - a dispersion model for predicting air pollutant concentrations near roadways.* California: California Department of Transportation. Report no. FHWA/CA/TL-84/15.
11. Borrego, C., Tchepel, O., Costa, A., Amorim, J., & Miranda, A. (2003). Emission and dispersion modelling of Lisbon air quality at local scale. *Atmospheric Environment, V.37, Issue 37,* 5197-5205.
12. Borrego, C., Tchepel, O., Salimim, L., Amorim, J., Costa, A., & Janko, J. (2010). Integrated modeling of road traffic emissions: application to Lisbon air quality management. *Cybernetics and Systems, Taylor and Francis.*
13. Briggs, D., Collins, S., Elliott, P., Fischer, P., Kingham, S., & Lebret, E. (1997). Mapping urban air pollution GIS: a regression-based approach. *Int. J. Geogr. Inf. Sci., 11(7),* 699-718.
14. Brown, A. L., & Affum, J. K. (2002). A GIS-based environmental modelling system for transportation planners. *Computers, Environment and Urban Systems, 26,* 577-590.