Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268 e-ISSN: 2395-3454	Vol. 16	No. 3	pp. 727-736	2017

Original Research Paper **Open Access**

Prioritizing Environmental and Transportation indicators in Global Smart Cities: Key Takeaway from Select Cities Across the Globe

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 02-01-2017
Accepted: 09-03-2017

Key Words:
Sustainability
Smart City
Urban town planning
Transportation
Quality of life
Accident fatalities

ABSTRACT

Over 53.85% of the world population lives in urban areas, which is expected to reach 66% by 2050. Cities being predominant centers of human settlement and activity, are a major driver of economic growth. Thus, the development of citizen friendly, economically viable and sustainable cities gain immediate importance. City transportation is considered a key pillar of quality of life for citizens in a city and today a smart, safer and faster transportation seems inevitable to steer towards enhancing the performance of city services and quality of life. However, without a safe mobility, "smartness" in city transportation is bound to remain a distant dream. The findings of the study indicate that air pollution in terms of particulate matter (PM10, PM2.5) is found to be a significant factor related to transportation related fatalities in select cities across the globe aiming to become smart cities. Out of these, PM10 is found to be of major importance. Incidentally, contrary to the popular belief, the usage of public transportation is not found to be a significant factor in determining transportation related fatalities. These insights also act as a key take-away and a replicable model for other cities across the globe aiming for becoming smart cities. This is particularly important in view of the "Smart City Mission" recently launched by the Hon. Prime Minister of India Shri. Narendra Damodardas Modi aiming at developing/transforming 100 cities as smart urban settlements in India.

INTRODUCTION

Despite ongoing debates about the future of urban development in many western countries been increasingly influenced by discussions of smart cities, yet surprisingly little is known about so called smart cities, particularly in terms of what the label ideologically reveals as well as hides (Hollands 2008). It is cited that there are over three hundred city-regions around the world with population greater than one million, which are expanding vigorously, presenting many new and deep challenges to researchers and policy-makers in both the more developed as well as the less developed parts of the world (Scott 2002). An analysis (Delmelle et al. 2014) highlights the importance of potential land-use policies, especially densification, when a balance between urban development, environment preservation, energy savings, and the achievement of quality of life for current and future generations are concerned. The processes of global economic integration and accelerated urban growth make traditional planning and policy strategies in these regions increasingly inadequate (Scott 2002). Undoubtedly, cities across the globe, as predominant centers of human settlement and activity, are a major driver of economic growth. In 2013, a survey of 1000 global CEOs, from 27 industries across 103 countries, supported by indepth interviews with more than 75 CEOs globally - the largest study to date, revealed that the corporate sustainability movement is broadening, with a deeper awareness and commitment evident in every quarter of the world (Hayward et al. 2013). As per the World Bank statistics of 2015, mother earth harbors nearly 54% of the human population as urban population (Word Bank Data 2015). In the current ongoing debates and UN's projections (Horsley et al. 2016), it is expected that by the year 2050 about 66% of the global population shall be living in cities. Crude oil, coal and gas have been the main resources for world energy supply (Shafiee & Topal 2009) and these fossil fuels, driving economic growth , are getting depleted rapidly. Thus, development of citizen friendly, economically viable and sustainable cities with sustainable production and consumption patterns gains immediate importance. Towards this effect, the concept of " Smart Cities" has gained prominence and immense relevance across the globe. Making a city "smart" is emerging as a strategy to mitigate the problems generated by the urban population growth and rapid urbanization. Yet little academic research has sparingly discussed the phenomenon (Chourabi et al. 2012). Also, inner-city children have high rates of asthma and exposures to particles, including allergens, may cause or exacerbate asthma symptoms (Wallace et al. 2003).

City transportation is considered a key pillar of quality of life for citizens in a city. Currently, commutation and logistics in most of the cities are dominated by public and private road transportation mode. Some large and mega cities have metro and local train network as the backbone transportation mode. Hitherto the focus of transportation has mainly been on faster movement across a city. Amidst attempts to make our cities smart in sync with theme of sustainable development, today a smart, safer and faster transportation seems inevitable to steer towards enhancing the performance of city services and quality of life. However, without a safe mobility, "smartness" in city transportation is bound to remain a distant dream. Smart cities require smart transportation (Glancy 2013). On one hand, pedestrians and bicyclists are the victims of countless car crashes in U.S. cities as well as around the world (Delmelle & Thill 2012). The traffic safety studies have underscored the hazardous conditions of pedestrians in developed countries such as the United States, which calls for increased public awareness of the pedestrian safety issue and better knowledge of the main factors contributing to traffic hazard for urban pedestrians (Ha &Thill 2011). On the other hand, in developing countries with densely populated cities, accident and fatality rates are among the highest in the world, mainly affecting the economically backward and vulnerable who lack their own means of transportation. Some 600 million people are expected to be living in India's cities by 2031, as per a World Bank study. Currently only about 20 Indian cities with populations over 500,000 have any kind of organized public transport systems (Prabhakar et al. 2015). Rather, the share of public transport in large Indian cities has actually declined from some 70 % to almost 40 % during 1994-2007. Furthermore, India's accident and fatality rates are among the highest in the world, mainly affecting the poor and vulnerable who do not have their own means of transportation (Prabhakar et al. 2015). Thus, human life imperatively demands the highest priority in city planning by municipalities or local governments. In the light of all these and a constructive drive for progressive change, this work seeks to assess some of the important dimensions of "smartness" in transportation, eventually targeting transformation of the lives and living conditions of the fellow countrymen.

OBJECTIVE OF THE STUDY

a. To determine some of the accepted important indicators of transportation for a smart city with a focus on transportation fatalities.

b. To determine some of the accepted key indicators of environmental pollution (primarily air) for a smart city.

c. To assess the relationship between transportation fatalities (dependent variable) and core transportation related indicators (independent variables) of a smart city coupled with standard environmental (primarily air) pollution indicators (independent variables) to determine the significant factors related to the transportation fatalities and other insignificant factors.

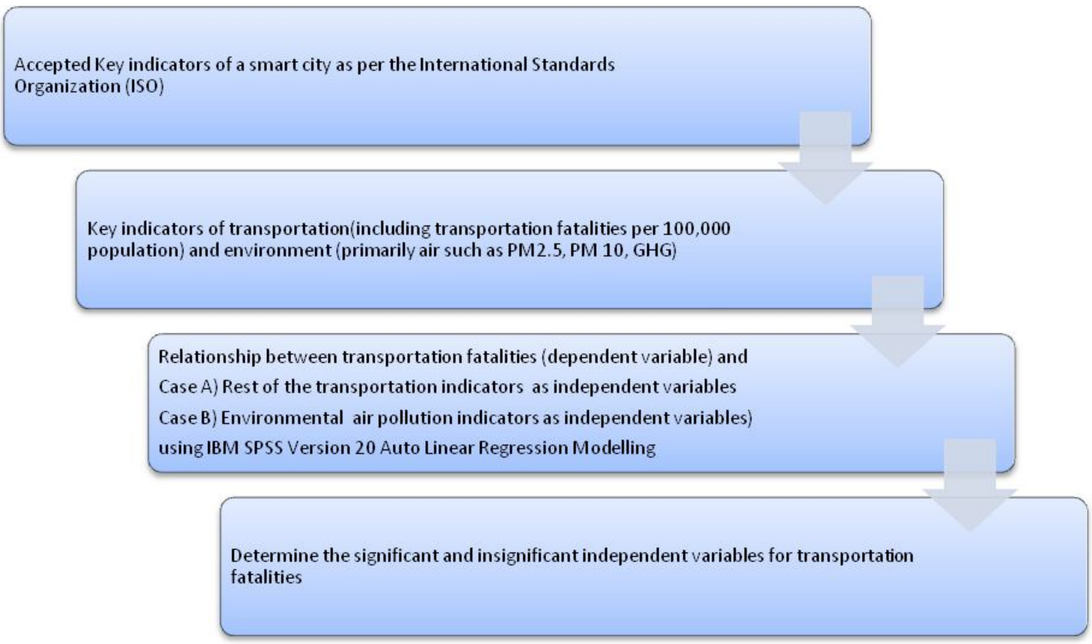


Fig. 1: Research methodology.

Table 1: Cities considered in the study.

S. No.	City	S. No.	City	S. No.	City
1	Helsinki	11	Haiphong	21	Saint-Augustin-De-Desmaures
2	London	12	Shanghai	22	Shawinigan
3	Amsterdam	13	Taipei	23	Vaughan
4	Rotterdam	14	Makati	24	Surrey
5	Barcelona	15	Melbourne	25	Toronto
6	Valencia	16	Greater Melbourne	26	Boston
7	Porto	17	Minna	27	Los Angeles
8	Amman	18	Johannesburg	28	San Diego
9	Makkah	19	Bogota	29	Leon
10	Dubai	20	Buenos Aires	30	Guadalajara

Fig. 2: Cities considered in the study.

If we could reliably establish cause and effect relationship between transportation fatalities and other indicators as above, in order to determine which of these are major drivers of transportation fatalities out of the above listed indicators, it could help the policy makers and city planners to prioritize indicators for a safe transport for a smart city.

METHODOLOGY

A sample of 30 cities (convenience sampling) across the globe aiming to become smart cities are considered and secondary data for their key transportation (including transportation fatalities) and environmental pollution (primarily air pollution) parameters collected from published reliable resources. This secondary data are utilized to assess the relation between the transportation fatalities as dependent variable and the various other transportation related indicators and environmental air pollution indicators as dependent variables to determine the significant factors. Towards achieving this end, the collected secondary data for these 30 cities are regressed using IBM SPSS Statistics Version 20 software. The attempt is towards assessing a first-hand relationship between transportation fatalities and standard environmental (primarily air) pollution indicators coupled with the use of public transportation from select cities across the globe. The aim is to highlight these as priority indicators and a take-away for policy makers and city planners targeting safe transportation in the near future. For establishing a cause and effect relationship between the key indicators of transportation and environment schematic as listed in Table 1. Linear regression analysis through SPSS (independent method: stepwise; regression coefficients : estimates, model fit, descriptives part and partial coefficients) is performed with “transportation fatalities per 100,000 population per year (f)” as the dependent variable and other indicators of city transportation and subsequently the listed environmental indicators (PM 2.5, PM 10 & Green

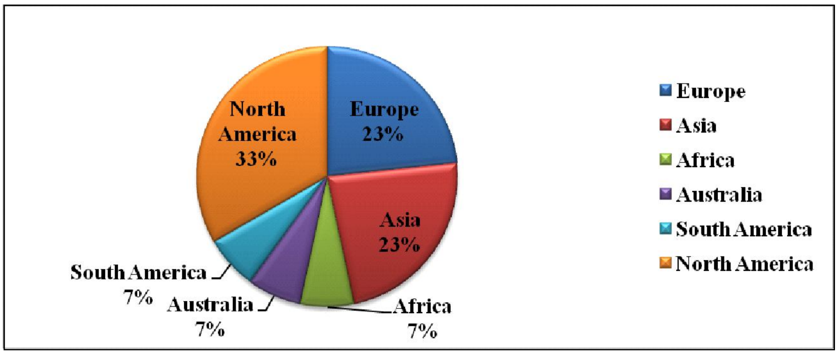


Fig. 3: Distribution of cities sample across the continents.

Table 2: Metrics for transportation and environment in cities.

Thematic	Core Indicators	Supporting Indicators
Transportation	km of high capacity public transport system per 100,000 Population (h) km of light passenger transport system per 100,000 population (l) Annual number of public transport trips per capita (p) Number of personal automobiles per capita (a)	Percentage of commuters using a travel mode to work other than a personal vehicle (o) Number of two-wheeled motorized vehicles per capita (m) Km of bicycle paths and lanes per 100,000 population (b) Transportation fatalities per 100,000 population per year (f) Commercial air connectivity per year (c)
Environment	Fine Particulate Matter (PM2.5) Concentration μg/m^3 Fine Particulate Matter (PM10) Concentration μg/m^3 Greenhouse Gas (GHG) Emissions in tonnes per capita	NO_2 Concentration SO_2 Concentration O_3 Concentration Noise Pollution % change in number of native species

(Reference: International Standards Organization, 2014)

House Gases GHG) as the independent variables. The entire process is indicated in Fig. 1.

SAMPLE SIZE

The sampling frame is a city. Based on convenience sampling, the foundation cities featuring in the World Council on City Data (WCCD) Global Cities Registry™, the 30 cities across the globe listed in Table 1 and Fig. 2, have been considered for the study.

ANALYSIS

"Smart city" is a buzz word these days. A city can be called a "smart city" if it provides its residents with a smart, connected urban mobility system which can improve their quality of life (Bansal 2015).

As shown in Fig. 3, out of the 30 cities, 7 belong to European continent, 7 belong to Asia, 2 are from Africa, 2 are from Australia, 2 are from South America and 10 are from North America. Thus, an attempt has been made for an assessment on a global perspective.

In recent times, there have been sincere attempts by the International Standards Organization (ISO) to define and establishes methodologies for a set of indicators targeting sustainable development of communities to steer and measure the performance of city services and quality of life. Applicable to any city, municipality or local government, attempt is to measure its performance in a comparable and verifiable manner, irrespective of size and location. ISO Technical Specification ISO/TS 37151 also lists 14 categories of basic community needs such as products and services geared at improving community infrastructures such as energy, water, transportation, waste and information and communication technology systems. Thus, transportation is an integral focus area for city smartness. However, safe transportation is paramount for any smart transport assessment in a smart city. Few of the transportation and environment as key themes associated with the core and supporting indicators are given in Table 2.

Table 3: Descriptive statistics.

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
KM_High_Cap_Pub_Tpt	27	102.87	.00	102.87	10.8526	3.86700	20.09352	403.749
Km_Light_Psngr_Tpt	27	290.32	3.25	293.57	122.2941	16.81357	87.36585	7632.792
Pub_Tpt_Trips	26	2094.96	2.29	2097.25	318.0950	87.40106	445.65969	198612.563
Personal_Auto	28	.74	.01	.75	.3821	.04234	.22404	.050
Percntg_Non_Personal _Travel	22	87.80	.00	87.80	42.1186	5.32862	24.99343	624.671
Two_wheeled_motorized	26	.46	.00	.46	.0585	.02147	.10950	.012
Km_bicycle_paths	27	176.05	.00	176.05	41.1800	10.19413	52.97025	2805.847
Trnsprtn_fatalities	26	41.33	.00	41.33	5.0665	1.56447	7.97727	63.637
Commercial_Air_ Connectivity	23	462785. 00	.00	462785. 00	146065. 9783	25807. 02487	123766. 14341	153180 58253.693
PM25	27	51.80	4.80	56.60	18.3611	2.67963	13.92376	193.871
PM10	25	155.00	11.00	166.00	42.0244	7.23622	36.18109	1309.071
GHG	26	45.34	2.17	47.51	9.6642	2.20100	11.22296	125.955
NO_2	26	43.00	9.00	52.00	31.2046	2.28451	11.64876	135.694
SO_2	25	63.00	.00	63.00	10.4260	3.02477	15.12387	228.731
O_3	24	81.00	.00	81.00	45.8479	3.75399	18.39071	338.218
Noise	12	80.47	13.53	94.00	48.2383	7.22813	25.03896	626.950
Prcntg_chng_native_species	10	5.65	.00	5.65	.7950	.58587	1.85269	3.432
Valid N (listwise)	7							

Table 4: Transportation indicators considered in the study.

Thematic	Dependent Variable	Independent Variables
Transportation	Transportation fatalities per 100,000 population per year (f)	km of high capacity public transport system per 100,000 population (h) km of light passenger transport system per 100,000 population(l) Annual number of public transport trips per capita (p) Number of personal automobiles per capita (a) Percentage of commuters using a travel mode to work other than a personal vehicle (o) Number of two-wheeled motorized vehicles per capita (m) Km of bicycle paths and lanes per 100,000 population (b) Commercial air connectivity per year (c)

The descriptive statistics, for the parameters listed in Table 2, for the 30 cities under study are given in Table 3.

1. According to it, on an average, 5.0665 transportation fatalities occur per 1,00,000 population per year with a standard deviation of 1.56447. Similarly the mean values of other indicators are given in Table 3.
2. Number of two-wheeled motorized vehicles per capita with a mean of 0.0585 has the least variance of 0.012 followed by number of personal automobiles per capita with a mean of 0.3821 and a variance of 0.050. Seemingly, on an average, very few people keep two wheeled motorized vehicles or personal automobiles in these cities.
3. The commercial air connectivity per year shows the highest variance followed by annual number of public transport trips per capita.

Now, the cases A & B as indicated in Fig. 1, were analyzed one by one to assess the relationship between the dependent and the independent variables.

***Case A*:** In case A linear regression model, the transportation fatalities per 100,000 population is considered as a dependent variable and the rest of the transportation indicators considered as independent variables as indicated in Table 4. The aim is to attempt assessing whether transportation fatalities can be significantly explained by parameters such as those related to high capacity public transport, light passenger transport system, annual number of public transport trips, number of personal automobiles per capita, usage of non-personal travel modes, two-wheeled motorized vehicles, bicycle paths and lanes and commercial air connectivity. The results of the model are given in Table 5 and Fig. 4, which indicate that none of the effects were found to be significant ($p<0.05$) and as such only 5.8% variation in trans-

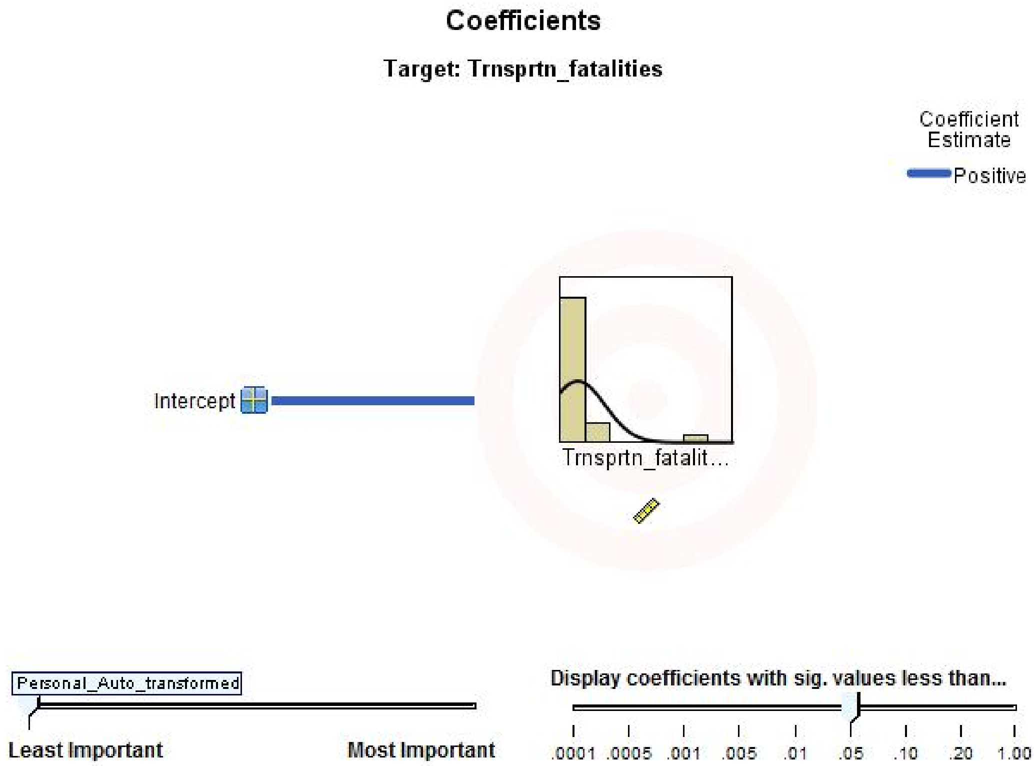
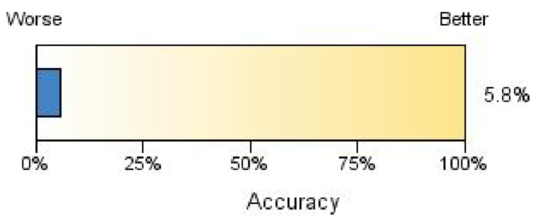


Fig. 4: Coefficients of various variables considered in the model.

Table 5: Model summary.

Target	Trnsprtn_fatalities
Automatic Data Preparation	On
Model Selection Method	Forward Stepwise
Information Criterion	108.881

The information criterion is used to compare the models. Models with smaller information criterion values fit better.



portation fatalities per 100,000 population is explained.

***Case B*:** In case B linear regression model, the transportation fatalities per 100,000 population is considered as a dependent variable and the environmental (air) pollution related indicators considered as independent variables as shown in Table 6. The aim is to attempt assessing whether transportation fatalities can be significantly explained by parameters such as those related to fine particulate matter, greenhouse gas, nitrogen dioxide, sulphur dioxide, ozone and noise pollution.

The results of the model are given in Table 7- 8 and Figs. 5-7.

i. The model is able to explain 68.3% of the variance in the value of transportation fatalities per 100,000 population per year as given in Table 6. Also, the predicted and observed values are close, as indicated in Fig. 5.

ii. While particulate matter PM10 is the most important estimator, PM2.5 is the least important parameter as shown in Fig. 6. Other estimators are insignificant at $p<0.05$.

iii. There are two outliers (record no. 9 i.e., Makkah and record no. 8 i.e., Amman) as indicated in Table 8.

iv. The coefficient for PM10 transformed is positive (0.317) while that for PM2.5 transformed is negative (-0.375). With increased population, higher vehicular traffic and traffic congestions are likely. This is further to result in increase of air pollution as represented by PM10 and PM2.5 values and increased probability of transportation related fatalities. With higher value of PM2.5, the

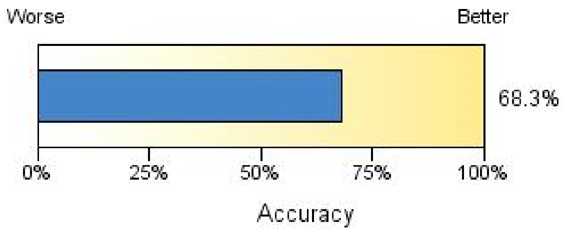
Table 6: Transportation and environmental pollution indicators considered in the study.

Thematic	Dependent Variable	Independent Variables
Transportation Environment	Transportation fatalities per 100,000 population per year(f)	Fine Particulate Matter (PM 2.5) Concentration μg/m^3 Fine Particulate Matter (PM 10) Concentration μg/m^3 Greenhouse Gas(GHG) Emissions in tonnes per capita NO_2 Concentration SO_2 Concentration O_3 Concentration Noise Pollution

Table 7: Model summary.

Target	Trnsprtn_fatalities
Automatic Data Preparation	On
Model Selection Method	Forward Stepwise
Information Criterion	82.053

The information criterion is used to compare the models. Models with smaller information criterion values fit better.



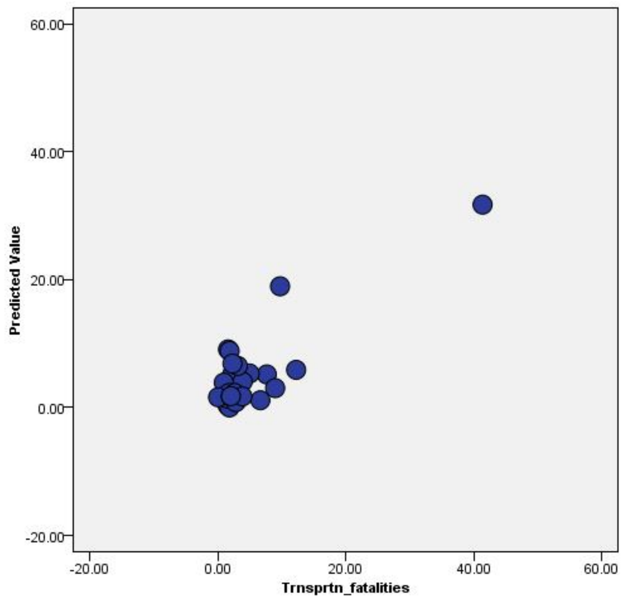


Fig. 5: Predictor importance.

Table 8: Outliers (Target: Transportation fatalities per 100,000 population per year).

Record No.	Trnsprtn_fatalities	Cook's Distance
9	41.33	10.994
8	9.70	0.518

Records with large Cook's distance values are highly influential in the model computations. Such records may distort the model acuracy.

citizens probably like to stay indoors and hence a reduction in the transportation fatalities.

ASSUMPTIONS/LIMITATIONS

1. The work is meant to conceptualize a framework and use it to explore/prioritize indicators of safe transportation for a smart city.
2. Pollution in selected cities assumed to be majorly contributed by commercial, institutional and household fuel combustion and agriculture.
3. Pollution through other modes such as from industries in the selected cities, assumed constant (no major variance expected).
4. Calculations are based on published data and information available.
5. All sources of data/information not independently verified.
6. Apart from the considered variables, effect of other variables (eg. confounding variables) considered under control/constant or ignored.
7. Normal conditions such as normal temperature and pressure considered as under which the observations/data/information has been taken.
8. A sample cannot always represent the whole population.
9. Resource (esp. time and money) constraints.
10. Limited data availability.

RESULTS AND CONCLUSIONS

Air pollution in terms of particulate patter (PM10 and

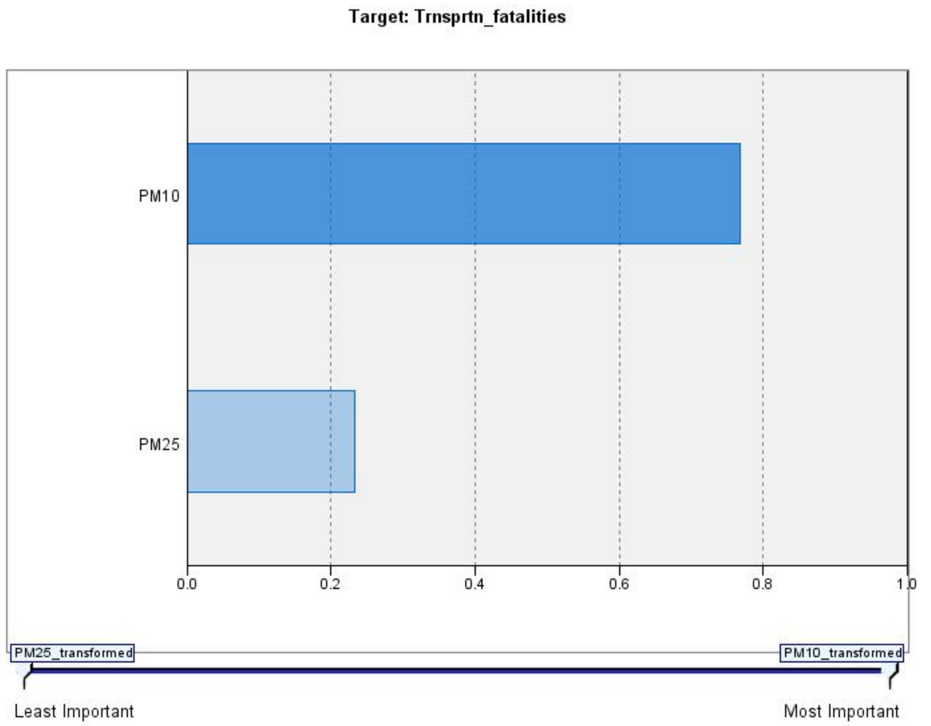


Fig. 6: Predicted by observed (Target: Transportation fatalities per 100,000 population per year).

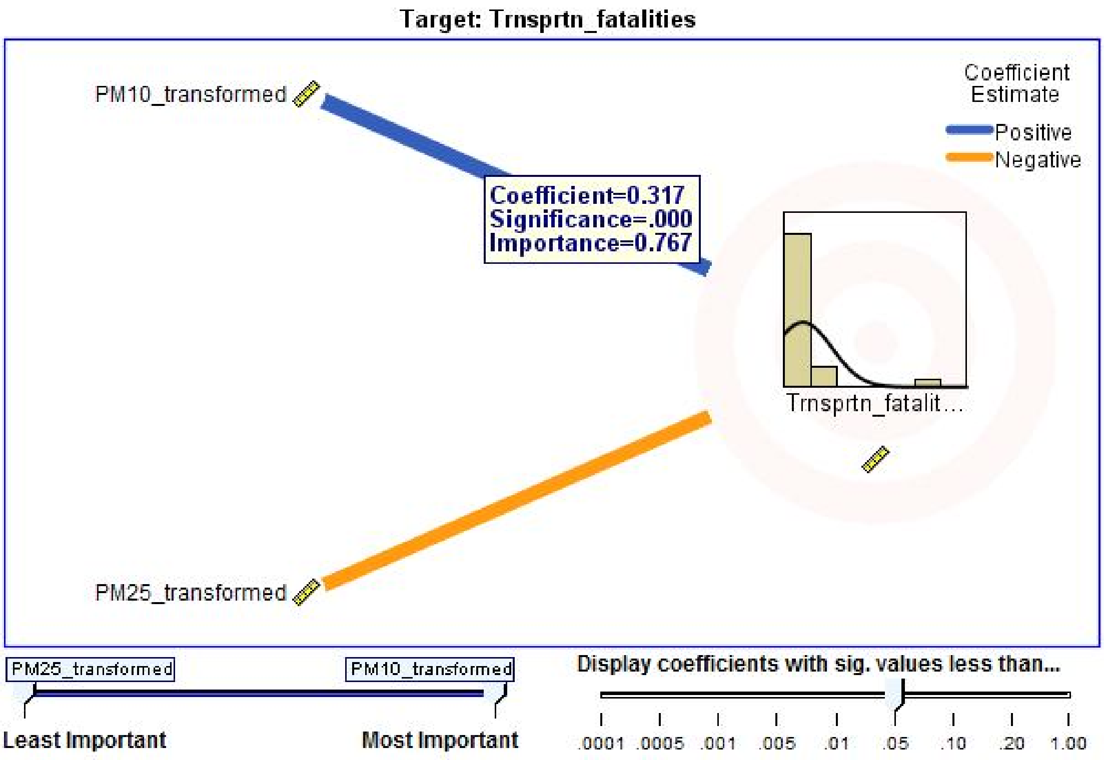


Fig. 7: Coefficients at p<0.05 (PM_10 Transformed 0.317, PM 2.5 Transformed -0.375).

PM2.5) is found to be a significant factor in determining transportation related fatalities in the select cities across the globe. However, vehicular traffic is not found to be a major contributor to the air pollution (PM 2.5 and PM10 levels) indicating other sources e.g., industrial pollution contributing to this air pollution. Driving in polluted environment (air) affecting the mental alertness/ concentration levels during commuting-driving/cycling/ walking and recovery post accident coupled with lack of awareness of traffic/safe driving/cycling/walking rules seems to be a likely explanation. Also, in environmental conditions with higher values of particulate matter 2.5 (hazy/ low visibility) , the citizens seemingly might prefer to stay indoors (NY Department Environmental Conservation FAQs)/off the transportation or drive more cautiously, which could possible explain its negative correlation with transportation fatalities. Interestingly, it is found that the usage of public transport does not seem to have an impact on transportation related fatalities, which is contrary to the general perception that increased usage of public transportation and public transportation infrastructure could decrease transportation fatalities and pollution. The public transportation is found to be an insignificant contributor to air pollution in the selected cities and also an insignificant factor in determining transportation related fatalities. With increased population, higher vehicular traffic and traffic congestions are likely. This is further to result in increase of air pollution as represented by PM 10 and PM 2.5 values and increased probability of transportation related fatalities. Currently, NOx emissions from industrial processes continue to receive maximum attention (Khader et al. , 2004). However, as per earlier studies, the factors responsible for air pollution (PM 10) are commercial, institutional and household fuel combustion and agriculture (Guerreiro et al. , 2014). Thus vehicular pollution is not assumed to be majorly contributing to PM 10 levels. Further auto linear modelling similar to Case A and Case B shows that PM10 is negatively related to personal auto i.e., it decreases with increased personal automobiles per capita city population. Also, the usage of personal or two-wheeled motorized vehicles seems to be quite low in the cities under study. Comparatively personal auto is found to be of more importance (but negatively related) in determining air pollution (PM10) indicating that personal automobiles might be a cleaner and safer option in these select cities. Further, in environmental conditions with higher values of particulate matter 2.5, the citizens seemingly stay indoors/off the transportation which could possibly explain its negative correlation with transportation fatalities.

Focusing on curbing air pollution (especially PM10 and PM2.5 levels) coupled with enhancing awareness and skills of citizens related to vehicular driving and traffic safety is likely to yield more effective positive results in curbing the transportation related fatalities rather that just prioritizing capital intensive public transport related technology infrastructure as a solution towards curbing transportation related fatalities.

The outcome of the study is also an enhanced awareness and appreciation of a Smart City Indicators as a holistic approach for sustainable development in the context of urgent need of methods for environmental assessment of human activities. The study enables a better understanding of the importance of some of the core performance indicators of environment and transportation in the context of smart cities. It also acts as an enabler to integrate the environmental and mobility/transportation component in decision making processes by assisting stakeholders with useful information to assist in:

- Development of public policies
- Decision-making
- Territorial planning
- Increasing citizens' awareness on environmental issues

Thus these findings also act as a key take-away and a replicable model for other cities across the globe aiming for becoming smart cities. This is particularly important in view of the "Smart City Mission" recently launched by the Honorable Prime Minister of India Shri. Narendra Damodardas Modi.

FURTHER WORK

Study could be done with bigger sample size for bringing in more accuracy in the study. Other factors (intercept) as indicated in Importance- Significance matrix above can be explored to enable incorporation in the least square model more accurately and significantly. The existing study is cross-sectional. With availability of larger data sets, a larger sample size (cities) and longitudinal analysis (time series) country-wise/state-wise (such as for India) could yield more accurate and geographical and country/state specific results. Effect of confounding variables such as interrelation among and between other indicators could also be investigated.

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