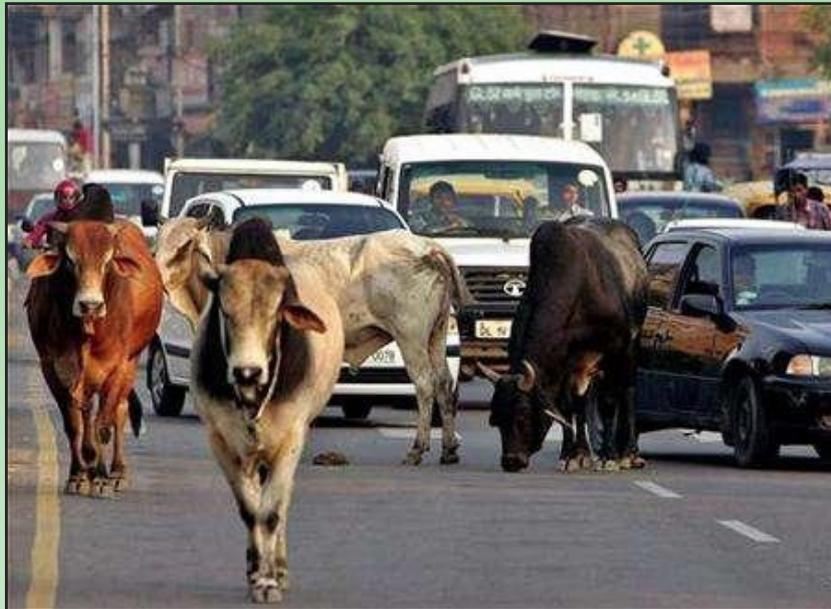


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The cover photograph is reproduced with the kind permission of  
Professor John Adams

### **Culturally programmed drivers deferring to a small herd of sacred cows: result - deferential paralysis**

Our cover photo published with the permission of John Adams (Adams, 2016) shows the daily reality of a situation where we already have the equivalent of a system that mirrors the world of driverless cars (DC). All those who have used roads in Delhi or Kolkata will know that if a car meets a cow the car must stop, wait and defer. We are told that DCs will also stop, wait and defer so pedestrians achieve the same kind of protected status as the cow in India. This, we are told, will all be wonderful and massively reduce death and injury on the roads because DCs will detect pedestrians and cyclists within a defined range and stop. If we are to believe the overblown rhetoric surrounding DCs (or autonomous vehicles as Schiller explains in this issue) this is what will happen when DCs take over the role played by regular vehicles in world cities.

Our view is that sacred cow status will not be conferred on children, older citizens who cannot move very fast, those pedestrian with any kind of hearing or sight problem and those who just try to cross a road when it is very busy and they have to cope with something like a 15 second gap between cars. It is inconceivable that an ideologically pro-car corporate world backed 100% by politicians and mopping up billions of dollars of investment will allow a few pedestrians or cyclists to interrupt the flow of cars so that every journey takes much more time than the current journey.

In this issue we have two very thoughtful articles about the brave new world on offer from those who want to see more cars on our streets and who are mesmerised by the power of technology and cannot visualise a street that is without cars and is a street for people and a delightful place to use as a social space, circulation space, friendly space and play space. The future is being shaped by billions of dollars on the same old ideology that we have put up with for 100 years and is based on people moving around in individualised, motorised, expensive, street clogging metal boxes.

Preston Schiller in his article "Automated and Connected Vehicles: High Tech Hope or Hype" provides us with some clarity about "Automated" vehicles (AV) and the hype that surrounds their promotion. The acronym-rich world of HOVO, ADAS, AV and CC is explained and the author points to some very real technical problems involved in making sure the DC/AV recognises people and avoids them and makes decisions about who or what not to avoid if a choice has to be made between hitting a group of children or a bus (for example). Given the very serious things that go wrong with very sophisticated nuclear power stations, weapons systems and high speed trains we should not be surprised if things go wrong with millions of computer algorithms making decisions about speed and direction in streets populated by human beings.

The wider consequences flowing from large scale adoption of DC/AV cars have not received the attention that Schiller devotes to energy use, travel demand, hacking, cost and pollution in addition to finally delivering the death blow to streets for people. In DC/AV world, streets are traffic sewers and cities lurch towards the extermination of walking, cycling and public transport and these deep and serious transformations of city life are not factored into any kind of evaluation of this rampant virus technology. Even at the level of public expenditure and budgeting the UK has already established a very clear priority order (1) spend huge amounts of tax dollars on electric vehicles and EV charging points (2) build hugely expensive useless new roads such as the Heysham M6 link Rd in Lancashire (NW England), the Aberdeen Western Peripheral Road (Scotland) and the £1 billion M4 relief road around Newport (Wales) (3) destroy bus services because there is no money for vital public transport links and (4) allocate trivial amounts to improving the walking and cycling environment.

If we do get large numbers of DC/AVs on the roads of our cities and they do what the technocrats say they will do which is never hit a pedestrian or a cyclist then it is abundantly clear that the auto mania

ideology will “kick in” and a powerful combination of law makers, local authorities, traffic engineers, car builders and planners will re-shape the city in a very real physical sense. All roads that are designated as DC/AV roads will be denied to pedestrians and cyclists to avoid the unacceptable result of billions of dollars of cash being spent on the technology and the cars being stopped by “anti-social human beings”. People will not be allowed to get near enough to trigger the failsafe systems that are talked about as improving road safety. The best way to improve road safety is to ban people and this will now complete the process started by Henry Ford over 100 years ago.

Electric Vehicles (EVs) are very attractive indeed. They provide a very convenient “solution” to a number of problems e.g. climate change if the electricity is generated by renewable energy and air pollution that currently kills 52,000 people every year in the UK and most of the deaths are from pollution generated by vehicles. So EVs allow us to continue to stuff our streets with traffic hinder the development of walking and cycling and take valuable cash away from public transport. They fully support the auto mania ideology.

From a UK perspective it is clear that huge amounts of public money are available for car buyers or potential car buyers. The UK government offers these subsidies to EV purchasers:

- o 35% of the cost of a car, up to a maximum of either £2,500 or £4,500 depending on the model
- o 20% of the cost of a van, up to a maximum of £8,000

The ‘cost’ is the full purchase price you pay for the basic vehicle - including number plates, vehicle excise duty and VAT. It doesn’t include delivery charges, the first registration fee or any optional extras.

<https://www.gov.uk/plug-in-car-van-grants/what-youll-get>

There is no grant to those of us who do not have a car and have chosen a car-free life style. If there are environmental and cli-

mate change reasons for giving an EV purchaser a gift of £2500 from public funds then I would like to apply for the same level of reward on the understanding that I will not buy a car and I will not borrow a car. Those who opt for car-free living suffer a double hit. Not only do we not get a grant but we put up with poor quality public transport, the loss of bus services, dirty, polluting diesel trains, overcrowded trains and railway stations that never see a bus and are just not part of any integrated provision of high quality public transport services. The ideological preference to reward car owners and drivers is very strong and is matched by the punishment meted out to the “failures” in society who walk, cycle and use a bus. Support for EVs is not a contribution to sustainable transport and damages the chances of ever achieving a truly sustainable transport future. Holzapfel, in this issue, provides some important insights into EVs and why we should be less than enthusiastic about their growing numbers and association with a sustainable transport agenda. He argues, rather convincingly, that EVs will increase CO2 emissions. This will prove very uncomfortable for the large number of “green” organisations and climate action groups who advocate EVs as a way of dealing with decarbonisation in the transport sector.

DCs/AVs and EVs require lots of additional car parking, they support the construction of very expensive, very damaging new roads and they do not contribute to shifting streets and cities in the direction of streets for people and high quality social space. They also produce health damaging particulate emissions. These come from brakes, tyres and road wear so those who claim that EVs are pollution-free are in denial about an uncomfortable piece of scientific information.

Fundamentally the whole DC/AV/EV world is an expensive way of supporting an old, discredited ideology. The idea that cities can function as high quality places to live and work with large amounts of car parking, new roads and congested streets is a huge fallacy and is supported by eye wateringly large subsidies. The idea that several billion people can look forward to a wonderful world populated by DC/AV/EV

is an ecological and fiscal fallacy of enormous proportions. It is time to wake up to what real transport sustainability means and it means as many journeys as possible not by car and as many as possible by ultra-safe walking, cycling, high quality bus, tram and local rail and this will also produce delightful, beautiful cities.

There are many claims on what could be regarded as a worthwhile contribution to sustainable transport and all of them require a high degree of scrutiny and evaluation. We are delighted to include in this issue a contribution on Delhi's air pollution problem and the impact of the "odd-even" number plate trials. Arpit Shah and Sundaravalli Narayanaswami discuss the odd-even trials in some detail and conclude that this kind of vehicle rationing will not be enough to deal with air pollution in Delhi. They conclude that an effective response to serious levels of air pollution will require "a multi-pronged approach involving improved public transport, stricter emission norms, reduced congestion levels, vehicle control measures and incentives for environmentally friendly modes of transport."

Sustainable transport is a very good example of sitting in a room with an enormous elephant in the corner with a strong, never made explicit, agreement that we must not mention the elephant at all or even show that we know it is there. The sustainable transport elephant is very clear and embraces congestion charging, car free streets and living quarters, large highway space reallocation in favour of walking and cycling and seamless totally integrated public transport that is never stuck in congested traffic. We could add an end to very large subsidies and in India an end to very large cars and drivers being allocated to politicians and senior officers. Important people must experience what it is like standing at a bus stop, crossing the road, riding a bike and finding a seat on a train. This also applies to the UK and it would be a pleasure to travel on a dirty, overcrowded, diesel train and talk to a Member of Parliament, government minister or senior civil servant about the quality of our sustainable transport options.

We are also delighted to include a second article on India by Mr Gosavi and his colleagues on "A density linked framework for planning for mass transit in the context of Indian cities". We have run several articles on density and sustainable transport in sustainable cities over the last 10 years including some that stimulated a very intense debate along the lines of "density is not destiny". This article provides a framework for considering the applicability of mass transit interventions in Indian cities and that is long overdue and welcome. What we also need in all cities around the world is a huge ideological shift and transformation away from the thinking that building new roads is of any use at all. This is the subject of the Mobility book (Whitelegg, 2016) and a mobility transformation is a critical example of a "Great Mindshift" (Goepel, 2016). Sustainable transport and sustainable cities will happen but not until we have dumped the outdated and discredited ideology of the 1960s and replace it with something so much more intelligent.

John Whitelegg  
Editor

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**Reducing Delhi's Air Pollution – The Odd-Even Trials and Other Options**

*Arpit Shah, Sundaravalli Narayanaswami*

**Abstract:**

The Delhi Government is evaluating the effectiveness of a vehicle-rationing scheme in curbing Delhi's high air pollution levels. We analyze the scheme in the context of Delhi's mobility needs and contend that it will not be enough to control air pollution. Controlling vehicular emissions is important in the long run, given the increasing number of vehicles in the city. This will require a multi-pronged approach involving improved public transport, stricter emission norms, reduced congestion levels, vehicle control measures and incentives for environmentally friendly modes of transport.

**Keywords:** Delhi, Odd-Even, Road Rationing, Delhi Pollution, Vehicular Emissions, Congestion

**Density linked framework for planning mass transit in the context of Indian cities**

*Nachiket Sharadchandra Gosavia, Prof. Dinesh S Hegde, Dr. Lakshmikant Harib*

**Abstract:**

The present article attempts to develop a framework for planning mass transport for Indian cities/urban agglomerations. The framework treats density as an intervening variable for determining the mode of mass transit. Additionally, an attempt is undertaken to identify whether urban population and urban expanse follow a discernable pattern. Using ranks, the worst affected cities/urban agglomerations are identified.

**Key words:**Power law, India, population Density, urban population, urban expanse, transit system

**Automated and Connected Vehicles: High Tech Hope or Hype?**

*Preston L. Schiller*

**Abstract:**

The autonomous vehicle (AV) appears to be very much on the minds and screens of the motoring public, if not yet in automobile dealership showrooms or on the roadways in large numbers. A great deal of funding is being made available to develop AV technologies by government and within industries associated with such technologies. The AV is also receiving unprecedented, often uncritical--if not confused, attention in the mass media around the globe. The latest technological advance--or setback, is becoming front page material in print media and receiving prominent coverage in the broadcast media. This article will explore the history, various types and promotion of this curious invention's trajectory as well as evaluating the claims made on its behalf and possible limitations for its adoption on a grand scale. The goal of this article is not a technological or technical evaluation of automated vehicles but rather a review of some of the claims made on its behalf by its promoters in order to put this phenomenon in a perspective informed by social science, policy formation, planning and the experience that even the best intended innovations often produce questionable results and unintended consequences.

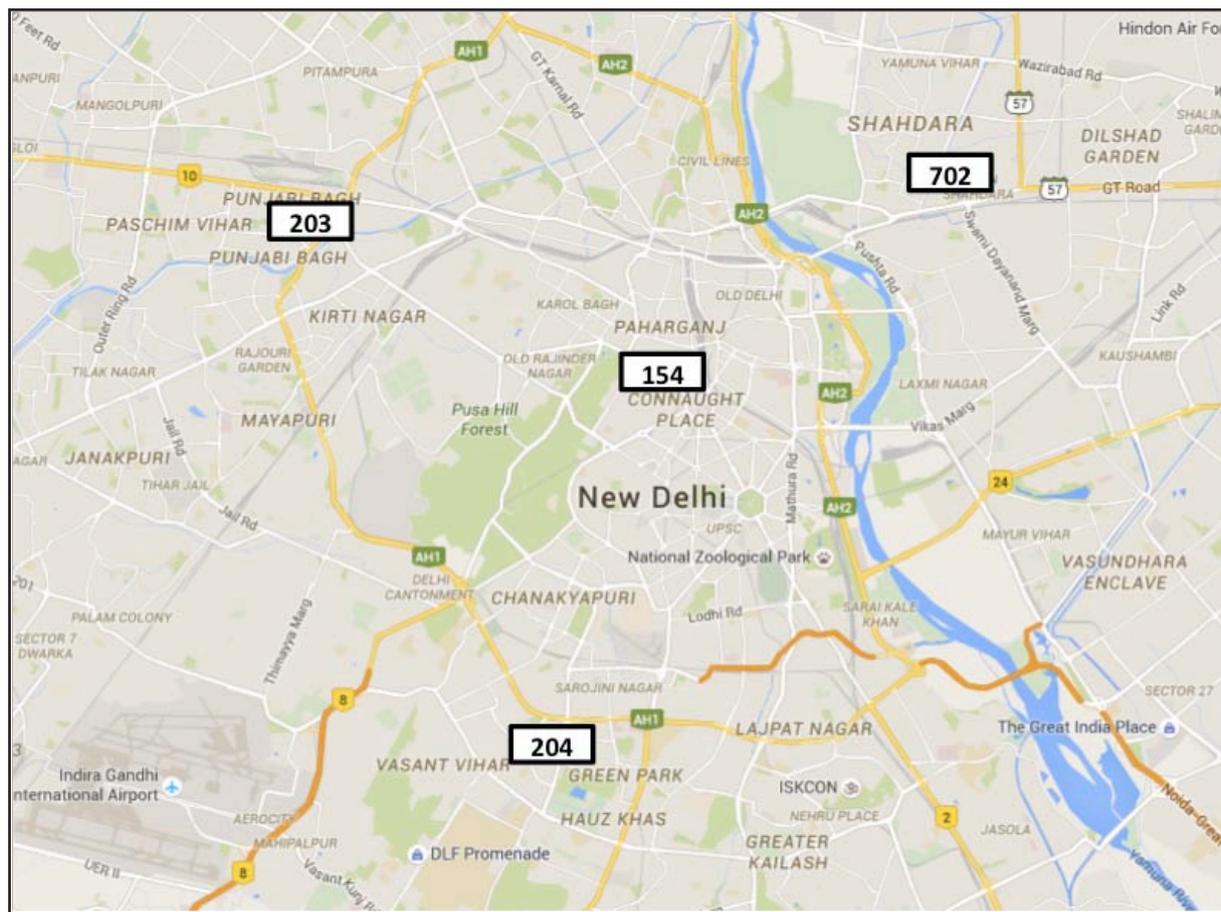
**Keywords:**Autonomous Vehicles (AVs), Automated Driver Assistance Systems (ADAs), Connected Cars (CCs), transportation policy, freight transport, Intelligent Transportation Systems (ITS), transportation technology, traffic congestion, ride-hailing services, car-sharing services, transportation safety, bus rapid transit (BRT), transportation safety, traffic safety, transportation energy, Greenhouse Gases (GHGs), Electric Vehicles (EVs), parking, public transportation, transit, automation, traffic infiltration, urban density, automated highway system (AHS), car culture, commuting

## Reducing Delhi's Air Pollution – The Odd-Even Trials and Other Options

Arpit Shah, Sundaravalli Narayanaswami

### 1. Introduction

The World Bank ranked Delhi's air as the most polluted in the world in a survey of 381 cities in 2014. Delhi's Particulate Matter (PM) 2.5 levels routinely cross  $150 \mu\text{g}/\text{m}^3$  (see Figure 1). According to the World Health Organisation, safe levels for PM 2.5 are  $10 \mu\text{g}/\text{m}^3$ . The story for other air pollutants in Delhi is similar. High air pollution levels are known to be a serious cause of health problems in urban populations<sup>1</sup>.



**Figure 1:** Peak PM 2.5 levels ( $\mu\text{g}/\text{m}^3$ ) in select places in Delhi on June 5, 2016

Source: Delhi Pollution Control Committee

The Delhi Government recently ran a vehicle-rationing scheme on a trial basis to control the city's high pollution levels. Private vehicles with odd and even number plates were allowed on the roads on alternate days from Monday till Saturday from 1st to 15th January 2016. Violators were fined **INR 2,000** to ensure compliance. For details see Business Insider (2015) 'Delhi's air most polluted among 381 cities: World Bank' Business Insider. <http://www.businessinsider.in/Delhi-air-most-polluted-among-381-cities-World-Bank/articleshow/49102343.cms> viewed on 14 Jan 2016

forts were made to provide adequate public mobility during the trial period. People were encouraged to carpool. The Government ran 6,000 additional buses and operated the Delhi Metro at a higher frequency. 10,000 volunteers were hired across the city to support the implementation process.

Through this trial, the government hoped to evaluate the effectiveness of vehicle rationing in reducing the city's extremely high pollution levels. To assess the policy, we need to answer two important questions. Can the current scheme be effective

in bringing pollution down to desired levels in the long run? If not, what other interventions should the Government consider to reduce vehicular emissions?

To answer these questions, we look at the odd-even vehicle-rationing scheme in the context of Delhi's mobility needs. Section 2 looks at mobility trends in Delhi, while Section 3 assesses the likely effectiveness of the odd-even policy in reducing the city's air pollution and looks at other issues

raised by the scheme. Section 4 looks at literature from other cities to suggest potential interventions the Government can consider. Section 5 concludes this paper.

## 2. Mobility in Delhi

To begin with, we look at the evolution of transportation and mobility in Delhi over the last 3 decades. Growth in registered private vehicles in Delhi has outpaced the growth in population (see Table 1). While Delhi's population has grown almost 3 times since 1981, privately registered vehicles increased more than 18 times.

Year	Population (millions)	Annual Population Growth Rate (%)	Registered Private Vehicles (millions)	Annual Private Vehicle Growth Rate (%)
1981	6.22		0.45	
1991	9.42	4.24	1.57	13.30
2001	13.85	3.93	3.15	7.18
2011	16.79	1.94	6.52	7.53
2015 <sup>a</sup>	18.13	1.94	8.48	6.79

**Table 1:** Growth in Population and Registered Private Vehicles in Delhi from 1981-2015

Note: <sup>a</sup> Estimated based on previous decade's growth figures

Source: *Delhi Statistical Handbook 2015; Statistical Abstract of Delhi 2014*

Year	Cars per 100 population	Motorcycles per 100 population	Total private vehicles per 100 population
1981	2	5	7
1991	4	13	17
2001	7	16	23
2011	13	26	39
2015	16	31	47

**Table 2:** Cars and motorcycles per 100 population

Source: *Statistical Abstract of Delhi 2014*

While motorcycles are still the dominant form of registered private vehicles, growth has been driven more by cars since 1981. Delhi had 16 cars and 31 motorcycles per 100 population in 2015, up from 2 cars and 5 motorcycles in 1981 (see Table 2).

The increase in road network coverage in Delhi has not kept pace with the growth in the number of vehicles. Cars per km of road in Delhi have risen from 32 in 1981 to 255 in 2015 (see Table 3). This increase points to the dense congestion and traffic gridlocks that are a regular part of Delhi's roads now.

The fact that Delhi's streets are congested is well recognized both by the government and media<sup>2</sup>. Traffic studies in Delhi have shown that the volume of traffic on many key roads exceeds the capacity of those roads (see Table 4).

Out of 59 locations looked at in a RITES survey, less than 30% had a volume capacity ratio of less than 1, implying that most major roads in Delhi are congested (RITES 2010).

The changing modal shares of Delhi's transport also point to increased congestion on the roads (see Table 5). Research shows that the proportion of trips undertaken in Delhi's public transport (buses and the Metro) declined from 60% to 46% between 2001 and 2008. There was a further decline to 31% by 2012 (Government of Singapore 2014; RITES 2010).

<sup>2</sup> There are regular articles in popular media talking about the traffic gridlocks and congestion in the city. For example, look at: Pandey, M (2012) 'Growing congestion on Delhi roads likely to reduce speeds to 5kmph' India Today. <http://indiatoday.intoday.in/story/get-ready-to-crawl-at-5kmph-in-delhi/1/209708.html> viewed on 17 Jan 2016

Year	Vehicles per km of road in Delhi
1981	32
1991	74
2001	111
2011	199
2015	255

**Table 3:** Vehicles per km of road  
Source: *Statistical Abstract of Delhi 2014*

Location	Volume Capacity Ratio (value greater than 1 indicates congestion)
Road and Rail Bridge (near Yamuna Bazar)	3.59
Patel Road (Near Shadipur Rob)	2.72
ITO (near ITO bridge)	2.09
Nizamuddin Bridge	2.08
Tilak Marg	2.01
Ring Road near Naraina Rob	1.9

**Table 4:** Volume capacity ratios at key locations in Delhi  
Source: *RITES 2010*

Mode	Proportion (%)
Bus	27
Rail	4
Private transport	23
Walk	35
Cycle	6
Para-transit	5

**Table 5:** Mode shares in Delhi in 2015  
Source: *Government of Singapore 2014*

City	PM 2.5 - Annual mean ( $\mu\text{g}/\text{m}^3$ )	PM 10 - Annual mean ( $\mu\text{g}/\text{m}^3$ )
Delhi	153	286
Melbourne	5	18
Chicago	13	22
London	8	23
WHO recommended levels	10	20

**Table 6:** Ambient air pollution in various cities  
Source: *World Health Organization 2014*

Even after this decline, Delhi's modal shares compare well to many other cities in the world. In 2012, environmentally friendly modes such as public transport, walking and cycling accounted for 72% of all trips in Delhi, compared to just 23% in Melbourne, 37% in Chicago and 62% in London (Government of Singapore 2014). Despite this, Delhi's pollution levels are higher than many of these cities (see Table 6). Delhi's PM 2.5 levels of  $153 \mu\text{g}/\text{m}^3$  are the highest in the world, while PM 10 levels are also very high at  $286 \mu\text{g}/\text{m}^3$ .

This indicates that better modal shares are not sufficient to drive down air pollution. Government policies need to play an active role in managing pollution levels while ensuring adequate public mobility.

### 3. Understanding the Odd-Even Policy in the Context of Delhi's Air Pollution

To assess the likely effectiveness of the odd-even policy, we look at the causes of air pollution in Delhi and the contribution of vehicles affected by the policy to total air pollution.

#### 3.1. Causes of Air Pollution in Delhi

It is not clear if vehicular emissions are the leading cause of Delhi's air pollution. A Ministry of Environment and Forests white paper in 2003 mentioned that vehicles cause 72% of the air pollution in the city (MoEF, 2003). However, this was contradicted by later government studies. A Central Pollution Control Board (CPCB) study, conducted along with the National Environmental Engineering Research Institute (NEERI) in 2008, suggested that vehicular contribution to particulate matter emission was only 6.6%. Road-dust, the biggest polluter according to the study, was the cause of more than half of

Delhi's particulate matter (CPCB, 2008). A second government study conducted by the System of Air Quality Forecasting and Research (SAFAR) re-iterated the previous study's findings and blamed road-dust as the major cause of pollution. A recent IIT Kanpur study again indicated road dust as the largest contributor to the city's PM10 levels<sup>3</sup>.

Even within vehicular emissions, private cars are not seen as the biggest polluters. Estimates by the Society of Indian Automobile Manufacturers (SIAM) say that vehicular emissions cause 20% of the air pollution in Delhi, and private cars, which are subject to the rationing policy, cause only 3% to 4%. Two-wheelers, which are exempt, are responsible for 30%-40% of total vehicular emissions and trucks are responsible for another 30% to 40%. Moreover two and three wheelers generate more emissions than privately operated four wheelers<sup>4</sup>.

### 3.2. Likely Impact of the Odd-Even Policy

Given the wide range of estimates of the contribution of vehicular pollution to total air pollution, can the current vehicle-rationing scheme bring pollution levels down to desired values?

Firstly, the current scheme provides exemptions to many categories of vehicles. These include two-wheelers, CNG vehicles, cars driven by women, cars with handicapped people, cars registered to VIP's, commercial vehicles (auto-rickshaws and taxicabs), etc. Two-wheelers and vehicles registered to VIP's represent 5.9 million of the 8.8 million registered vehicles in the city (Delhi Statistical Handbook 2015). A further 0.8 million cars are estimated to run on CNG<sup>5</sup>. Further exemptions are pro-

3 For details see Chatterjee, P (2016) 'Vehicle exhaust, dust, what fouls the air the most? Studies disagree' The Indian Express. <http://indianexpress.com/article/explained/vehicle-exhaust-dust-what-fouls-the-air-the-most-studies-disagree/> viewed on 17 Jan 2016

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5 Estimates on the number of CNG cars were re-

vided to cars with women drivers, cars with handicapped persons etc. If these exclusions are also factored in, only 2 million of the 8.8 million vehicles in Delhi are likely to be affected by the odd-even policy. Assuming the ratio of odd to even vehicles to be roughly equal, approximately 1 million vehicles will be affected by the policy on any given day. This represents 11% of the total number of vehicles in the city. Studies on the odd-even policy in other cities have shown that vehicles that are still on the road travel more as they ferry more passengers, carpool and make more trips. Assuming that on-road vehicles drive 5% more than usual, the total vehicular distance travelled reduces only by 7%. If vehicular emissions are considered to cause roughly between 20% and 70% of Delhi's air pollution, the odd-even scheme ought to reduce total pollution between 1% and 5%, approximately. Given that Delhi's PM 2.5 levels are 15 times higher than the recommended World Health Organization (WHO) guidelines on average, the scheme on its own will not be enough to bring down air pollution to desired levels.

Studies in other parts of the world show similar conclusions. A 2008 study by Dr. Lucas Davis of the Haas School of Business on Mexico's vehicle rationing scheme showed that it had no impact on air pollution. In fact, there was an increase in the total number of vehicles in circulation in the city, as people started purchasing multiple vehicles to counter the policy (Davis 2008).

### 3.3. Other Issues with the Odd-Even Policy

Proponents of the scheme point out that the reduced number of vehicles on the road has resulted in a reduction in Delhi's major traffic bottlenecks. Travel times have reduced, and public buses are also able to transport passengers faster. Being on the roads has been described as a better experience since the enforcement of the policy<sup>6</sup>. However, if people start pur-

ported in Indian media. See Zeenews (2015) 'Delhi odd-even rule: CNG car owners throng gas stations for exemption stickers' Zeenews. [http://zeenews.india.com/news/india/delhi-odd-even-rule-cng-car-owners-throng-gas-stations-for-exemption-stickers\\_1839603.html](http://zeenews.india.com/news/india/delhi-odd-even-rule-cng-car-owners-throng-gas-stations-for-exemption-stickers_1839603.html) viewed on 14 Jan 2016

6 For details see Dwivedi, A (2016) 'Eyes on the odds: A day in the life of a volunteer working to implement

chasing multiple cars as seen in Mexico, then these effects might reduce in the longer term.

Critics have pointed out that vehicle rationing is unfair on car owners. Further, commuting becomes uncomfortable, as already strained public transport systems get more crowded. According to expert estimates, 13,000 buses were required to manage the extra load on public transport during the duration of the scheme, but the government announcement said only 6,000 additional buses would be provided<sup>7</sup>. Even that did not materialize in the initial days of the scheme as less than 2,000 additional buses were actually operational<sup>8</sup>.

#### 4. Controlling Vehicular Emissions

While overall control of air pollution requires initiatives beyond the transport sector, emissions from vehicles will continue to rise as the number of vehicles increases. To address the issue of transport emissions, this section looks at alternate policies the Government can consider to check vehicular pollution in the long term.

As shown in Figure 2, we have grouped these policies into a few types - initiatives that reduce congestion, initiatives that curb emissions from a given vehicle, initiatives that control the number of vehicles, initiatives that incentivize public transport and initiatives that facilitate environmentally friendly options like walking and cycling. There are overlaps - for example, initiatives that incentivize public transport will also reduce congestion. The grouping

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Delhi's odd-even policy' The Indian Express. <http://indianexpress.com/article/cities/delhi/eyes-on-the-odds-a-day-in-the-life-of-a-volunteer-working-to-implement-delhis-odd-even-policy/> viewed on 13 Jan 2016

<sup>7</sup> Estimates by Prof. Guttikunda of the advocacy site urbanemissions.info. See Pradhan, K (2015) 'Delhi pollution crisis is the new capital punishment' India Today. <http://indiatoday.intoday.in/story/delhi-pollution-crisis-smog-capital-punishment/1/549028.html> viewed on 13 Jan 2016

<sup>8</sup> For details see The Indian Express (2016) 'Taking a bus: Less than half of promised number on the streets, with few passengers' The Indian Express. <http://indianexpress.com/article/cities/delhi/taking-a-bus-less-than-half-of-promised-number-on-the-streets-with-few-passengers/> viewed on 13 Jan 2016

is based on the dominant effect the initiative is likely to have.

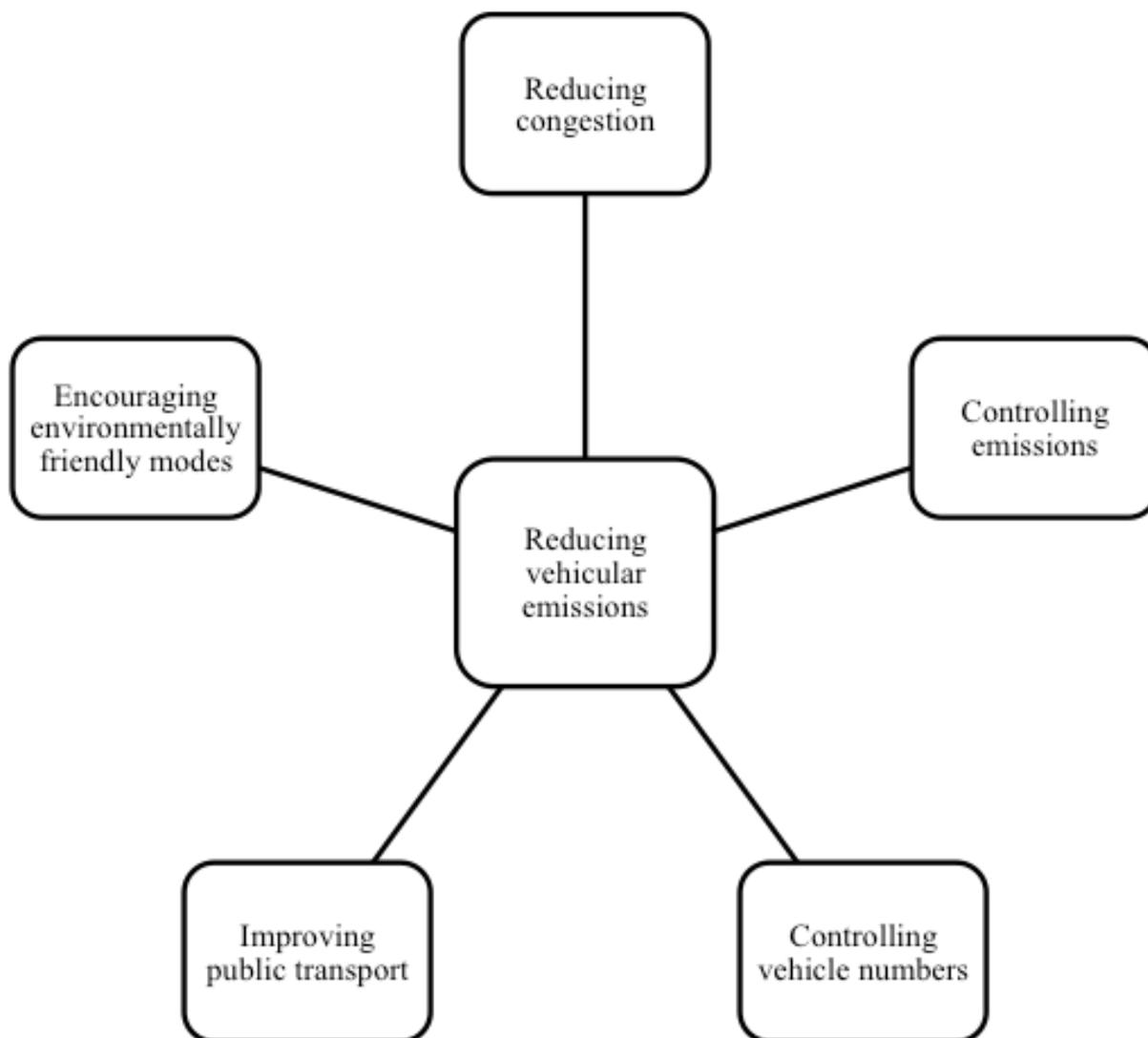
#### 4.1. Reducing Congestion

Congestion itself increases vehicular emissions and air pollution. Studies have shown that congestion leads to vehicles consuming more fuel for the same distance traveled. Reducing congestion can lead to emission reductions of 10% to 30% (Barth & Boriboonsomsin 2009).

Multiple strategies can be adopted to deal with congestion. One is to introduce congestion pricing in crowded areas during peak hours. This has been attempted by cities like London and Stockholm. Both NO<sub>2</sub> and PM<sub>10</sub> emissions reduced by 12% and vehicle speeds improved in London's congestion charging area (Beevers & Carslaw 2005). Stockholm saw benefits in congestion and pollution because of the scheme without the congestion problem spilling over onto other roads. This was because many of the affected motorists moved over to public transport. Congestion also reduced as motorists shifted to non-peak hours to avoid charges (Eliasson, Hultkrantz, Nerhagen, & Rosqvist 2009).

Freeing up road space by reducing informal parking is another way to deal with congestion. Many busy areas in Delhi suffer from road space being blocked by cars. In many cases, these parking spots are not paid for and reflect a hidden subsidy to car owners. A government committee report called 'How to decongest Delhi' talks about rationalizing parking in places like Nehru Place, Connaught Place, Karol Bagh and Lajpat Nagar, among others. The proposed solution in the report talks about developing multi-level buildings for parking and enforcing no-parking in other areas (MoUD, 2015). Cities like London have allowed market forces to determine rates for scarce parking space in congested areas (Roychowdhury 2010).

Newer technologies like intelligent routing systems can help reduce congestion. These systems calculate the most energy efficient route to the destination based on real time traffic information, origin-destination inputs from the users and the available road networks in the area. The



**Figure 2:** Reducing vehicular emissions

objective is to create smooth flowing traffic to reduce emissions due to congestion (Boriboonsomsin, Barth, Zhu, & Vu 2012). Simulations have been run using data from China to validate that such strategies actually reduce pollution (Yao & Song 2013).

#### 4.2. Controlling Emissions

Emission norms in India significantly lag those in Europe and North America. Mandating more stringent emission standards will be highly effective in controlling vehicular pollution. India is currently on Bharat Stage IV emission norms while Europe is already at Euro 6. India lags Europe by almost 10 years with regard to emission standards.

Apart from the lag, emission norms even when applicable are not adequately enforced. An audit by the Central Pollution Control Board in Delhi in 2013 found that a significant number of pollution control

centers were inadequately staffed, had faulty equipment and were using fudged data for certification (CPCB, 2013). There is a need to ensure that standards are rigorously enforced.

#### 4.3. Controlling the Number of Vehicles

Cities like Singapore and Shanghai have adopted policies to control the total number of vehicles on the road. This can be done through different instruments like vehicle quotas or vehicle taxes.

Singapore and Shanghai use vehicle quotas to control the number of cars that can be sold each month. Quotas are sold through an auction process, so the price of the quota effectively gets added to the price of the car for the purchaser. The number of quotas is fixed by looking at estimates of the total number of cars on the road and the number of old cars that will

be scrapped during the year (Roychowdhury 2010).

Singapore also taxes cars very heavily at the time of purchase. Car taxes are typically more than 100% the price of the car. The price of BMW or Mercedes cars in Singapore can be four to five times the price in the US. Even this helps disincentivize purchase of cars and encourages people to use public transport<sup>9</sup>.

#### **4.4. Improving Public Transport**

High quality public transport systems are characteristic of cities that have managed to curb pollution levels. Examples include Berlin, London and Singapore.

Improvements in Delhi's public transport system need to start with better multi-modal integration across buses, trains and para-transit modes. Lack of proper integration leads to excessive waiting time during changeovers. Integration of train and bus timings and having bus stops near train stations would ensure a seamless commuting experience. Poor end-mile connectivity implies that reaching the public transport system is in itself a time-consuming, expensive experience. Reaching a train station or bus stop can mean an expensive ride in an auto rickshaw or cab. Bus services need to stop closer to residential locations to ensure quick access to public transport. The current lack of multi-modal integration is well recognized by government with plans being made to tackle the issue (MoUD, 2015).

Improved commuting experiences in public transport will help people reduce reliance on private vehicles and shift to trains and buses. This will directly benefit the environment through reduced vehicular emissions and also have indirect benefits through reduced congestion.

#### **4.5. Encouraging Environmentally Friendly Modes**

Walking or cycling is encouraged in many cities as a solution to both congestion and pollution. Many cities have dedicated cy-

cling lanes with proper infrastructure to share and park bicycles. Walking experiences can be improved and made safer by having dedicated pavements on each road with proper pedestrian crossing and traffic signals.

However, walking and cycling are not prioritized in Delhi. Roads in Delhi are shared by a variety of transport modes, with priority being given to faster moving traffic. There are no continuous pathways for pedestrians to approach bus stops or well-maintained pavements to walk on. Service lanes for slower modes like walking and cycling are lacking on most roads (Tiwari 2001). The needs of cyclists and pedestrians need to be considered while developing infrastructure for faster modes of transport.

Environmentally friendly modes can also be encouraged through improved public awareness campaigns. Such campaigns have been pioneered in the UK with 'walk to school weeks', 'bike to work days' and the like. These are complemented with messaging and advertising regarding environmentally safe travel choices. Such initiatives have been attempted in Australian cities as well (Rose & Ampt 2001).

### **5. Conclusions**

Delhi's air pollution levels have been rated as the highest in the world. The Delhi Government is assessing the effectiveness of an odd-even vehicle-rationing scheme in improving air quality to safe levels. We analyze the likely effectiveness of the scheme by looking at Delhi's mobility needs and the causes of air pollution in the city. While overall control of air pollution will require initiatives beyond the transport sector, controlling transport sector emissions is important given the growing number of vehicles in Delhi. However, our analysis shows that the odd-even vehicle-rationing scheme is unlikely to be effective in improving air quality to safe levels. Vehicle rationing has typically been used as an emergency stopgap measure to control pollution for a few days. Paris used it for a day for emergency control of high pollution, while Beijing used it to reduce pollution levels just ahead of the Beijing

<sup>9</sup> For details see Aquino, K (2011) 'BMW at \$260,000 as Singapore Tax Keeps Cars for Rich' Bloomberg Business. <http://www.bloomberg.com/news/articles/2011-02-16/bmw-3-series-costs-260-000-as-singapore-tax-keeps-cars-for-rich> viewed on 17 Jan

Olympics in 2008<sup>10</sup>. Long-term evidence in support of such schemes is also lacking, given experiences from other places like Mexico.

There are multiple other initiatives the government could adopt to reduce vehicular emissions. Congestion pricing, improved parking spaces and intelligent routing systems can be used to reduce traffic congestion and emissions. Tightening emission standards can reduce pollution, while vehicle numbers can be controlled through quotas and taxes. Public transport improvements can lead to more efficient mobility in the city. The Government can also take steps to encourage the use of environmentally friendly modes of transport like cycling and walking.

Many cities around the world use many of these initiatives in a multi-pronged approach to tackle both congestion and pollution. For long-term sustainability, stringent policies built on scientific judgments that address all sections of the society are needed. Such policies should rely on strategic thinking and not be based on emergency stopgap measures.

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10 A number of initiatives used by other cities have been looked at in the Hindustan Times (2015) 'Traffic rationing: Rules other countries followed to cut pollution' Hindustan Times. <http://www.hindustantimes.com/delhi/delhi-s-odd-even-traffic-rationing-similar-rules-in-other-countries/story-guZHHnqHimgzcrN-7JjYWL.html> viewed on 14 Jan 2016

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## **Density linked framework for planning mass transit in the context of Indian cities**

*Nachiket Sharadchandra Gosavia, Prof.  
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### **1 Introduction**

The Indian urban scape is plagued by a mismatch between master-plan and actual development (Dutta, 2012). This has led to an exponential increase in ownership and use of private vehicles (Wilbur Smith Associates, 2008; Sreedhar, 2011). As a consequence, the Indian urban scape is on an unsustainable growth trajectory. According to National Electric Mobility Mission Plan-2020 (NEMMP-2020) (Sundareshan, 2012), urban transport is one of the key areas for reducing greenhouse gas emissions. For realizing the low carbon growth path, rapid transit system needs to be planned and developed in these cities/urban agglomerations (UAs) (Mohan). In this backdrop, the present study tries to identify the parameters that are likely to influence the type of transit system i.e. skeletal bus service, bus rapid transport, light rail transit (LRT) and / or heavy rail transit (HRT).

Although these transit systems cater to different urban densities, the primary focus of the Planning Commission (now NITI Ayog) was on bus based transit system. As a result, the prevalence of the private vehicles/intermediate public transport continued and the use of transit system ridership reduced drastically. In this backdrop, the present article attempts to develop a density linked framework that links type of urban density and urban expanse to the type of transit system.

After introducing the topic in the first section, the second section links urban population density to the mode of mass transport. In this section, urban population density is considered as an intervening variable. Considering density is a variable arising from the interaction between population and urban expanse, the third section investigates, whether population and urban expanse follow a discernable pattern. In the fourth section, an attempt to identify sustainable cities and sprawling cities/urban agglomerations is undertaken.

en. For identifying the worst affected cities/UAs, the concept of rank reversal viz., population and urban expanse is considered. The article concludes by summarizing the findings.

### **2 Urban population density- The intervening variable**

According to Pushkarev and Zupan (1977) (Extracted from Angel et al. (2011)) for a skeletal bus transport to be sustainable, a minimum residential density of 6-8 house holds or 25 jobs per acre are required. 'Sustainable transport' in this context mean a transport that is self sufficient or a system which does not require external financial aid e.g., subsidy. This would mean that for determining the type of transit system, urban population density needs to be determined. The primary focus of this article is on the Indian urban scape and mainly those cities which have a population in excess of a million. Thus, for identifying these cities the article relies on Census-2011. Likewise for estimating the urban area/developed area and those cities that have grown as economic shadows, data from Demographia -10th edition is used. To check the validity of this data, the data is cross-validated with the Census of India-2011. In addition, the data of Demographia-10th edition is compared and contrasted to include new cities/urban agglomerations that were likely to cross the million population mark. Unlike the Census-2011, which maps number of individuals residing in an administrative ward, the Demographia-10th edition computes the urban area by night time photography, this results in a better resolution.

Unlike cities of the developed world, which have a central business district, Indian cities/urban agglomerations tend to have a mixed development, i.e., the residential population is spread across the complete urban geography. Hence, the census not only maps the house-listing but also the population enumeration. This would mean that in either case, the primary focus of the census is the residential unit or the origin of the trip. It may be inferred that the census residential density or the urban density becomes the intervening variable for planning the transit system. The urban density considered here is the gross

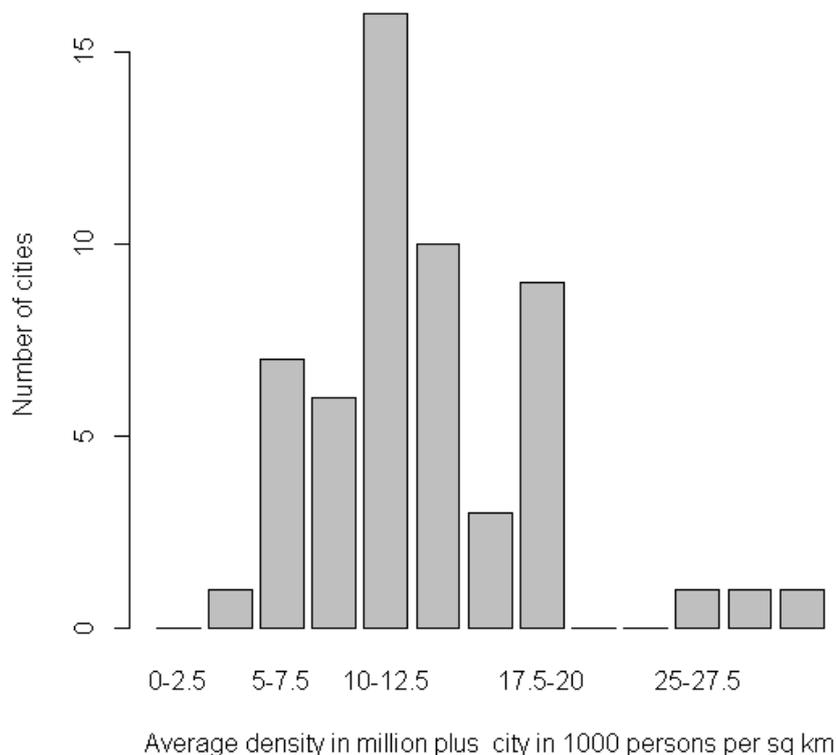
density and the denominator includes road space, non-descript open space and other public utilities that are a part of the administrative ward area. Figure 1 depicts the different urban density baskets and the number of cities in each basket.

One of the earliest studies linking urban density to the success of transit was done by Pushkarev and Zupan (1977). Rather than the study considering density in terms of individuals per square kilometre (sqkm), the study considers number of residential units per acre in residential areas and number of jobs per acre in the commercial sector. According to this study a density of 6 residential units per acre or 25 jobs per acre is required for a skeletal bus transport to be successful. Using “247.10 acres equal to one sq.km” as the conversion factor and assuming, each residential unit consists of 2 members, this density translates into a gross density of 3000 persons per sqkm.

On comparing this density to Figure 1, it can be deduced that all the cities/urban agglomerations (UAs) of India should have some kind of transit system. Table 1 shows

minimum threshold densities required for transit to become sustainable.

Even though the study by Pushkarev and Zupan (1977) (extracted from the online TDM encyclopaedia) reports a threshold density of 4500 persons per sq.km for LRT, a recent study by Flannery et al. (2015) reports a threshold of 2322 persons per sq.km, which is half the earlier reported threshold. It is observed that the threshold density for frequent bus service, express bus with foot access and express bus with auto access is higher in comparison to light rail transport. This difference may be attributed to the carrying capacity of the mode and the speed of the mode. In addition, bus based transit follow a circuitous rout in comparison to light rail transit, which would mean that buses are catering to historically developed infrastructure, wherein the trip length is smaller in comparison to light rail transit or rapid transit. Thus, it may be deduced that the differentiating factor between these modes is the length of the trip and the peak hour peak direction trip carrying capacity. Or alternatively, it may be deduced that a frequent bus service can handle up to 5000 peak



**Figure 1:** Density wise distribution of Indian cities having population in excess of a million

Mode	Service type	Minimum density (Dwelling units per acre)	Minimum density (persons/sqkm)	Area and location
Skeletal Bus service	20 trips per day	4	2000	Neighbourhood
Regular bus service	40 trips per day	7	3500	Neighbourhood
Frequent bus service	120 trips per day	15	7500	Neighbourhood
Express bus (foot access)	5 buses during 2 hr peak period	15	7500	Average density over 50 – sqkm area within 16 to 24 kms of a large downtown
Express bus (Auto access)	5-10 buses during 2hr peak period	15	7500	Average density over 32 -sqkm tributary area, within 16 to 24 kms of a large downtown
Light rail	Five minute headways or better during peak hour	9	4500	Within walking distance of transit line, serving large downtown.
Rapid transit	Five minute headways or better during peak hour	12	6000	Within walking distance of transit stations serving large downtown.

**Table 1:** Characteristics of transit mode (adopted from: *Online TDM Encyclopedia - Transit Oriented Development*)

Note: Down town refers to the central business district or the urban core

hour peak direction trips, while express buses can cater to 5000-10,000 peak hour peak direction trips (phpdt). Similarly, light rail transit can handle up to 10,000-30,000 phpdt, while rapid transit or heavy rail transit can cater to 30,000-90,000 phpdt.

On comparing the observed urban density to the density threshold (for transit to become sustainable), it may be inferred that in 48 of the 55 cities/UAs the density exceeds the minimum threshold beyond which bus based transit (all forms), light rail and rapid transit become viable. For identifying the mode of transit that suits the city/UA the trip generating potential of the city requires to be assessed. The trip generating potential can be approximated by comparing the average density and the service area/area of urban agglomeration.

(Table 2 shows the density-serviceable area mode options). In the context of Indian cities urban core decay is not observed. In addition, these cities tend to follow mixed development. Thus, segregating a central business district from its suburbs becomes a daunting task. For adjusting the open space distance of 16-24 kms (as observed for bus service), urban areas are segregated into five area categories. These categories are up to 100 sqkm, 100-200 sqkm, 200-300 sqkm, 300-400 sqkm and area greater than 400 sqkm. Correspondingly, the urban density has been divided into three segments. These segments are density between 4500-6000, 6000-7500 and density greater 7500.

Based on the area/location specifications in Table 1, Table 3 attempts to determine a plausible transit mode priority. Segrega-

Density/Area	4500-6000	6000-7500	>7500
Upto 100sqkm	-	-	20
100-200	1-	1	15
200-300	1	-	5
300-400	2	-	2
>400 sqkm	1	3	5

**Table 2:** Distribution of cities/UA based on area and density

tion similar to Table 2 is used for determining transit mode priorities. For determining mode priorities city nomenclature similar to Newman (2006) is used. According to this classification, walking cities were and are dense, mix-use cities no more than 5km in diameter, while transit cities had a diameter of 20-30 kms, with dense corridors along the transit lines and stations. Likewise, automobile cities could spread up to 50 kms in all directions and the observed density was low to very low i.e. density below 3000 persons per sqkm. Using this concept, transit modes are determined.

In ideal case, with increase in urban density, the transit system can be scaled up, i.e., the frequency can be increased to match the travel demand. But for this to happen, the population density should be normally distributed. To check whether population densities are normally distributed, the

distribution, i.e., sample in Figure 1 is subjected to Shapiro-Wilk normality test. This test examines whether the sample follows a normal distribution. The resultant p-value of  $0.01213 < 0.05$  shows that the null hypothesis cannot be accepted. (The null hypothesis for the Shapiro-Wilk normality test is that the sample follows a normal distribution). This would mean that scaling rule with respect to transit provision may not work. This observation is corroborated by the study commissioned by the Ministry of Urban Transport, Government of India (Wilbur Smith Associates, 2008). Thus it may be inferred that with increase in density, town/transport planners would have to make provisions for a transit system that can handle higher peak hour peak direction trips.

It may be reckoned that population density arises from the interaction between population residing in the urban area and

Density/Area	4500-6000	6000-7500	>7500
Up to 100 sqkm	Combination of regular and frequent bus service	Regular and Frequent bus service	Regular and frequent bus service
100-200	Regular and frequent bus service	Regular and frequent bus service	Regular and frequent bus service/ upgradeable to express bus (foot access)
200-300	Regular + frequent/ upgradeable to express bus (foot access)	Regular + frequent bus/ planning for light rail transit	Frequent+ express bus (auto access)/ planning for light rail transit
300-400	Frequent + express bus (foot access)	Frequent + express bus (auto access)/ plan for light rail transit	Frequent + express bus (auto access) + light rail transit
>400 sqkm	Frequent + express bus (auto access)	Frequent + express bus (auto access)/ plan for rapid transit	Frequent + rapid transit

**Table 3:** Mode priorities based on density and expanse of city/UA

the respective urban expanse. For generalizing the above observations, the next sections examine whether a generic pattern to urban population density exists.

### 3 Power law and urbanization

As stated in the earlier section, the dynamics of density needs to be understood. This dynamics of density is represented by the interaction of urban population and urban expanse. Even though, city formation is a stochastic process, cities across geographies appear to follow a pattern in the form of a power-law (Gabaix, 1999). The Power-law or the Zipf's law states that cities across geographies tend to follow a log rank relation i.e. the population of a certain city is  $1/n$  times the population of the largest city, where 'n' is the rank of the city. Although, this rule has been found to hold across the developed nations, temporal variations have been observed. Krugmann (1994) had shown that urban areas in United States of America followed Zipf's law like characteristics.

Although the monocentric city form ensures continuity in the labour market (Bertaud, 2004), maintaining the monocentric structure requires concerted efforts from both, the town planners as well as the transport planners. Heilig (2012) projects that urbanization in developing nations like India would be the fastest. It is projected that the cities in the fast urbanizing countries would be expanding at 4% per annum (Angel et al., 2005). As a result, the urban areas would double within 17 years; such an interaction in the Indian case is not documented. Hence, to ensure that cities/urban agglomerations remain mono-centric, the interaction between population and urban expanse need to be understood.

#### 3.1 Zipf's law and Population residing in million plus cities of India

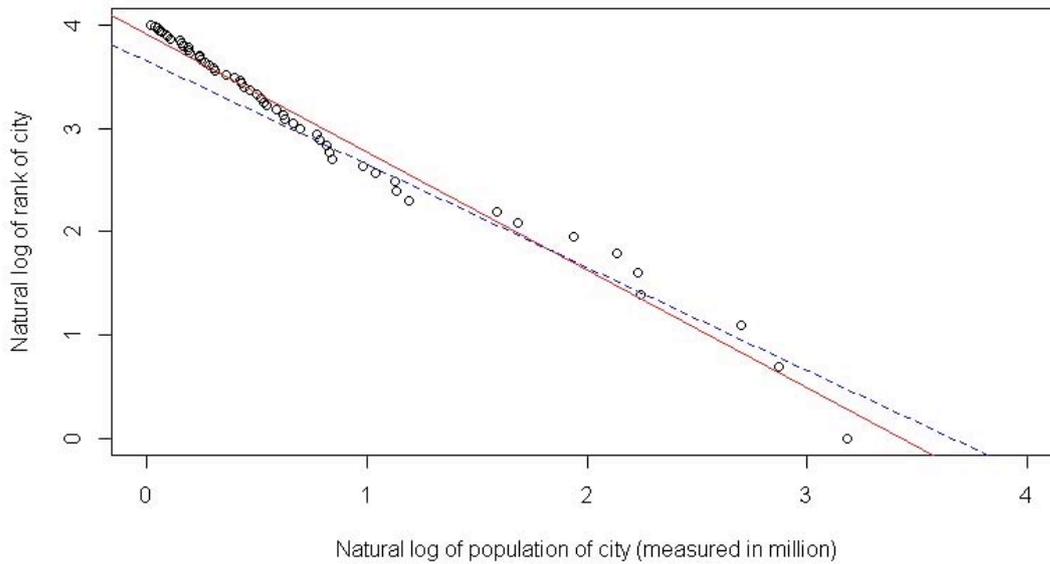
According to Census-2011, around 31% of Indian population is residing in urban areas. (Chandramouli, 2011). At the current rate of urbanization, 40% of the Indian population is likely to become urban by 2030, and by 2050, more than half of India would become urban. It is anticipated that 497 million individuals would be added to its urban population by 2050 (National Ur-

ban Transport Policy, 2006). Due to this increased rate of urbanization, the number of cities having a population in excess of a million would increase from the current 55 to 85 (Sankhe et al., 2010). Of the 85 cities having a population of more than a million, six cities would have a population in excess of 10 million (1 crore), as many as thirteen cities would have a population in excess of four million (forty lakhs) and 68 cities would have a population above a million. The urbanization trends tend to show a missing link in terms of small cities and large towns (Bhagat, 2011), a phenomenon also shown by the density distribution of Figure 1.

Even though the applicability of power law to Indian urban population was tested by Basu and Bandyopadhyay (2009) and Gangopadhyay and Basu (2009), none of the studies have tested this relation post census-2011. The study by Gangopadhyay and Basu (2009) includes all towns having a population above 200000 individuals. The estimated value for the Zipf's scaling exponent was 1.9133 with a standard error of 0.0073, while in the study by Basu and Bandhopadhyay (2009) the Zipf's scaling exponent was estimated to be 2.05. Both the studies estimated the Zipf's scaling exponent by regressing the log of the rank on the log of the cumulative density function. Both the studies primarily considered all clusters that were classified as urban. The present analysis considers urban agglomerations having a population in excess of a million. Therefore to estimate the Zipf's scaling coefficient rather than regressing the log of the cumulative density function of the city category on the log of number of cities falling in the population bucket, the log rank relation is used.

The dotted-line is the Zipf's reference line i.e. slope =  $-1$ , while the continuous line is the regression line.

Even though the latter method of estimation may lead to a downward bias, after accounting for the cultural and linguistic barriers to migration (Soo, 2014), the bias may not be statistically significant. From Figure 2 and Table 4 it is observed that the slope of the regression line is statistically different (greater than) from the Zipf's reference line i.e.  $-1 \notin (-1.1412 \pm 0.0230)$ .



**Figure 2:** Diagrammatic representation of Zipf’s law for Indian cities

This result indicates that unlike any other the observations of Bhagat (2011) are

Coefficient	Estimates	Standard Error	t-stat	p-value	Adjusted R2
Intercept	3.9173	0.0247	158.49	<2e-16(~0)	0.9785
Slope	-1.1412	0.0230	-49.63	<2e-16(~0)	

**Table 4:** Coefficients of regression result with respect to population

natural phenomenon (Gabaix, 1999), Indian cities having a population in excess of a million are not on their stable long run path (as defined by Sharma (2003)). If the universality of the log-rank relation is assumed, then the larger slope implies that the population growth rate in the more populated cities/UAs is greater than its stable path or conversely, in the longer run the smaller cities would grow at a faster rate. Considering that UAs are berths of economic activities, in the longer horizon, a paucity of a quality public transport in the lower ranked UAs and no policies curtailing ownership/use of private vehicles, motorization rates in these UAs are likely to be much higher than the projections of XIIth five year plan (2012-17) working group on urban transport (Sreedhar, 2011) and are even likely to exceed the aggregate vehicle density projections of Dargay et al. (2007). This would mean that an immediate intervention in the form of planning a transit system is necessitated. Further, as the population growth rates tend towards secular rates, a baseline scenario for transit provisions can be developed. This would enable development of decadal transport plans for the cities/UAs. In case,

likely to hold, the population would shift to the larger cities resulting in sprawling of the urban agglomerations. This phenomenon would necessitate the construction of a quality transit system.

### 3.2 Urban expanse of Indian cities and the Zipf’s law

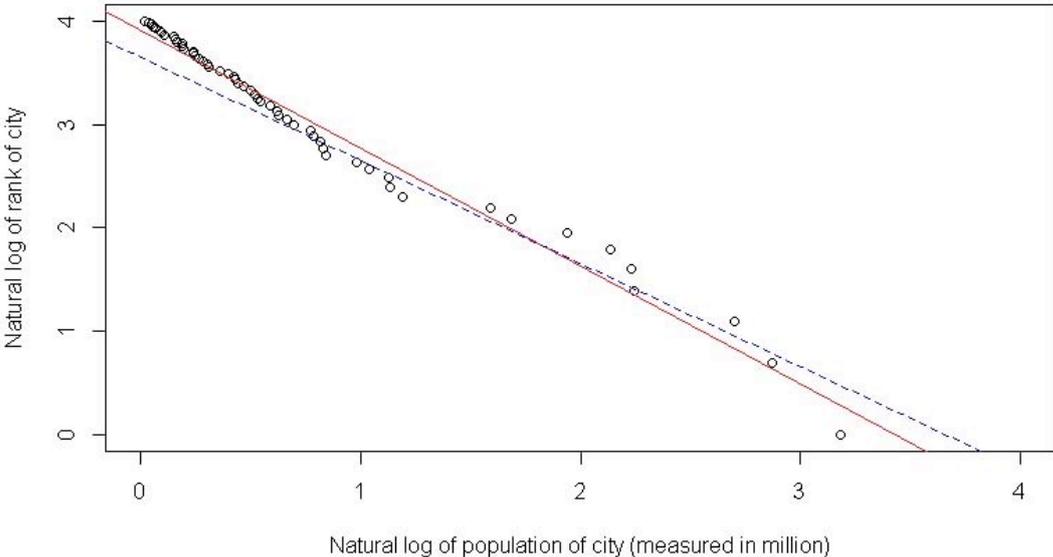
One of the other defining parameter of UAs is its urban expanse. Newman (2006) acknowledges that historically the mode of transport has defined urban expansion and eventually the size of the city/UA. Besides Marchetti (1994), Metz (2008) also confirms the invariance of travel time budget (a concept proposed by Marchetti (1994)). Transit mode design based on this concept is likely to ensure the sustainability of Indian urban agglomerations. Presently, a bulk of the Indian UAs suffers from underprovisioning of public transport and supporting infrastructure. Even though, the 12th five year plan (2012-17) addresses these issues, an over reliance on bus based transport (Ahluwalia, 2011) is observed. Considering buses can support up to 10,000 peak direction peak hour trips, the mode may not remain viable in densities that far exceed 10,000 persons per sq.km. Addi-

tionally, this mode tends to share right of way with other road users. With reducing average speeds this mode is likely to be adversely affected (Wilbur Smith Associates, 2008; Sreedhar et al., 2011) and is likely to result in increased use of private vehicles. For avoiding this over reliance on energy inefficient modes, planning for a mass transport becomes imperative. For planning this system, baseline urban expansion trends need to be developed.

Further, as projected by Angel (2011) and as observed in India, the cities are expanding in areas of no or multiple-jurisdiction (Dupont, 2007). To sustain the economic activities and ensure that private costs are low, villages and smaller towns within 50 kilometres of a city or an erst-while urban area have developed. This has resulted in the birth of at least one-third of the new urban settlements (World Bank, 2013). This expansion tends to push the boundaries of periurban interface areas outwards (Dutta, 2012). The variation in Master plans and actual development implies that baseline city expansion projections are not available and that changes to master plans are for accommodating the sprawl. This would mean that transport

corridors tend to lag human settlements. Alternatively, this would mean that there would be underprovisioning of transport infrastructure and subsequent transport infrastructure changes would be a daunting task (Small, 2007). Taking a cue from Krugmann (1994), the present sub-section examines whether Indian UAs follow the power law.. For checking whether Indian UAs follow this pattern, night image patterns of Demographia-10th edition are used. This not only accounts for the extended peri-urban growth but also discounts the non-utilized areas like National parks and rural lands that are still to be developed. This phenomenon becomes important for developing transport corridors and correctly estimating the gross urban density.

From the regression results as depicted in Figure 3 and Table 5 it can be inferred that the set of UAs are strictly following the Zipf’s law, and that at an aggregate level, these areas would follow a similar pattern of expansion. Based on these results it can be inferred that urban agglomerations are following the law of proportionate growth or Gibrith’s law (Sharma, 2003) and that this trend is likely to continue in the near



**Figure 3:** Application of power law to urban expansion of Indian UAs

Coefficient	Estimate	Standard Error	t-stat	P-value	Adjusted R2
Intercept	3.5600	0.0197	180.30	<2e-16 (~0)	0.9798
Slope	-1.0006	0.01955	-51.18	<2e-16 (~0)	

**Table 5:** Coefficients of regression with respect to urban expansion

future.

From these results, transport planners can develop a baseline urban expansion scenario, and accordingly, make transport corridors. This will ensure that the lag between transport infrastructure provision and human settlements is eliminated.

As stated in the second section, urban population density is the ratio of population and area. In Figure 1, it was observed that 10,000-12500 was the modal class, while, the density mean was 13,160 and the median was 12092. The next section investigates whether urban expansion and population are correlated and can the worst affected cities/UAs be identified.

#### 4 Rank reversal and density

Historically, it was observed that cities/urban agglomerations were maintaining their group characteristics i.e. four of the five most populated cities still remain the most populated. On comparing these cities to the cities with the highest density, it is observed that barring Mumbai (refer Appendix A), none of the more populated cities are in this category. For the success of transit, population density needs to be kept high or alternatively leapfrogging low density development needs to be curtailed. Population and urban expansion are related. The present section attempts to identify those cities that are sprawling and as a consequence are likely to become unsustainable. The identification of sprawling cities/UAs is done by contrasting population rank and urban expanse rank.

Assuming that there exists a healthy population density, with increase in population a proportionate increase in urban expanse would take place. This would mean that the population rank of the city and its rank with respect to urban expanse would remain the same. Cities/UAs that have a higher rank in comparison to their urban expanse rank are denser in comparison to those cities that have same ranks in both the categories and can be considered to be the more sustainable ones, while cities undergoing rank reversals are cities that are sprawling and would become unsustainable in the future. The cities with their ranks are listed as 'rp/ra', where 'rp' is the

population rank, while 'ra' is the area rank. From the analysis of ranks, it is observed that 24 cities/UAs have higher population rank in comparison to their urban expanse rank and as pointed out earlier are some of the more dense cities/UAs. Six cities retain their ranks across both the categories; while a majority (25) of cities/UAs undergo rank reversals.

The more sustainable cities are Mumbai [2/6], Kalyan [13/38], Vijaywada [29/52], Ranchi [44/53], Surat [7/9], Madurai [30/46], Gwalior [47/54], Assansol [37/50], Rajkot [33/47], Ahmedabad [7/11], Kannur [26/39], Kozhikode [19/29], Aurangabad [40/48], Patna [18/23], Varanasi [31/35], Kanpur [11/18], Nashik [28/31], Jabalpur [36/40], Jodhpur [43/44], Meerat [32/34], Agra [23/26], Vadodara [22/25], Nagpur [14/16] and Chennai [4/5]. Chennai and Nagpur have a much lesser density in contrast to the remaining 22 cities. From this result it may be deduced that these cities are likely to sprawl in the near future. Additionally, it may be stated that to avoid the urban density petering out, provision for multi-modal transport based on the average density-transit serviceable area needs to be initiated. This provisioning is over and above the present infrastructure. Although Solapur [55/55], Kota [51/51], Delhi [1/1], Bhopal [20/20], Lucknow [12/12] and Indore [15/15], retain their ranks, due to the vast difference between their densities, no conclusion about ideal density can be drawn.

The remaining 25 cities namely, Guwahati [54/49], Dhanbad [39/37], Jamshedpur [34/33], Amritsar [41/36], Vasai/Virar [48/41], Tiruchirappalli [50/43], Thiruvananthapuram [25/24], Bareilly [[53/45], Kolkata [3/2], Mysore [52/42], Pune [8/7], Durg-Bhalainagar [42/30], Raipur [45/32], Srinagar [35/27], Allahabad [38/28], Ludhiyana [27/22], Coimbatore [16/14], Bangalore [5/3], Jaipur [10/9], Hyderabad [6/4], Kollam [46/21], Malappuram [21/14], Thrissur [21/10], Chandigarh [49/19] and Kochi [17/8] have experienced rank reversals. With no plans catering to future expansion, a mismatch between master plan and actual growth will result in dominance of private vehicles. In addition, planning for mass transport in

these cities will become a daunting task. To avoid leapfrog development, density linked capping will have to be initiated.

## 5 Discussion

The paucity of a mass transport is steering the Indian urbanscape on an unsustainable trajectory. The primary onus of the Planning Commission (now NITI Ayog) was on bus based transport, This has resulted in a mismatch between transport provision and demand. To avoid this mismatch, the present study develops a framework linking average urban density and urban expanse to transit mode.

This framework is generic and can be used for planning mass transport for cities of the developing countries. The data requirement of this framework is minimal. In addition, through rank reversals, the worst affected cities/urban agglomerations can be identified. These results can be used for prioritizing the urban transport construction.

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## **Does our future lie with electric dinosaurs?**

*Helmut Holzapfel, Wolfgang Lohbeck*

It can be heard from all sides: Electric cars are the way of the future. Strange alliances are being formed that extend well into the ranks of climate activists. Internal combustion motors should be forbidden as quickly as possible. They don't belong in a decarbonised cosmos, in a brave new world where there's no place for the combustion of carbon. Decarbonisation is the new orthodoxy – so far, so good. And electric cars will bring us to this decarbonised future. No one seems to disagree.

And that is precisely why it's time to do just that.

The buzz word "decarbonisation" is undergoing the same loss of meaning that the term "sustainability" suffered some time ago as every milk carton came to be adorned with claims featuring the word. Now whatever goes under the label of "decarbonisation" is judged to be sacrosanct. The automobile industry and the political establishment are enjoying great success on this basis. Electric cars are being marketed as part of the solution for moving towards a decarbonised world, giving vehicles of this sort a mantle of immunity that should render them unassailable. And even climate activists are letting themselves be carried away by this hype. The fact is, however, that more electric cars – at least of the sort that the automobile industry would currently like to sell – will raise rather than lower emissions of CO<sub>2</sub>.

Automobiles are not power plants which have to be decarbonised directly at the source.

Electric cars consume energy produced by dirty power plants, and their production involves very substantial emissions of carbon dioxide. Even if one assumes that electric cars are powered with electricity from Germany or Norway that has a high renewable component, it is still the case that an electric car emits more carbon dioxide in total for years than an economically designed petrol-powered vehicle. When we look at things from a global perspective, the prospect is even worse.

The "electric" label functions as a *carte blanche* for all those aspects of automobile-based transport for which cars properly have a bad reputation. It is a general excuse for doing nothing to achieve an overdue reduction in the total amount of automobile traffic, or to develop truly sustainable forms of collective mobility.

The automobile industry is endeavouring to transform innovative technical initiatives – which electric motors certainly are – into their opposite. To really reduce the amount of carbon dioxide generated through transport, industry must, on the one hand, offer completely different products. And on the other hand, we must significantly alter our behaviour. Electric trains and bicycles, for example, operate far more efficiently than electric cars.

What is being promoted as "decarbonisation" in the transport sector is just old wine in new bottles. This old wine involves vehicles featuring ludicrously excessive weights and engine power that simply grows more and more extreme. It's all presented in a new package as electric and decarbonised. It's amazing how a certain type of technical "solution" makes it possible to keep everything exactly as it is. We simply have to switch to an electric motor and we can continue in our cars as before – only with even more weight and speed.

It would seem that all that's necessary is simply to exchange the motor and - presto - decarbonisation is complete. In fact, the opposite is true. The motor is not the main problem, rather the weight of the vehicle and its power output. The electric motor is simply a new sort of packaging. And it's having the desired effect. No one speaks any more about truly saving energy.

The electric car models that really are catching people's interest don't save energy at all. The reason for this – and it will be with us for some time to come – are the batteries' large space requirements and enormous weight. The archetype of the electric car that has captured the popular imagination – and at the same time its most inane incarnation – is the Tesla automobile. It solves the problem of the travel range provided by battery power very sim-

ply: An enormous and exceedingly heavy pack of batteries is installed under the passenger compartment – no problem!

Indeed, if these vehicles are to have an extensive travel range, such large and heavy battery packs are unavoidable. The paradigmatic Tesla 90 weighs well over 2 tons without passengers, a load that must always be transported. The energy required for that transport is not reduced because it comes from electricity rather than petrol. On top of this, these dinosaur cars have enormous acceleration capability because of their electrical motors, which makes them use even more energy.

The tranquillizer: “E-motor = decarbonisation” is having amazing (and the desired) effects. Automobiles no longer need to be designed to be smaller, lighter, slower or to have less power. They can grow without limits, immeasurably, as each new generation of SUVs demonstrates once again. When these vehicles are driven at high speeds and accelerated rapidly, then their energy consumption is much higher than in conventional, lighter cars.

And when they are used for long-distance travel, they must be recharged frequently which is not a minor problem. Up until now the charging stations for electric cars have typically been located in cities. Petrol stations on the highways would need very high-capacity connections to the electric grid and lots of space, since recharging batteries takes substantially longer than filling a tank. As soon as the millions of electric cars that in many countries are being promoted with state subsidies are actually in use for long-distance travel, there must also be charging stations the size of football fields along our highways. Currently neither this space nor the high-capacity electrical connections are available. Building such facilities requires energy. Planning and construction often take a great deal of time.

With this limited potential for long-distance transport, the electric car’s immediate future seems limited either to use as a rental vehicle or as an exceedingly small vehicle for personal urban use – also in limited numbers. Until now, recharging stations in cities have mostly been installed at central

locations. If electrical charging should also be made possible at residential flats, then our cities (having finally moved beyond the failed urban planning vision of adapting cities to cars) will instead be transformed into giant parking lots equipped with electrical charging stations.

And this is our vision of the “decarbonised city”?

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## **Automated and Connected Vehicles: High Tech Hope or Hype?**

*Preston L. Schiller*

### **Introduction: HOFOs, ADAS, AVs and CCs**

The term 'autonomous vehicle' is commonly, and somewhat erroneously, applied to several related but somewhat distinct technologies under development for motor vehicles. The true AV is one in which the vehicle is fully automated and capable (supposedly) of guiding itself through traffic to a destination chosen for it by its owner or controller. Through various forms of sensors and on-board devices the vehicle is supposed to be able to detect and respond to a variety of road conditions; physical conditions of the road, nearby traffic and animate beings--two or four-legged--in or likely to enter its path. The AV may or may not be dynamically connected to the internet. An automated vehicle dependent on its dynamic internet connection for guidance and control is known as a connected car (CC). The early technology which allowed a human-controlled motor vehicle to perform in a very limited semi-automated manner is known as 'hands-off, feet-off' (HOFO) for relatively familiar technologies such as the widely used 'feet off' cruise control, and some types of braking systems and the first generation of human monitored assisted steering (hands off). More complicated than HOFO is the continually developing Automated Driver Assistance Systems (ADAS) technology. This ranges from already developed and implemented HOFOs to an array of automated guidance (steering), braking, crash prevention and even parking technologies. (Hummel et al 2011, Trimble et al 2014, Choi et al 2016)

Rather than precise labels, these phenomena suggest a spectrum of motor vehicle (MV) control and guidance ranging from the conventional driver-vehicle arrangement, through HOFO and ADAS to AV and CC. Differences between HOFOs, ADAS, AVs and CCs also have significant philosophical, cultural and legal implications. (Glancy, 2012; Millar, 2014; Markoff, 2016; Quain, 2016)

By comparison, the European Parliament Research Service (EPRS) Briefing of Jan. 2016 defines automated, autonomous and connected vehicles in a slightly different, but also useful, way:

Automated vehicle: a motor vehicle (car, truck or bus) which has technology available to assist the driver so that elements of the driving task can be transferred to a computer system.

Autonomous vehicle: a fully automated vehicle equipped with the technologies capable to perform all driving functions without any human intervention.

Connected vehicle: a motor vehicle equipped with devices to communicate with other vehicles or the infrastructure via the internet.

Cooperative – Intelligent Transport Systems (C-ITS): systems consisting of vehicles accompanied by a communication and sensor infrastructure with which the vehicles – fitted with appropriate on-board devices – are capable of communication between themselves and with the infrastructure.

(Source: EPRS, 2016, Glossary)

Hands-off/feet-off (HOFO) and Automated Driver Assistance Systems (ADAS) vehicles imply the presence of a human driver ultimately in control who may cede control or guidance for a period of time to one or another computerized systems. Cruise control, the ability of a motor vehicle to maintain a set velocity with the driver's foot off the fuel pedal, was an early form of HOFO. At present there is a great deal of activity and attention and investment, public and private, being made in each of the three types of automated or semi-automated vehicle technologies. The ultimate connected car would operate with or without a human presence, would not have a steering mechanism for a human to operate under any circumstance, and would be in constant motion fetching or delivering passengers and parcels as directed from the all powerful internet cloud.

## History: From flying carpets to DARPA and Google cars

Autonomous vehicles have had a long history in myth, fiction and science fiction and a somewhat shorter history in application. The longer history can be traced back centuries to stories themed with flying carpets moving persons about for good or evil and then on to the lore that began to surround self-propelled or self-guided vehicles and weapons that began to emerge in the nineteenth century, including the auto-tiller for sailing ships and the self-guided torpedo for maritime combat. (Weber 2014) Indeed, it is somewhat of a misnomer the personal motor vehicle (PMV) developed in the late nineteenth century has popularly come to be known as the automobile, since it is not, in fact, self-directed but until recent experimentation, has always been under human guidance.

It is also important to note that military purpose has guided or surrounded autonomous vehicles, in fact or in fiction, since their earliest accounts. The desires of the automobile industry, exemplified in General Motors 1939 World's Fair Futurama exhibit featuring the drive-to--drive-through America of the future complete with automated highways and vehicles, have also influenced public perceptions around AVs (Weber, 2014)<sup>1</sup>.

The shorter history of the AV in application can be traced back to inventions such as the 1930s Sperry Gyroscope autopilot for aircraft and Nazi rocketry in World War II, then on to RCA's Sarnoff Laboratories AV work that began in 1949 which led to its teaming with GM in the 1950s to develop a highway automation demonstration and prototypical AVs such as the late 1950s Firebird III. But it was the development of computers, especially microprocessors, and advances in programming, especially around artificial intelligence (AI), robotics and space exploration, from the 1960s onward, that accelerated the development of AVs and began its significant funding. Parallel to the development of surface AVs was the development of autonomous or semi-autonomous underwater and air vehicles such as the Predator drone, mostly

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<sup>1</sup> also see the discussion of Futurama in Schiller, et al, 2010

used for military purposes, although with some valuable civilian uses. The development of surface AVs capable of navigating in real traffic, rather than just at the test facilities of automakers, was limited to a few noteworthy experiments beginning in the 1980s such as Ernst Dickmanns' Mercedes van developed at Bundeswehr University, Munich, and a similar effort at Carnegie Mellon University, Pittsburgh. (Weber, 2014; Nowakowski et al, 2014)

U.S. governmental interest in the field was also manifested in the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) which included a program and funding for research and demonstration projects for automated highways. This led to the 1997 demonstration of highway automation in San Diego, CA, by the General Motors-led National Automated Highway Systems Consortium (NAHSC). (Nowakowski et al 2014)

The development of autonomous vehicles switched into high gear fueled by the interest and funding of the U.S. defense establishment's Defense Advanced Research Projects Administration (DARPA) which began a series of contests beginning with the 2004 \$1 million desert challenge. DARPA was hoping to develop a significant fleet of military AVs by 2015. The 2004 results were disappointing but the 2005 contest produced a number of vehicles capable of navigating the Mojave Desert (California) course successfully. By 2007 the contest became an "Urban Challenge" in a simulated urban driving environment where contestant vehicles had to obey traffic regulations while addressing road blockages and moving obstacles; several experimental AVs were able to successfully complete the course. (Weber, 2014; Fagnant & Kockelman, 2015; Nowakowski et al, 2014)

As AV technology and performance improved through the years between 2000 and 2010 most automakers, large and small, West and East, began to direct more and more attention to its development, or at least to the furtherance of related technologies such as HOVO. By 2010 the Google car was sufficiently advanced that the issue of AVs began to attract regulatory attention. Since discussion of AVs has

become part of daily life in most motor-ing societies attention needs to be given

### **Sebastien Thrun; AI, AV and pizza-fetching Pribot developer**

... Sebastian Thrun, (was the) team leader for Stanley, winner of the 2005 Grand Challenge. Thrun lost a friend to an auto accident in his youth, which motivated him to research self-driving. When he led the (2005) team he was Director of the Stanford AI (artificial intelligence) Lab. ... By the late 2000s Google had moved beyond its core search business in several ambitious directions ... . Founders (Larry) Page and (Sergey) Brin especially liked to take on pivotal problems a few uncomfortable but exciting notches short of being solved, what they termed "moon shots."

An early example had been Street View for Google Maps, co-developed by ... Thrun. In 2008 he encouraged another self-driving veteran on his team, Anthony Levandowski, in a side project called the Pribot – a Prius modified for the stated goal of fetching pizza on its own.

The Pribot's success helped convince Google's founders that self-driving, too, might be a technology on the cusp. They assigned the Pribot ... a series of challenges such as driving 100,000 miles on public roads, and even descending San Francisco's twisty Lombard Street. It passed, and they made Thrun co-head of a new effort, Google X, geared to launching "moon shot" ventures.

Thrun recruited Levandowski and many of the other top researchers in the field, including Urban Challenge star Chris Urmson. The team began the hard work of transforming the raw capabilities demonstrated in desert Challenges into a consumer system; one polished enough to safely carry living passengers in the real world of traffic, and commuting, and family vacations.

Google's system has guided a fleet of Prius and Lexus vehicles over half a million miles without causing any accidents, and the firm is a leading advocate for fully self-driving cars. But as to how it might deploy the technology, Google is keeping its options open.

(Source: *Weber 2014*)

to how and why this curious invention is being promoted--and by whom.

### **The promotion of HOFOs, ADAS, AVs and CCs**

The promotion of HOFOs, ADAS, AVs and CCs has been undertaken over many years by several major players, these include:

- National or International Governments: The governments of the United States, European Union, China, Canada and numerous other countries are actively sponsoring programs of research funding and legislation formation to facilitate the development and production of AVs Chignall, 2016; Markoff and Mozur, 2016). The U.S. has long had programs supporting what is has termed intelligent vehicles and highway systems (IVHS) and intelligent transportation systems (ITS) and advancing the cause of AVs and CCs is the highest priority of the ITS program:

"The ITS Strategic Plan's framework is built around two key ITS Program priorities— realizing connected vehicle implementation and advancing automation. The priorities reflect stakeholder feedback on the need for the ITS Program not only to conduct research, but also to help with deployment and implementation of specific technologies related to connected vehicles and automation"

(ITS Joint Program Office 2014; Barbaresco et al, 2014; Sessa, C. and M. Fioretto 2013). As noted above in the history section there has been a long and extensive involvement of military interests in AVs and the considerable presence of the U.S. Department of Defense (DOD) in research and development (R&D) involving AI and automation as applied to weapons development has also aided the development of AVs.

- State-Provincial-Regional-Local Government: Many states, provinces, regional and local governments are creating funding mechanisms, often in partnership with auto industries, as well as well as developing strategies and processes aimed at the regulation of AVs. Some cities, either already influenced by high tech interests

in their vicinities, or hoping to attract high tech and automaking firms, are rolling out welcoming mats by encouraging them to use their roads to test AVs. While the federal government of Canada is only minimally involved in supporting AVs, the Province of Ontario is quite involved in working with automakers in these regards. (Ticoll 2015; Dougherty, 2015)

- The armaments industries are very interested in AVs due to the interrelationship of AV technology with weaponry, including unpiloted air and undersea vehicles such as the Predator drone and undersea automated vehicles; the first DARPA contests aimed to have a battlefield AV capability.

- The non-military high tech sectors of national economies are deeply involved in developing automated vehicles or software and other products related to AVs. Some-like EMBARQ, who have been supported in the past by fossil fuel and highway interests have been boosters of approaches such as bus rapid transit (BRT), and have led the attack against electrified rail transit--are more recently coming around to a multi-pronged approach to urban transportation including newer high tech (and often unproven) urban transportation applications and planned integration of communications, transportation and land use planning (Gazibara et al, 2010).

- Apple Inc. is developing an AV as well as forging a relation with Didi Chuxing, China's biggest ride-hailing service. Google is, of course, investing heavily in the development of an autonomous car, as well as exploring an AV ride-hailing service that would replace most vehicle windows with screens--the better to attract attention to numerous flashing advertisements. Google and Amazon.com are investing heavily in on-demand delivery services and associated software; perhaps if Amazon's delivery drones don't work out then either a Google or Amazon AV will bring your package to your driveway and flip it onto your porch? (Newcomb, 2016; Isaac, M. and V. Goel, 2016; Pyle, 2014; Gazibara et al, 2010)

- The automobile industry, worldwide, is deeply involved with HOVO-ADAS-AV-CC research and implementation, many of them promising to have vehicles with some

or all of these advanced features available within a few years, although there are significant differences in opinion and approach among them as to which is the best approach and most likely trajectory for applications in these areas (Boudette and Isaac, 2016; Kageyama, 2015; Ohnsman, 2014).

- Several of the major automakers and ride-hailing services are forging links as part of their joint strategies to sell AVs in the future and do away with drivers and increase profitability (Isaac and Boudette, 2016; Davies, 2016).

- Many promoters of automated vehicles believe that AVs will reduce crashes and, therefore, save money on insurance claims that should translate into rate reductions for vehicle owners. The automobile insurance industry appears superficially supportive of AVs in the belief that this technology will reduce crashes and concomitant repair and liability costs. But many observers do not believe that insurance premiums will be lowered in proportion to such savings in the near term, but rather that the reduced costs will only inflate industry profits. The situation for automobile insurers is less clear further out in the future (III, 2016).

- The transportation research and policy establishment--especially those aspects of it which tend to promote mobility--is extremely active in advancing automated vehicle approaches. These efforts are often greatly assisted by relations with university-affiliated transportation research centers such as very sophisticated testing facilities sometimes operated in close cooperation with automakers. (Boudette, 2016b). Some curious combinations of mobility research units, automobility and telecommunications interests and NGOs purporting to support alternatives to automobility have also emerged around AV issues (Gazibara et al, 2010). The development of AV technology also presents challenges and opportunities for aspects of the engineering profession closely linked with automobility infrastructure, such as the profession of civil engineering. Some prominent AV promoters have urged that profession to take notice and begin to form cooperative and supportive relation-

ships with a range of automated vehicle interests:

"ITE (Institute of Transportation Engineers) should reach out and form robust collaborations with vehicle manufacturers, systems and app developers, professional organizations, and governmental bodies that are already actively promoting autonomous vehicle technologies, and strive to find ways to achieve synergies that will benefit not only ITE members but also society as a whole" (Lutin, et al, 2013).

- When a new technology with vast global reach and penetration emerges can the marketing, advertising and public relations (PR) enterprises be far behind? One might expect that they would be working to position themselves in the forefront of the promotion of this technology, especially since its emergence will be prominently featured in a wide array of media; print, broadcast and internet-social. Public reception will need to be shaped and clever messages will have to be formulated in order to assure its commercial success--and that of the promotional industries facilitating it. One major global PR player appears to be positioning itself for AV promotion through a number of reports aimed at influencing corporations, involved publics and governmental entities. According to its analysis, "The Future of Driving: Five Ways Connected Cars Will Change Your Life," the public can expect wondrous services from AVs:

1. *You'll be safer:* Automated driving will greatly reduce the chance of accidents – and remove the need for traffic lights!
2. *You'll have more "me" time:* Your car will be able to drive itself and park itself. So stretch out and read a book, or chat with your friends online as you travel. Jump out the car at the restaurant and meet your friend for lunch, whilst your car goes to park itself.
3. *You'll have more money:* Your insurer will never worry about your driving history again. And get your car "uber-ing" or start ride sharing.
4. *You'll visit the doctor less:* Your car will become the most advanced mobile device that you use, capable of

becoming a "clinic" through its health-care apps. Get a health check-up whilst you're being driven to the office!

5. *You'll want to commute more often:* Your connected car will be part of a network that provides a commuting service for you. You'll finally be able to enjoy a stress-free, enjoyable travel experience.

(Ipsos MORI, 2016, bolded in original)

According to this analysis it appears that the only thing that the AV-CC will not do is cook your breakfast and serve it to you whilst you are whizzing along in perpetually flowing traffic that never experiences a problem or a pedestrian.

### **Issues, Questions, Promises and Problems**

Given the many broad claims and boasts that AV boosters have launched, such as the Ipsos list cited above as well as sweeping claims by some academics (LutinKornhauerRevDevAV.pdf), it is not unfair to ask for more narrowing, more specifics. For a start one might query: "Just what is the problem that AVs are meant to solve? Is it congestion? Crash reduction? More mobility for those feeling travel constrained?" This section will look at a range of issues and questions that surround AVs as well as explore some of their promises and problems. The following section will assess the reality, rather than the hype, of AV development at present and the foreseeable future. Among the several major issues that confront the development of AVs are numerous technical challenges facing HOV-3s-ADAS-AVs-CCs a few of which are:

- The shortcomings of its detection systems to distinguish among things that appear similar in shape, such as a pothole or a puddle, discern differences between shadows and structures, or to identify road markings, signage, etc. in bad weather.
- The limitations of the algorithms that are guiding them, especially the inability to respond sufficiently to other unconnected vehicles or moving objects in mixed traffic, as when the Google car swerved and crashed into a transit vehicle because its algorithm "expected the bus to get

out of its way.” The inability to detect and identify the side of a large truck that was crossing its path was a causative factor in the widely publicized Tesla HOF0 crash in 2016 (Vlasic and Boudette, 2016).

- The limitations of computerized mapping and GPS guidance, especially when they may not be up-to-date with current road conditions or infrastructure changes.
- The ethical and technical dilemma of whether the computer algorithm guiding the car can navigate the complex ethical dilemmas inherent in vehicular mobility. The classical “trolley problem” of ethics and philosophy, whereby an operator (in this case a computer algorithm) has to choose between whose lives to save, will find its analog in AVs, especially when glitches in programs surface.

The world of traffic is extremely complex, perhaps in certain simple situations the computer may make the correct decision, but the blanket promise of AVs safety may be something of an over-reach. Still, it is a great PR ploy as a television advertisement from a major manufacturer of luxury vehicles demonstrates:

“The 2014 Mercedes-Benz E-Class includes cars that can see like a human. It can stop itself. For example, a young girl chases after her soccer ball into the street, which triggers the E-Class to stop immediately. It doesn’t just see the future, it is the future” (iSpot.tv, 2014).

The “ball in the street” trope has long been used by automobility interests to frighten parents by exaggerating the dangers of children playing in or near streets and to justify anti-pedestrian restrictions. In today’s situation, where traffic calming and shared or pedestrianized streets has become more popular, the fright of children running into the street (where children shouldn’t be!) is a latter day version of the automobility interests undying commitment to preserve all streets, even in low traffic residential areas, as the unquestioned domain of the motor vehicle. (Boudette, N.E., 2016a; Vlasic and Boudette, 2016; Davies, A., 2016; Zolfagharifard, 2015; Jaipuria, 2015; Norton,

P.D. 2008)

There are several complex public policy and governmental regulation issues emerging around AVs:

- In the U.S., and Canada to a certain extent, the federal government develops an array of policies and regulations guiding and governing safety issues and vehicle standards; crash worthiness, product safety matters (seat belts, air bags, etc.), fuel efficiency, emission standards, vehicle classification and also has some influence over speed limits on federal roadways, etc. The policies and regulations for vehicle operation, with the possible exception of long-distance trucking and some aspects of long-distance passenger services, are left to the states and provinces; licensure, most speed and load limits, etc. It is unclear where AVs, ADAS or even HOF0s, might fit into this division of powers and responsibilities. For instance, if the controls CCs are connected by an interstate internet system, what will the jurisdictional arrangements be? How will the integrity of the internet-based system be assured? Could there be multi-state impacts similar to the situation of large power grid failures? At present only a few state, provincial and local jurisdictions are allowing AVs and ADAS to operate on their roadways and the federal governments are either watching or very slowly beginning to think about national implications. There is a great deal of murkiness-if not a vacuum, surrounding regulation and restriction at all levels of government: What will the situation be if and when AVs become more available and grow in numbers? (Nowakowski et al, 2014; Kessler, 2015)
- Despite the regulatory vacuum at the federal level in the U.S. and Canada, several automakers are charging ahead with the development and marketing of HOF0-ADAS features in new vehicles and nothing is slowing the various developers of AVs and CCs from charging forward with their development efforts and marketing hype (Kessler, 2015).

### **Possible positive features of HOF0s, ADAS, AVs and CCs**

- *Deep market penetration needed:* While it is difficult to separate the likely “wheat” from all the hype “chaff” surrounding vehicle automation, it is likely that there could be some aspects that would be beneficial. But the greatest promises of automated vehicles are not likely to be realized short of at least a ninety per cent market penetration and, even then, only on fully grade separated roadways--not in ordinary urban and suburban traffic situations. Their promise is also unlikely to be realized unless and until the overwhelming majority of motorists eschew private ownership in favor of some sort of car-share arrangements (Fagnant and Kockelman, 2015).

- *Energy and GHGs:* Automated vehicles, especially AVs and CCs, will likely be fully electric powered and, with complete or near complete market penetration, could shed many pounds or even tons of weight since they will not need heavy engines and drive trains or some of the heavy emissions and safety structural features now built into internal combustion engine (ICE) only or hybrid vehicles. A lighter weight would be dependent on advances in electric storage technology allowing AVs to operate with a smaller, lighter batteries. If all the vehicles on the road were AVs or CCs there would not be the risk inherent in lighter vehicles crashing with heavyweights and there could be some additional energy efficiency from regenerative braking. This could translate into significant energy use and GHGs reductions, especially on automated highways where closer packed platooning might be possible and depending on the sources of the electricity and the time of day (or night) when charging occurs. It is unclear how much energy and GHGs reduction would occur under some scenarios of urban traffic and deadheading deployment (running empty one way to or from passenger origins or destinations). Additionally, it is unclear as to how much generated traffic and increased demand for personal vehicular transport would be created with AVs; most scenarios see increased demand for segments of the population currently unable to or unlikely to drive such as children and the elderly which would lead to increased levels of energy consumption.

- *Pollution:* There would almost surely be

a significant reduction of local air pollution with the adoption of electrified HOFs, AVs or CCs. Whether there would be significant reductions in regional air pollution depends upon the fuel source and technology of electrical generation.

- *Parking reductions:* A huge reduction in parking demand is promised by AV & CC boosters. But this would likely only occur in a scenario where private ownership of vehicles is minimal and most motorists would avail themselves of AVs through car-shares or automated on-demand ride-hailing services. As indicated below, generated traffic could consume the road space relieved by lessened parking and thereby reduce this potential benefit.

- *Traffic congestion reductions:* Under optimal market penetration scenarios, AVs and CCs could reduce congestion on grade-separated and controlled “smart highways, smart infrastructure” or, possibly, on a completely separated “smart lane.” This could be accomplished through a variety of vehicle stacking and platooning phenomena. But without a major realistic and large-scale demonstration it is not yet clear whether AVs and CCs would reduce vehicular congestion on most urban streets due to the great complexities of their traffic situations, especially if pedestrians and cyclists are to be appropriately accommodated. Certainly a major reduction in crashes will help urban traffic flow, but the buy-back phenomenon of traffic generated from increased demand for travel from currently unserved and underserved populations may offset vehicular congestion reductions (Fagnant and Kockelman, 2015).

- *Freight movement:* automated or robotic vehicles are already used widely in carefully controlled environments in certain industrial applications, from warehousing to mining. There is also considerable interest and activity in the development of electric HOFs and AVs for long distance trucking. This would require the existence of carefully controlled special lanes and a fair amount of “smart infrastructure” to allow platooning and other energy and highway space saving effects. The idea of freight electrification is not new (Gilbert & Perl, 2008) but the possibility of fleets

of automated trucks could do much to reduce some of freight movement's externalities as well as enhancing its safety for operators and other persons and vehicles in its operating environment. If policy will and funding are made available at sufficient levels this aspect of HOFs and AVs could be realized within a fairly short time frame, especially since several fairly viable vehicle models, especially HOFs, are already well-developed (Ticoll, 2015; Taso and Botha, 2003; Markoff, 2016b).

- *Public transportation--transit:* Full automation has already been successfully implemented in a number of urban rail transit-fixed guideway-grade separated systems. Automated busways could probably be successfully developed in similarly grade-separated and intersection controlled corridors, such as Los Angeles' transit system's (LACMTA) Orange Line bus rapid transit (BRT) and similar BRT systems around the world. It is conceivable that urban and suburban transit providers could better address the problem of the "last mile;" how to deliver passengers to and from the transit line closest to their origin or destination when that line is greater than comfortable walking distance. A small automated transit vehicle accommodating no more than twelve passengers would be able to navigate neighborhood streets better than a standard bus. The success of services such as "Uber Pool" demonstrates that a market for such a service exists. With imaginative planning and policy it is possible that public and private providers could cooperate within a "Mobility as a Service (MaaS)" framework so that the best features of mass transit could be combined with the most attractive and cost-effective aspects of ride-hailing services to fill this service gap. It is possible that such vehicles could provide a good mobility option for many persons now relying upon paratransit service and perhaps even provide some local parcel delivery services without filling the neighborhood skies with drones (Heikkilä, 2014; Manjoo, 2016a; Taso and Botha, 2003; Pyle, 2014; Bruun and Givoni, 2015).

While this scenario might work for wealthier countries where personnel now engaged in driving transit vehicle could be redeployed to other service provision ar-

reas, such as security and information, it might have negative consequences in less wealthy countries where jobs in transit and paratransit are major sources of income for many people.

- *Mitigate roadway expansions:* It is possible that, if the most optimistic of AV scenarios were to be realized, that demands for increasing the capacity of major highways could be mitigated by the compression of high speed traffic made possible by AV and CC technologies. But, then, what does one do with all these extra motor vehicles once they leave the exit ramp? Would the historic congestion and slowing of traffic now common to most expressways simply be transferred to urban streets?

### **Possible negative consequences of HOFs, ADAS, AVs and CCs:**

Several researchers, in addition to the authors of this article, point to a number of possible or probable negative consequences that could flow from wide-scale adoption of ADAS, AVs and CCs (Wadud et al, 2016; Bruun and Givoni, 2015):

- Travel speeds may increase on automated highways, due to reduced crash risk, which would increase energy consumption.

- Energy consumption might rise from increased travel as the cost of drivers' time is reduced and travelers, especially commuters, can make their in-the-vehicle time more productive which could lead to longer commutes. As previously noted it is possible that deadheading (a dispatched AV or CC running empty on one of its trip legs) could increase energy consumption. There is already concern in some safety quarters about HOFs increasing distracted driving considerably, including more sex in moving vehicles. (Pedwell, 2016) Since the privacy of the automobile, albeit mostly parked in an out of the way location, has often been associated with teen sex, one can only imagine how much time ADAS, AVs and CCs will spend on the road facilitating such trysts--especially when GoogleCar has its way and replaces most of the windows with computer screens flashing pop-up ads.

- Older persons, children and other populations traditionally excluded from the driver's wheel may increase their travel demands when AVs and CCs become widespread and readily available. This could increase transportation energy consumption and demand for space on urban streets, thus eliminating the potential for gaining urban space through the elimination of on-street parking.

- There may be health consequences; researchers have already documented the likelihood of increased motion sickness associated with AV travel. (Sivak and Schettler 2015)

- Depending upon pricing regimens, travel demand could increase if AVs and CCs lower the marginal costs of driving through the elimination of parking fees, vehicle maintenance costs, insurance, etc. A sort of AV Jevons paradox<sup>2</sup>.

- Similarly, if automating freight--either local or long distance, reduces the costs and time penalties associated with goods delivery, an increase or acceleration in consumption might occur. Imagine the glut that might ensue when consumers don't have to wait ten days to try ten pairs of shoes to find the right fit in a shoe; when automated logistics shortens that time span to one day; freeing the consumer to engage in nine extra internet shopping days. Or imagine what happens when automated freight allows you to order exactly what you want for travel while in a long line at an airport and have it delivered to the baggage department or lodging at your destination (Wadud et al, 2016).

- Traffic infiltration of previously low traffic neighborhood streets could increase significantly with the advanced navigational systems that would be incorporated into AVs and CCs. Such systems would choose the most direct and least congested pathway for the vehicle, regardless of neighborhood concerns or local traffic policy. Some GPS devices may already be doing this in some areas (GPS.gov, 2016).

<sup>2</sup> Jevons noted that with the increased efficiency of coal burning in the industrial revolution, more coal, not less would be burned due to its growing attractiveness as a fuel.

- Urban densities and activity intensities may be viewed as inversely proportional to high levels of per capita car use, although dense cities are often very congested due to their proportionally lower amount of land devoted to roads. High levels of motor vehicle saturation and asphalt domination will work against preserving open space or having an environment amenable to walking, cycling and surface transit. There are limits to how many personal motor vehicles, automated or not, can be crammed into urban space without rendering it unliveable and unworkable. In their rush to usher in a new motor vehicle millennium, the boosters of AVs and CCs have simply not done their homework; they've not done the spatial analyses necessary to test their beliefs and promises (Bruun and Givoni 2015; Shin et al, 2009; Fraade, 2015).

#### *What might the reality of automated vehicles be?*

In this article we have reviewed many of the claims made by promoters of AVs and we have tried to assess some of their major positive and negative features. The boosters of AVs and CCs have been busily painting a rosy picture of their future and conveniently ignoring or dismissing concerns about them. But more than positive or negative conjecture about the future, a sober assessment of the realities of the present and future--near-term and long-term, is sorely needed:

- AV and CC technologies, hardware and software--including telecommunications, might not develop as expected. There is considerable difference between real world experience and laboratory, simulation or virtual experiences. For all their shortcomings as motorists, humans are still remarkably competent in reacting to the challenges of the road; visual acuity, depth perception, recognizing hazards, etc. When sober, that is. There are problems in robotics that are extremely difficult to solve; simple human walking and running is proving to be extremely complex and difficult to imitate, which is why such robots look pitifully clumsy and unlikely to win any Olympics track and field competitions any time soon. Perhaps perfect driv-

ing may be beyond the reach of engineers? (Chalodhorn et al, 2010; Manjoo, 2016b)

- The bugs and glitches of HOFOS, ADAS and AVs are still abundant, as the crashes of Tesla and Google vehicles remind us. Perhaps not insurmountable, but perfection is likely more than just a couple years away. It is likely that HOFOS and ADAS technology, which still expects attentiveness on the part of the driver, might lead to increased risk from the distractedness now commonly associated with the use of cell phones and related devices while driving (Editorial Board, 2015; Greenermeier, 2016). It is ironic that the Google car crashed into a transit bus and forced considerable inconvenience for its passengers who had to disembark and wait for another transit vehicle. Google admitted, not without a hint of arrogance, that their automated car expected the bus to swerve and avoid their erroneous lane intrusion: "In the wake of the accident, Google acknowledged its role in causing the crash, noting that the car (computer program) "predicted that [the bus] would yield to us because we were ahead of it." While the mainstream media has seized upon the relatively poor record of experimental automated vehicles, in fairness to Google and other AV developers it must be noted that when the University of Michigan's Transportation Research Institute (UMTRI) studied the crash records of the experimental models undergoing road testing, it found that, while the available data indicated that such vehicles were over-represented in crashes and crash-related injuries, the AVs were not at fault for such crashes and that injury severity was lower than for conventional vehicles (Ewing, 2016; Zolfagharifard, 2015; McHugh, 2015; Vlastic and Boudette, 2016; Quain, 2016b; Davies, 2016; Ziegler, 2016; Isidore, 2015; Schoettle and Sivak, 2015).

- The hackability, manipulation of or control of car computers and their software by persons other than the owner and designated service personnel is a well-established problem for owners, regulators and the general public. For as many years as automakers have been incorporating computers into the operational controls of motor vehicles, owners and computer hackers have been finding ways of defeating

their integrity in a number of interesting ways, of which only a few are of interest to the matters under discussion in this article. Computer savvy owners may hack their car's computer in order to manipulate certain data, such as the true amount of miles/kms driven and other matters that may impinge upon its resale value or adherence to safety or environmental regulations. As the recent diesel emissions control scandals have demonstrated, some manipulation is undertaken by automakers themselves on a vast scale in order to evade environmental regulations. One can only imagine what might happen when computer savvy adolescents decide that they want to race each other, or when mischievous experts or cyber-terrorists decide to hack AV systems to see what it would be like to shut down all the free-way traffic of a major city (Perlroth, 2015; Hoag, 2012; Billington Cybersecurity, 2016; FlyerTalk Forums, 2010).

- Fleet turnover takes a long time: At the very least it can take on average a decade or more to turn over an existing standard personal motor vehicle (PMV) fleet. At present the rate of market penetration for electric vehicles (EVs) is at most two per cent of new PMV purchases in most countries where substantial automobile markets exist--even after considerable improvements in EV range and operational features. The market penetration for car-sharing is even smaller, less than two per cent of the car rental market in the U.S. and an infinitesimally small portion of the total car ownership, car rental and driving totals. Since most of the positive features of AV domination can only occur once their market threshold surpasses ninety per cent penetration, it could be many decades before this could happen (GlobalEV-market032415.pdf, Fagnant & Kockelman; Young, 2015).

- Infrastructure transformation needed for AV domination could be extremely expensive and may be beyond the reach of most cities or nations. While it does not appear that any reliable cost estimates exist of the expense transforming all the requisite transportation infrastructure of a whole large city to accommodate AVs or CCs, one can only surmise that the cost

would be gigantic. It could be especially expensive with CCs as every piece of the system would be expected to communicate with every other piece. There would have to be uniform standards for how each piece communicates. At present a simple vehicle sensor at a fairly simple signalized intersection costs thousands, if not tens of thousands, of dollars. Even granting AHS-AV-CC a validity to their claim that regular traffic signalization as we now know it would become obsolete under a true AHS regimen, there would still be enormous costs to developing and deploying the sensor technology needed to keep AVs and CCs rolling. Every roadway would have to have a continuous sensor capability along it. Multiplied by the tens of thousands of intersections and thousands of miles of urban roadways, just this one cost would be enormous.

Since, as noted above, a successful fleet turnover would likely take decades to accomplish there would likely be calls from the AHS-AV-CC promoters to create AHS systems parallel to existing mixed traffic roadways. The U.S. does not seem to be politically capable of raising its fuel taxes by even a small increment; its conventional funding source, the Highway Trust Fund, is bankrupt. In Europe public budgets are reeling under austerity measures. Even if a highly unlikely public consensus about road and full cost pricing of transportation operations were to ensue, where will the new hundreds of billions or trillions of investment dollars be found?

#### *Public resistance to automated vehicles*

There may be several major points of public resistance to the adoption of AVs or CCs. In addition to all the possibly negative problems associated with automated vehicles listed above there is the minor matter of public resistance or acceptance:

- There is often inertia or resistance to major change that affects one's lifestyle, daily life, or stemming from perception, misperception, understanding or misunderstanding of the proposed or impending change. This should not be overlooked or underestimated by researchers, planners or policy makers.

- Will the public that has been known to vote against traffic signal cameras to detect and deter persons who speed and run through red lights embrace centrally monitored and controlled personal vehicles? Will a public, especially in many of the wealthier societies, that is more and more wary of centralization support such a massive endeavor? Will those concerned about the 'surveillance state' or society embrace such monitoring? (Francois, 2014)

- If the California experience provides any guidance, the regulatory hurdles may be formidable and it may take much longer than AV and CC promoters admit for these to be drafted, tested, authorized and implemented (Dougherty, 2015; Nowakowski, et al, 2014).

- Will the vehicles be affordable for the average user? Will the monthly telecommunications packages that will, no doubt, accompany the vehicles be affordable? What cost controls, if any, might be exacted from the profitability-fixated private monopolies that will likely generate these costs by an ever-weakening public sector?

- Can the infrastructure necessary for AVs and CCs be made foolproof, even if it can be made hacker resistant? Can its fail-safe reliability be proven to a likely skeptical public? Can it be made completely glitch-free? If the public and media response to the Tesla (semi-automated) crashes is any indicator, there may be grounds for skepticism about the absolute safety of AVs and CCs (McHugh, 2015; Zolfagharifard, 2015).

- Following the above point about infrastructure; widespread use of AVs and CCs will probably not likely to be adaptable to most developing countries, despite India's efforts to create its own AV. The physical and operational shape of Indian cities works against a larger share for personal motor vehicles (PMVs), especially AVs, and India and many similar countries probably would be unable to afford the sorts of infrastructure changes demanded for these vehicles (Mohan, 2015; Stewart and Bertaud, 2015).

- Will the timeline for the development of a truly reliable automated vehicle be

so long and far into the future that all involved; developers, researchers, the public sector funders and the public simply tire of hearing decade after decade of promises and turn away from the AV hype and towards other solutions--like walking or cycling or transit? (Boudette, 2016b)

- The power of the car culture to shape mobility expectations, from early childhood car-seats through teen hot-rodding to the elderly refusing to relinquish their drivers' licenses, the hold that automobility has upon motoring societies is deep and strong. The many billions of dollars that automakers and their allies spend annually glamorizing the car and selling it as an extension of self and a powerful tool of self-expression may have succeeded in keeping power fantasies and dangerous driving near and dear to the hearts of many. Large swathes of the motoring public may simply be unwilling to relinquish their control of their vehicles (Schiller et al, 2010, esp. Chapters 1 and 2, Schiller and Kenworthy, forthcoming 2017; Quain, 2016a).

## Conclusions

There are many attractive aspects of automated and semi-automated vehicles. But there are many uncertain, unpredictable or even undesirable aspects of these as well. From a perspective of environmentally sustainable transportation the desirability of widescale adoption of these is questionable at best and retrograde under the worst imaginable scenario. In a thoughtful appraisal of the future, AV advocate John Niles thinks that it is unlikely that the timetable of AV developers will be met. Instead of a five to ten year timeline, it is more likely that ADAS technology will likely occur with "future creep" over a much longer time period to a point where most of the motor vehicle fleet will have become automated<sup>3</sup>. One possible scenario is that there could be an AV "transit leap" whereby the technology is developed for small transit vehicles and that these could replace most urban transit (Grush and Niles, 2016). While there certainly could be some useful applications of small AV transit, especially for first and last mile

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<sup>3</sup> personal communication John Niles, Global Telematics, July 20, 2016

needs and some specialized transit applications, it is difficult to imagine complex urban environments without core mass transit systems. Instead of wishful thinking about small AVs replacing bus and rail transit it might be more fruitful to look at ways in which AV technology could be applied to some of these. Some existing BRT lines, such as the Orange Line in Los Angeles, probably could be readily converted to automation. For the foreseeable future we are probably going to need plenty of human controlled buses, more than at present, to address urban transportation needs. ADAS could also help such needs as well as helping freight movement considerably.

The most optimistic scenario would have ride-sharing on-demand AVs or CCs saturating the vehicle fleet, which is necessary for their most positive energy, congestion, urban space saving (mostly parking) and safety effects to ensue. This assumes that the motoring population would forego the hold of the car culture, and personal ownership, in order to have a completely reasonable and orderly personal transportation system.

Perhaps we could go one step further and propose that humans have RIDF chips implanted under their skin so that the vehicles can find them and whisk them to Whereverland and back. Like most utopias, this is not likely to occur. Rather the worst of all automated vehicle worlds might occur: Motorists will refuse to relinquish personal ownership (or even control) of AVs, vehicle ownership rates will rise, demand for AVs will rise among traditionally non-driving populations (young, elderly, mobility challenged, etc), and cities will become even more car saturated and congested. The sexual activities of passengers, predicted to increase with ADAs and AVs (Pedwell, 2016 ), may be rudely interrupted when hackers gleefully shut the system down periodically. Humans will have invested trillions of dollars in systems that leave them worse off and more stranded in traffic than before.

It is possible that the ultimate technological problems are insoluble for AV and CC fleet domination to occur. Urban traffic may be too complex for even the smartest

of 'Silicon Valley' mavens to solve with fail-safe algorithms. Maybe driving, like walking or running, is a more complex phenomenon than it might seem. The robot that can run, jump or even walk just like a human has proven to be very difficult to develop due to the intricacies of human skeletons, musculature, nervous systems, mental capabilities and their interrelationship. The same might ultimately prove to be so for AVs to accomplish in urban traffic, connected or not.

Another possible scenario is for sustainable urban transformation and mobility scenarios to grow and become the desired future for all<sup>4</sup>. Then humans might increasingly abandon personal motor vehicles, and all their exorbitant financial and environmental costs, for taking transit, bicycling and walking into a better future.

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<sup>4</sup> Such as those described in Chapter 9 (Exemplars) of Schiller, et al 2010

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## **Transit Street Design Guide**

*National Association of City Transportation Officials*

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The foreword sets a very positive tone to this design guide:

“More and more cities are reimagining their streets, replacing outdated highway-based practices with fresh ideas that prioritise people and the quality of their lives. The immense popularity of walkable urban places, built in part on transit investments over decades, has helped lay the groundwork for a new paradigm in how we think about streets.”

This is a very detailed design manual to assist all those involved in city planning, urban design, and transport planning and sustainable outcomes for those living in cities. The book is a delightful mixture of detailed design standards and parameters and the shaping of cities in ways that will enhance the importance of public transport and reduce car use. The detailed design content is very thorough indeed and covers streets, stations, stops, networks, transit lanes, signals, intersection design, pedestrian and bicycle access and networks and performance measures. It is very refreshing indeed to see prominence given to the importance of numbers of people on streets and making best use of space to move people in the kind of conditions that will encourage walking, cycling and the use of public transport. Insufficient space was given to safety and risk of death and injury on the street and the guide as a whole would have benefitted from some content on the Swedish “Vision Zero” road safety policy. A highly efficient and attractive set of alternatives demand the kind of total safety offered by Vision Zero and also deals with the kind of problem currently giving rise to concern in London with cycling deaths and deaths caused by buses hitting pedestrians.

It is to be hoped that all those involved with urban design, public transport and healthy cities will find the details

they need in this book to design and implement a new paradigm and I suggest the authors and publisher contact the Mayor of London with a copy and with a strong recommendation to use the guide to help him with pedestrianizing Oxford St and converting the traffic sewer known as Euston Rd into a high quality pedestrian, bike and transit route.

John Whitelegg