

RESEARCH ARTICLE

Do Traffic Controllers Dream of Electric Cars?

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Traffic congestion is not a modern phenomenon, but the growth of motor traffic driven by the supply of petroleum is. This coincides with concern about climate change caused by carbon emissions to which transport makes a substantial and increasing contribution. It seems that private cars in particular cannot be useful without coming to dominate human activity and even whole economies, creating dependence, congestion and severance which paradoxically negate many of the benefits of mobility. Electrification may reduce carbon emissions, but is unlikely to support the same weight of motor traffic, and will not reduce its other effects. It is doubtful that sustainability, however defined, is compatible with current high and increasing levels of motorised movement, so a culture change will be needed.

Introduction

This paper draws its title obliquely from a science-fiction short story by Philip K Dick that was later interpreted in a cult movie. It is not about androids, but is about the future and artificial systems that seem to have their own agenda. It starts by considering the impact of motor traffic, moving on to growth, the role of culture and oil-dependence in a world threatened by climate change and pressure on resources. After pointing out some paradoxes and side-effects of motor traffic, it reviews the possibilities offered by new technology and alternative sources of power. Finding the prospects unconvincing, it concludes by looking at traffic, development and sustainability from a broader bio-economic viewpoint. While pessimistic overall, it finds that transportation and its associated culture may be in a position to respond flexibly.

Cost of traffic congestion

Traffic congestion has always been a feature of urban life, ever since people and goods sought to move along streets, competing for space with other uses. Juvenal (1st c) complains about the noise of deliveries after Julius Caesar banned wheeled vehicles from Rome during daylight. However, congestion is not necessarily all bad. As pointed out by Miller (1969), 'The only objective criterion for deciding what is a tolerable level of congestion is an economic one in which the cost of increasing the capacity is matched against the benefits so achieved.' OECD (2007) points out similarly, 'cost of congestion approaches are ... misleading when they neglect the fact that congestion is the outcome of crowding in urban areas – itself the successful result of other urban policies ... The impacts of congestion are not abstract – they must be linked to roadway users' experiences and expectations.' The Eddington Report (Eddington, 2006) estimated the cost of traffic congestion in the UK as £7–8 billion per

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annum – others have estimated up to £30B in the UK (LTT, 2012) and \$63B in the USA (Prashker, 2008). While admitting that, 'it is not realistic or cost-effective to eliminate congestion completely', the report still concludes that, 'the cost of not responding to transport pressures can be substantial', and, 'growing congestion on the network is a clear indication of increasing transport demand outpacing transport supply.' Thus traffic congestion is seen as a symptom neither of productive activity nor social dysfunction, but a lack of capacity to meet 'demand' that is held to be exogenous.

The real cost of responding to transport pressures includes not only external and social impacts, but the diversion of resources from more innovative or sustainable areas like energy-efficient housing (Passivhaus, 2015) or less energy-intensive forms of social organisation, as well as arguably perpetuating or exacerbating an unsustainable situation. According to the Standing Advisory Committee on Trunk Road Assessment, new traffic may be 'generated' by new provision (SACTRA, 1994), so it does not follow that increasing capacity will lead to less congestion and improved conditions in the long term. However, this could be confounded by falling oil and petrol prices, and governments' fear of losing tax revenue through increasing fuel-efficiency (Eliasson and Proost, 2015). The price of crude oil has more than halved between June 2014 and January 2015. While this is expected to lead to a gradual increase in demand, it has the opposite effect on supply, tending to make new sources like fracking and tar-sands as well as some existing production uneconomic. This could lead to a fall in greenhouse gas (GHG) emissions. But apart from complex economic impacts it may also weaken moves to sustainability and prolong oil dependence (Tverberg, 2014). These conflicting effects are summed up by the term 'Green Paradox'.

With a growing perception that humanity's numbers, demands on nature and waste products are getting out of control, there is a

need to tear one's gaze away from the wind-screen of relentless growth and look around at a wider context in which the present way as it is 'framed' is not necessarily inevitable or optimal. However, despite some good intentions, like the European Commission's roadmap to a low-carbon economy by 2050 (EC, 2014), the line of least resistance is to carry on as usual. Confidence in the world's ability to meet climate targets is low (IPCC, 2014). Potential solutions are likely to be challenged by unexpected events and unintended consequences (Taleb, 2007; 2008), as well as difficulty in coordinating action sufficiently across the world (Biello, 2014). So, other things being equal, 'business as usual' followed by crisis response appears a likely scenario. This paper aims to question some common notions and to suggest that transportation has characteristics that enable it to be as much a tool for solution as a contributor to these problems.

A recipe for jam

As commonly used, the term 'congestion' tends to be pejorative and misleading. Definitions are mostly symptomatic rather than objective and often fail to distinguish between unhealthy congestion and healthy crowding, in the senses offered earlier. This is illustrated by the quirkiness of some definitions of congestion gathered (Taylor, 2012) from several sources (DfT, 2002; Ceres, 2004; Naudé *et al*, 2005; Lay, 2011; 2012), including:

- Having to travel at less than the speed limit
- Speeds slower than 'free-flow' speeds
- Traffic demand such that interaction between vehicles slows the traffic
- Normal travel time more than doubled
- Speed less than 30 mph
- Moving very slowly at less than 10mph
- Excess of vehicles producing stopped or 'stop-go' traffic
- Stop-start conditions
- Traffic jam with stops of 5 or more minutes at a time

- Density greater than about 42 vehicles/km/lane
- Ratio of flow to 'network capacity' > a certain level

Only the last two are objective and the first, representing 19% of responses in the survey sample, is remarkable given that it is impossible to stick precisely to a speed limit! For an individual the concern is *any* delay, but for a traffic manager it is achieving the most reliable safe service given the perceived traffic demand, resources and policy constraints. Unreliability increases delay through the non-linearity of its response to variations in demand. Intelligent Transportation Systems (ITS) may be able to increase reliability without adding new capacity, but variability and unpredictability are fundamentally inseparable from traffic and congestion.

Recurrent congestion is self-limiting, for as demand approaches capacity escalating delay and unreliability discourage further growth of regular traffic. This is the equilibrium principle upon which most traffic modelling is based (Wardrop, 1952). The maximum rate of increase of delay occurs at the point of capacity. Beyond this, delay continues to increase at a rate limited by cumulative demand. In the worst case, for every hour of over-capacity, each added vehicle imposes 30 vehicle-minutes of delay on other traffic (Taylor, 2012). Congestion can be measured objectively in terms of this marginal total delay. While popular usage associates congestion with queues and shock waves on motorways, these are really just symptoms of demand exceeding capacity that happens to result in a breakdown in free flow. There appears to be no critical point other than simply exceeding capacity.

Traffic congestion and pollution tend to be endemic to cities, although they increasingly spill out into surrounding areas (Focas, 2014). Populations of some large developing economies are still less urbanised than older industrialised countries, for example India 31%, China 51%, Russia 73%, compared to an average of around 82% in northern

Europe and North America (CIA, 2011), but large populations, lower starting levels, rapid growth and migration into mega-cities offset this. How much congestion societies tolerate depends on social and economic factors. Some countries, in particular China, are applying innovative and even heroic measures to build efficient public transport networks (Kaiman, 2012) and clean power systems (Climate Group, 2012), but they are being overrun by crowds of motor vehicles fighting for space and creating gridlock and dangerous levels of pollution (WHO, 2005) and morbidity (The Times, 2013a), as individuals struggle to make a living in the only way they see available. This 'tragedy of the commons' (Hardin, 1968) is not a new phenomenon, but its scale is (The Times, 2011; Reuters, 2013).

Any self-limiting effect acts only through individuals, who do not perceive the externality they inflict on others. To restore the balance, operators may impose road use charges or other restrictions, but it is also the reason why these are unpopular. They are of no avail when isolated events bring about a disconnection between expectation and reality, or between the timescales of system and user response. In the UK a rock festival attracted so much traffic that many fans never even reached the event (Hampshire, 2011), and in China an unprecedented 100km jam lasted for 10 days (Global Times, 2010; The Times, 2010). More typically, there is a succession of instances of 'travel chaos' (actually a highly ordered state!) caused by incidents or weather events, but more often by the weight of traffic (Times, 2013b).

Supply or demand?

The reflexive relationship, where extra traffic generated by road building or improvement becomes excess demand justifying further provision, was well known to the US Department of Transportation as early as 1971, as recorded by Putman (1983). Traffic generation serves as a reality check on any scheme, but it has a dark and pernicious

companion in the notion of suppressed demand, which in its most radical form implies that new provision can satisfy needs that people did not know they had. This is a rather technical example of supply-driven growth, but the history of motorised transport, particularly on roads, has essentially been one of supply generating demand, the origins of which may lie in the industrial doctrine developed in the USA in the 1920s of manufacturing needs in order to sell new or more products (Ewen, 1976), or even earlier.

Expectations also can drive growth. Transport like any system is subject to inertias and lags in response to change. It takes time for land-use developments, and the traffic they generate, to catch up with new roads, as with tramways and railways before them (Levinson, 2006). People have evolved to weight losses more than gains (Kahnemann and Tversky, 1984), and this applies also to transport, whose undependable nature makes it prone to perception of loss (OECD, 2007). Even if service is adequate on average, significant failures will be remembered most. Conversely, if expectations created by a honeymoon phase of new development persist, they could lead to excess demand later, providing for which creates a reflexive cycle. A reflexive relationship between behaviour and expectations has also been noted in finance, where they amount to a bias making equilibrium unattainable (Soros, 1987). However, in transportation, supply may have been the stronger push historically and globally.

If the asymmetrical effects of supply push and expectations are seen not as curious details but essential to the phenomenon of growth in traffic, and some other types of elective/reflexive consumption, then these become more understandable and potentially manageable. Such pressures meet some resistance in limits like land availability and time budgets, and culture changes like loss of interest in driving by young men (what's cool about being stuck in a traffic jam with middle-aged shoppers and commuters?). In France, *estrangement* is said to be more widespread

(Normand, 2014). Fuel prices might have some impact in the unlikely event that they were to rise sufficiently. Public planning has become more environment-conscious both in design and appraisal. No-one in the industrialised world today would contemplate relieving congestion by razing established low-rise neighbourhoods in favour of tower blocks or driving a 6-lane motorway through the centre of a city. However it remains to be seen whether this 'greening' would be more than skin-deep in the face of severe economic pressures.

What kind of growth?

In the UK and other European countries, two perceptions are gradually becoming firmer. The first is that even the current level of dependence on motorised movement is unsustainable and dysfunctional. Despite various initiatives, relatively slow population growth, policy controls, and the 'Peak Car' hypothesis (Goodwin, 2010; Metz, 2010), the UK Department for Transport (DfT) is forecasting that traffic will increase by 35–54% by 2035 (Forster, 2012), and there are comparable figures for the USA (Prashker, 2008; Schrank *et al.*, 2010). Professor Stephen Glaister, director of the RAC Foundation which recently issued a critical report (RAC Foundation, 2011), has commented, 'Forget about Plan B, ministers do not even have a Plan A for dealing with the awful conditions forecast for the roads in the years ahead. It is a case of jams today and even more jams tomorrow.' The point that seems to be missing is that those 'awful conditions' will not be imposed from without but will be from people's collective choice to remain or become more dependent on cars. However, choosing not to be dependent on a car can be unrewarding, apart from in those major cities where geography and density naturally favour public transport or active modes are positively encouraged and made safe and convenient (see e.g. MTS, 2015).

The second is that agglomeration or intensification in cities may be more efficient

and sustainable than pursuing an 'American dream' of low-density suburban living if this encourages car use and discourages public transport, cycling and walking, although there is a view that suburban living need not be incompatible with these modes (Mees, 2010). Of course, concentrating population in cities carries risks, but dispersal that depends on unsustainable consumption cannot lessen them. Newman and Kenworthy (1992) provide evidence that car use, as measured by per-capita gasoline consumption, is almost inversely proportional to urban density. In the UK, private housing developers view what they call 'traditional' dwellings, with their corresponding not-so-traditional car-based lifestyles, as easier to sell, but more progress is being made towards making town and city centres liveable, sharable and walkable. Transport for London (TfL) has a vision to promote a 'village style' environment that could even involve sinking arterial roads in tunnels (TfL, 2013), although pedestrian lobbyists would prefer to see reducing the demand for motorised travel given precedence over engineering.

There is evidence that at some point in economic development the quest for 'quality of life' comes to outweigh that for 'quantity of life' (Graham, 2005). This may be happening in transport, where the discretionary nature of much travel competes with other discretionary activities, and where heavy traffic growth is extensive, meaning more of the same with diminishing returns of utility and satisfaction. Since quantity and quality are in inverse relationship under such extensive growth, it will be self-limiting if quality is a criterion. However, the context can also change over time. Economic life-cycle theories envisage that once-new methods and technologies, possibly developing out of the previous cycle, become obsolete and even counter-productive over time (Tomes, 2004). Maybe 'car culture' is following this pattern.

Studies suggest that human happiness depends more on comparisons than on absolutes (Graham, 2005). So it is unhelpful for

achieving sustainability that Adam Smith's view that, 'it is in the progressive state of further acquisition that the majority of people are happiest' (Georgescu-Roegen, 1977) still appears to be actively encouraged by industry, and by governments when they promise 'growth' in exchange for votes. SACTRA (2000) asks whether economic growth is 'decoupling' from traffic growth, consistent with such psychological effects. To be fair to governments, economic growth is often seen as the price not only of re-election but of political stability, though this should be more a cause for concern in the global context of growing gaps between haves and have-nots combined with mass poverty (Science, 2014), where the cost of maintaining stability is likely to be higher than in 'Western' democracies (Baten and Mumme, 2013).

Transportation in the frame

How the balance between costs and benefits of any activity is calculated depends on what impacts, global as well as national, are taken into account in or left out of calculation. This in turn depends on framing or cultural and institutional assumptions and expectations, interacting reflexively with past and current provision and resource supply (Tennoy, 2010). For example, 'time saving' is still ranked highly in appraisal, despite the fact that constrained time budgets mean it translates in practice into increased distance travelled (Metz, 2014). As these insights, and wider impacts (DfT, 2005; Vickerman, 2007), are taken into consideration more fully in appraisal, they may force the future of transport to be decoupled from the production and consumption of motorised, especially car transport driven by a contentious supply of cheap fuel. Sustainable motorised transport is an oxymoron as long as its energy dependence (Perl and Gilbert, 2010) drives its dominance of economic and social activities, time valuation, environmental impact, resourcing policy, and displacement of alternatives. In a broader perspective, the recent as well as past behaviour of industrialised countries in

pursuit of their interests, which at the present time are popularly understood to mean oil supplies, is increasingly being questioned.

The machine stops

While humanity would naturally rather take the line of least resistance, which is to dig, burn, drive and spend its way out any situation, there is an increasing suspicion that this cannot continue. One reason is climate change, even if its magnitude remains uncertain, though less so following the latest reports (IPCC, 2013/4). Researchers are sceptical that targets for reducing carbon emissions can even be approached let alone achieved under present conditions. Another is depletion of resources, though this appears to exclude coal, oil and gas which may be too abundant for our own good (Berners-Lee and Clark, 2013), not to mention new sources like fracking and tar-sands, and methane hydrates from the deep ocean which amount to a massive store of a powerful greenhouse gas (DoE, 2011). Consumption in the 'BRIC' countries [Brazil and other South/Central American states, Russia, India and China] is growing with their rapid industrialisation and large and in some cases growing populations. While some of these countries are leading developers of sustainable methods, all have vast resources, human and material, to supply conventional growth.

It is hard to believe that climate concerns or moderately increased fuel prices can have a decisive impact on the present tango of inexorable forces and insatiable appetites, but a severe cut in supply would be a game changer. At the present time, supply amounts effectively to one thing, petroleum, which determines the supply of everything else. Without petroleum, there are no giant logging operations in Indonesia or Brazil, no supershops carrying rain-forest timber, palm oil, refrigerated beef, cars or plastic toys across (and occasionally into) the oceans, no energy drinks and throwaway aluminium and plastic packaging, no piles of unwanted newsprint, less ecological harm caused by

discarded trash, imported invasive species and diseases, drug traffic and endangered animal products, and moves to greater self-sufficiency and efficiency in such uses of fossil fuels and materials as remain. This list is selective, but highlights the distortions that can be produced by a supply of cheap fuel and transport. It would be an exaggeration to say that without oil, everything stops, because there could be adaptation, and humanity is often presented as a naturally, if not supremely, adaptable species. Indeed, it will be argued that movement including transportation is one of the most potentially adaptable of human activities.

Running the gauntlet of the human race

If one is seeking a reason why parents are afraid to let their children walk to and from school, especially in the dark, let alone in a wartime total blackout as recalled by Lord Tebbit in a recent radio interview (BBC, 2013), one should look to what has changed. An obvious change is the level of motorisation (Hillman, 1993; van Goeverden and de Boer, 2013). Today, anywhere in the UK apart from in town centres and some other attractors such as shopping or leisure centres, major rail stations, airports etc, there are likely to be many more people sitting in cars than making their own way outside them. Modern life revolves around cars, even to the extent of still being the primary way some people express their identity. Fail to dash for the kettle when the TV advertisements come on and the first thing you are likely to see is a car, often presented as though motorised movement were an end in itself. Yet 25% of UK households do not have access to a car and half the population does not possess a driving licence (DfT, 2011), including of course children whose mobility is increasingly restricted, leading to concern about the consequences for their psychological as well as physical health.

The 1997–2010 UK Labour government launched the Eco-Towns initiative for fifteen

new towns to be completed by 2020 (ENDS, 2011), now reduced to three 'Garden Cities' (DCLG, 2014), each with an average of around 5,000 dwellings for up to 20,000 inhabitants. One such town is planned near Bicester, a small country town with 31,000 population, where currently 48 per cent of all trips and 70 per cent of commutes are by car (Oxfordshire, 2014). Despite a veneer of sustainability, Echenique *et al* (2012) conclude, 'it is unlikely that UK eco-towns will be sufficiently large and self-contained to avoid becoming automobile-based dormitory towns.'

This might matter less if cars were not so energy intensive so that they dominate or displace competing forms of movement and create severance (Bradbury *et al*, 2007). Severance is usually defined as the separation of local communities by transport infrastructure or road traffic (Anciaes, Jones and Mindell, 2014). The length of car trips in Britain peaks at only around 5 kilometres, well within cycling range. But travelling by bicycle or public transport, which are much less energy-intensive, is viewed as unsafe, slow, uncomfortable or inconvenient. Cycling is arguably a way of saving time by using *surplus* energy, since human calorific intake is only loosely related to activity and money cost. If saving time also saves *costly* (not surplus) energy then it can be considered efficient in an absolute sense, but with motorised transport saving time generally *costs* energy.

Zeno's paradox

Continuing the theme of running ever quicker to stand still, we can point to certain internal contradictions that arise from car-dependence. Car use is seen as representing 'free choice' and the exercise of personal freedom, though arguably it is the most intrusive and demanding form of private behaviour in public places ever invented. Much of the practical appeal of motor vehicles comes from their immediate availability, mobility and door-to-door convenience.

Yet they spend increasing time immobile in queues. Dissuading drivers by road or access charges, or imposing pre-assigned slots, can distribute road space more efficiently as well as equably, but defeats the flexibility of cars. Driving could become like flying, 'if you've time to spare ...'. Restricting parking can have a similar effect (Shoup, 2011), but charges are often perceived as arbitrary. Restrictions needed mainly at peak times, precisely when individuals perceive the greatest need to travel, with minimum hindrance, add a further paradox.

In the past it has been easier, politically, to provide for a growing number of cars and thereby both solve an immediate problem and buy time before it resurfaces. In advanced economies today, provision tends to be incremental and tactical (e.g. ITS, Smart Motorways, adaptive systems) rather than strategic (building new highways) and this can be effective because thanks to the non-linearity of congestion a small increase in capacity, say 10–15%, can give relief, but only temporarily. It has also been easiest to promote safety by steadily increasing the crash-resistance and braking performance of cars, leading to the possibility of risk compensation, while marginalising vulnerable slower modes (Adams, 1993). There is an ongoing trend to reverse this in many towns and cities, by segregating motor vehicles, imposing low speed limits and establishing attractive shared spaces. But behind the dominance of motor traffic lies a huge industrial chain involved in producing, promoting and fuelling cars, often referred to as a 'barometer of the economy', whose elements act together in 'push-pull' fashion, making it difficult to control any one of them singly (Berners-Lee and Clark, 2013).

Reserving roads for a few privileged motorists would be nonsensical and probably would not much improve the lot of other modes anyway. Many cars stuck in a jam are less dangerous and may be less of an obstacle to pedestrians and even cyclists than fewer cars moving at high speed. That cars give

rise to paradoxes is a hint that there is a fundamental contradiction somewhere. Other energy-intensive forms of transport are not immune to paradoxes, indeed the more energy-intensive they are, the worse disruptions tend to be, but for most people, ships, trains and planes are supplements rather than substitutes for human locomotion. Cars remake the world in their own image, and cannot be generally useful without also becoming malignly dominant and even defeating their own object. Their energy intensiveness is an insurmountable barrier to creating a truly shared environment.

The dream of General Motors

There are moves towards automation and electrification of vehicles. A well-publicised conflict between technology and driving involves the mobile phone. Now not only hand-held but hands-free phones are being condemned as dangerously distracting, and recently a Sat-Nav has been implicated in a death crash (The Times, 2013c). As 'Vision Zero' (no road deaths) becomes more conceivable through technology, any kind of distraction on crowded roads is seen as dangerous, and legal liability an increasing threat. New situational awareness systems based on radar and cameras backed by sophisticated drive-by-wire systems may take over from drivers in emergencies, and Google and others have demonstrated autonomous but otherwise conventional vehicles. This may lead (*must* lead) to automated vehicles being allowed and then mandated on motorways, and eventually all roads. That, says Hecht (2013), 'would finally rid cars of their most dangerous component – the nut behind the wheel.' However, this familiar witticism misses the essential nature of motor vehicles.

Bill Ford, grandson of Henry and Executive Chairman of the Ford Motor Company, favours shared on-demand electric Personal Transit pods (Ford, 2011), but rival General Motors has released a video demonstrating its personal urban mobility concept called the Electric Networked-Vehicle (EN-V) (General

Motors, 2013). The EN-V is an enclosed 2-seater balanced on two side-by-side wheels like a Segway, relying on advanced sensing technology augmented by vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communications for autonomous driving. It is designed primarily for an urban environment, but what kind of urban environment?

An EN-V is briefly shown negotiating an almost empty traditional shopping street at crawl speed, but another sequence shows autonomous vehicles crossing each other's paths at full speed at a major urban intersection. Without the reassurance of traffic signals, it is not obvious how cyclists and pedestrians could negotiate such a junction. If traffic would stop for them at least as frequently as today, much of the benefit of this robotic sword-dance would be lost. The stronger message here is that the world of the future will be a network of superhighways, although the prospect of travelling at 120 km/h in a tiny pod with a minimal shell to absorb impacts is rather alarming.

All systems can fail, and the more automated or rule-based they are, the more catastrophic the consequences are likely to be. This is because as automation gradually eliminates basic errors and pushes envelopes, serious accidents, though increasingly rare, are more likely to result from combinations of circumstances that are difficult to predict and program a correct response to – examples can be cited from *Titanic* to modern jet airliner crashes. This technology could eliminate some fossil-fuel dependence, but far from offering a liveable solution, it could increase dependence on motorisation, worsening severance and encouraging sprawl. An intermediate alternative is the electric bicycle, use of which has reportedly exploded in China. However, this has led to a rise of deaths and serious injuries on roads shared with motor vehicles (Khan, 2014). A further 'futuristic' option would be to put all motor vehicles in tunnels or elevated roads, but construction of the first would be massively expensive and disruptive, and lock cities into

an inflexible pattern, while the second would reverse the current trend towards calmer more liveable cities.

Fields of gold

Larger vehicles and engines, including '4WD/SUV culture', have negated much recent gain in engine efficiency (Schipper, 2010), and alternative fuels and sources of power to petroleum are sought (NEA, 2010). Because of production costs bio-fuels may have less impact than optimists suppose, as well as leading to destabilising rises in international food prices (Chakraborty, 2008), and therefore do not represent a sustainable alternative at current consumption levels. It has been estimated that the land needed to grow bio-fuel feedstock for all the traffic on a motorway would extend several kilometres on either side of it (Berners-Lee and Clark, 2013). 'Green' modes and home-working would have less impact on carbon turnover than is generally believed (Hanley, 2011). Nevertheless, the European Commission would like to eliminate all petroleum-fuelled vehicles from cities by 2050 (EC, 2011), but it is hard to see how the range and carrying capacity of today's cars can be matched.

With use of hydrogen as a non-GHG fuel currently marginal, electric vehicles are being promoted, both conventional types and light vehicles as described above. But given the limitations of renewable generation, and the political difficulties and long lead-times associated with expanding nuclear power, only gas or coal fuelled generation can satisfy even today's demands. In the UK, although overall energy use has fallen since 2005, transport consumes 36 per cent of all energy (DUKES, 2013), and produces around 25 per cent of GHG, of which motor vehicles account for 92 per cent (DfT, 2013). Around 72 per cent of UK electricity is currently generated from fossil fuels (DECC, 2012), and energy supply is responsible for 40 per cent of CO₂ emissions, and while CO₂ emissions from transport have fallen by 10 per cent between 1990 and 2012, this is the smallest reduction

achieved by any economic sector (DECC, 2013). With current technology, electric cars are about twice as efficient users of fossil fuels as equivalent petroleum cars (Eberhard and Tarpenning, 2006), so GHG would fall by about 11 per cent, but generation would need to rise by 28 per cent to maintain current transport activity. UK generating capacity has been somewhat variable over the past 30 years (IEA, 2013) but its average growth rate has been below 1 per cent per annum. Light electric vehicles in cities would reduce electricity demand, but what about inter-urban travel? In short 'business as usual' in an electric economy is not guaranteed.

Waiting for Godot

One of the achievements of the period roughly from 1850 to 1950 was the devotion by certain visionary individuals of wealth acquired through trade or industry to better the life of the people. This philanthropy included building settlements like Bournville and Welwyn Garden City in England, and other once solid institutions like friendly societies, hospitals and schools. Today, bodies like the Bill and Melinda Gates Foundation conduct less monumental activities though on an international scale. In transport, recognising that businesses and government have limited ability to initiate paradigm shifts, there are individuals and bodies questioning conventional approaches and promoting visions of a less driven way of living and working. In the relatively cosy environments of Europe and its offshoots, for example, Rogers (2014) calls for intensification of living in cities, Jan Gehl promotes a wider vision of shared spaces (Bramley, 2014), while Mees (2010) believes public transport can adapt more effectively to current dispersed lifestyles. Elsewhere there are success stories like Curitiba in Brazil (Garrick *et al*, 2006).

Where are the people who are going to deploy benign global visions in a 21st century where superstates and multinationals constitute a virtually independent economic

network superimposed on the rest of the world? Apropos transport, where is the person who will say, 'It is impossible to spend any time on the study of the future of traffic ... without at once being appalled by the magnitude of the emergency that is coming upon us. We are nourishing at immense cost a monster of great potential destructiveness, and yet we love him dearly. To refuse to accept the challenge it presents would be an act of defeatism.' This is not a quotation from a recent editorial (Whitelegg, 2013), but from the 1963 report *Traffic in towns* (Buchanan, 1963). Fifty years on, the monster has become entrenched and the magnitude of the challenge has increased from around 200 million motor vehicles in 1970 (The Physics Factbook, 2001) to 1 billion today, 2 billion by 2035 and 2.5 billion by 2050 (Sperling and Gordon, 2008; IPS, 2013). The International Energy Agency estimates that over 60% of all oil is consumed by the transport sector and transport is driving future increase (IEA, 2009). Transport is not only a massive and still growing consumer of mobile fuels, but drives increasing demand for them by facilitating the production, delivery and consumption, without compensating disposal, of other products that depend directly or indirectly on fossil fuels. Technology, including automation and 'greener' vehicles, may increase effective capacity on the existing road network and reduce accidents and pollution, though as pointed out earlier not social-spatial effects like severance and sprawl. One view is that significant social changes brought about by innovation may have reached saturation, at least temporarily (The Economist, 2013).

Technology alone will not reduce the cultural dependence on car travel, whose self-reinforcing nature is the engine of congestion, and may well increase it if concentrated on vehicle automation rather than alternatives to physical travel like telecommunications and urban intensification. Nor will technology alone stop the relentless growth of consumption generally, unless we can move from a linear process of

resource-to-waste to one of cyclic renewal, in which case total consumption and energy use for mobility will almost certainly have to fall. Some take an optimistic view that a concerted global effort can achieve this (Aftabuzzaman and Mazloumi, 2011).

Improved reliability and efficiency in specific areas are commendable in principle, provided that achieving them does not lead to harm or inefficiency elsewhere. However, attention tends to be given piecemeal to the different sectors, and the implicit assumption is that reducing any kind of utility is a last resort. Achieving true sustainability will need a culture-change in populations and a corresponding paradigm shift in governance. If utility *is* to be maintained, the key is sustainability, but what exactly does it mean?

Sustainability

The Brundtland Commission in 1987 defined sustainable development as, 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs.' According to the US Environment Protection Agency, 'Sustainability is based on a simple principle: Everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment. Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations' (EPA, 2014). NEA (2010) defines sustainability graphically as the intersection of social, environmental and economic viability, equitability and bearability. This begs two questions. First, whether all the criteria *can* actually be reconciled, even in principle. Second, sustainable at what level? Maybe one can identify five levels:

- (1) 'sustainable' growth beyond present levels of consumption,
- (2) sustaining present levels of consumption,

- (3) at a lower level that in some sense satisfies 'demands' and 'requirements' by ensuring that resources of some kind will always be available,
- (4) at a level that can be maintained by renewable resources alone,
- (5) at a level compatible with long-term ecological sustainability in the sense of reversing the loss of other species and biodiversity, and adapting to the natural environment rather than just exploiting it.

Given the difficulty of voluntarily reducing *any* consumption, (1) or (2) seems the most likely interpretation, with (3) riding on the art of the possible, while (4) and (5) are at best aspirational. If the present situation can be represented by the mathematical analogy 'humanity > environment', sustainability might be expressed by 'humanity = environment'. However, equality does not fix the magnitudes of quantities that are not independent. Its interpretation depends on how much biodiversity, wilderness, and climate and political stability humanity is prepared to tolerate in the process of meeting its requirements. Option (5) might be expressed as 'humanity < environment', humanity embedded within and adapted to the natural environment, not just what is left of it now but what it might rebound to. There is no precedent to help determine what this should mean in practice or how it can be achieved, but it may be possible to define a minimum level of natural sustainability objectively in terms of the diversity and connectedness needed to preserve biological resilience (Rohr *et al*, 2014).

Lover of the bio

The perception of humanity's relationship to the natural environment as a whole has broadened enormously in the past half-century, particularly through the exploration and exploitation of space and through visual media. However, this holistic-organic view of the Earth, whether from orbit or from the Moon, or even the rings of Saturn

(NASA, 2013), is essentially a static one. Some branches of science address human development as a *process*, but mostly from a cultural or economic viewpoint. For a complete understanding it needs to be viewed also as a *biological* process. As such it is not greatly different from the growth of any organism, which exploits available resources to increase its numbers and security, and acts or evolves to change its environment for its own benefit.

Changing the environment has been practised on a grand scale for billions of years by the lowliest organisms, algae and bacteria, which are credited with releasing cloud-seeding gases and oxygen, and by higher organisms absorbing carbon dioxide to build shells, leading to carbon being sequestered in vast limestone deposits. Early life has even been credited with triggering global ice ages, with the implication that life does not always act benignly or even in its own interest. While individual species proliferate as long as they can, complex biological systems tend to establish homeostasis through negative feedbacks (Lovelock, 1979). Homeostatic systems have limits to the forcings they can tolerate, and rather than adjusting gracefully they may break down catastrophically when the interconnected negative feedbacks turn positive or fail in cascade. However, we are not completely helpless, as where the nature of such forcings is evident, catastrophic events may be predictable and preventable (Sornette, 2009).

Humanity as a whole is still in the proliferation stage, and is credited with causing a 'sixth extinction event' in which species are becoming extinct at 1000 times the background rate (Pimm *et al*, 2014). Some industrialised societies seem to be moving towards a degree of stability for reasons indicated earlier. This does not preclude, indeed may enable, massive changes in society as well as technology within a lifetime. Credit-card-carrying citizens of rich democracies may view the economic, social, religious and pathogenic confines endured by their ancestors and many people in the present world

as pathological, but these could be seen as stages in a biological, or bio-economic, process where chance rather than destiny rules. Ferguson (2011) proposes that liberal democracy requires six largely unrelated conditions to be present simultaneously. Acemoglu and Robinson (2012) cite the importance of 'critical junctures' or favourable conjunctions of place and event, for replacing 'extractive' institutions, meaning those that combine exploitation with subsistence, by 'inclusive' ones that foster individual self-realisation. In democracies the separation of powers and empowerment of citizens regardless of origin, gender and wealth are taken as basic rights, and act as checks and balances. Universal access to cars and other products has a positive side of consistency with democratic equality and freedoms. Yet the behaviour of populations of these countries, multinational corporations founded in them, and some states supported by them, remains largely extractive. Mass transportation contributes to this both by its demands and by enabling such behaviour to continue. A crucial question is then whether transport can contribute to a solution.

Less is more

There are human needs that are ineluctable like air, water, food and shelter. Less immediate ones constituting liberal society include freedom of thought, speech, movement and exchange, access to education, health support, decent environment, creative social interaction, and intellectual and emotional stimulation. Then there are ones that are optional or largely generated by the supply of products themselves, among which can be counted casual shopping for inessential things, and inessential travel to inconsequential destinations, often viewed as a form of therapy. This may be put in perspective by considering the differences between least and most at each level. The average food energy consumption of the poorest most malnourished parts of central Africa is 1900 Calories per day compared to 2500 in the richest countries, a difference of

only 32 per cent (CWFS, 2006). In contrast, annual average incomes vary from \$226 in Malawi to \$93,714 in Qatar, a difference of over 41,000 per cent (World Bank, 2014a). However, access to vehicles ranges from 1.26 per person in San Marino to one for every 500 persons in Togo, topping the lot with a difference of 63,000 per cent (World Bank, 2014b). It is inconceivable that this could represent a difference in access to an essential commodity.

Conclusion

It is always difficult to view the present rationally and objectively in the context of history, since what will emerge as important in the future may not be evident amid the jumble of the present. The most radical conclusion reached is that it is impossible to achieve sustainability and avoid the environmental and political consequences of our behaviour with the numbers of people and their demands that are anticipated (Lovelock, 2007). Urban intensification appears to move in the right direction, but can only be gradual if it is not to be uncontrolled leading to the sort of slum conditions found in some cities (UN-Habitat, 2007). So rather than following our unprovoked assault and years of occupation by an orderly campaign to win the heart and mind of nature, there might have to be a succession of withdrawal actions in response to natural or naturally exacerbated insurgencies, in which those societies with the greatest adaptability will survive. The more favoured countries in the northern 'temperate' regions, collectively responsible for starting the whole business, may be in the best position to retreat from the consequences, but may still not escape them.

Concerning transport it is possible to be more optimistic. Despite the complexity of networks and patterns of movement, and the ceaseless competition among and between users and providers, it exists in a simplified and somewhat separate economy, and appears to involve a high degree of discretion. As long as there is fuel or power, especially for cars, it will keep running and growing,

until it hits capacity or some other limit of toleration. If the supply of fuel were to stop then motor traffic would stop too, and provided that the circumstance is not also one of total social breakdown, people would adapt to the situation, and after a while might even wonder what all the urgency had been about.

Inessential journeys can of course provide inspiration, and freedoms surely lead to betterment of life's basics, but the message is that human activities lie on a spectrum, and much transportation, especially by car, lies well to the inessential end, and therefore will expand or contract according to prevailing supply and constraints. It may therefore be sensible to eschew the easy option, and devote effort to less disposable goods, rather than depending on relentless movement, consumption and inevitable waste to spin off a few marginal or temporary benefits. Such a paradigm shift will call for much more attention to the real and long-term consequences of choices, but a positive effect may be to unleash a storm of virtuous innovation.

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