GRESHAM COLLEGE

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# The Environmental Challenges of MegaCities

PROFESSOR CAROLYN ROBERTS

Good evening, ladies and gentlemen and welcome to my fifth lecture on an environmental theme this academic year. This evening I hope to take you on a journey across the world, from London to some of the other large, and indeed largest cities in the world, to prompt you to think about how they are evolving today, to speculate on how they can or will function in future, and to consider the environmental limits that may constrain them.

Sixty years ago, the prescient American science fiction writer Arthur C. Clarke described the Earth after the passage of a thousand million years of human history. The oceans have passed away, deserts encompass the globe, mountains have been ground down to dust by the wind and the rain (he had no conception of plate tectonics then), and humanity is clustered into one giant city, Diaspir – an intricate labyrinth of brightly coloured spires and towers in which almost everyone lives an internally-focussed life – frightened to look out from the parapets. As a hydrologist, I rather liked the 6 mile diameter circular river, nicely violating the laws of fluid dynamics, but I was less impressed by the assumed all-male governance arrangements; some things were, from the perspective of the 1950s, unimaginable. Despite this, even the women of Diaspir are not in the main unhappy and citizens occupy themselves by playing virtual reality games based on sagas of the past (a sort of immersive Downton Abbey, I imagine), physically isolated from their friends in small rooms, but associating in cyberspace. Apart from the fact that they live for centuries, life is not unlike that of some twenty first century British teenagers. But here is the difference: the infrastructure of Diaspir is entirely controlled by a giant computer, whose memory banks hold the patterns for creating any object that is required, rebuilding the structure, supplying food and water, entertaining people and meeting those other basic human needs that were identified so ably by Maslow in 1954, apparently through some form of 3D printing or holograms. Although sanitation arrangements are not described, robots do the dirty work and the citizens anyway no longer need to know how the city works. 'Physiological' and 'Safety' needs as defined by Maslow, and indeed some of those needs that Maslow thought were higher in the hierarchy, are being met. Everything is 'smart', secure, stable, static and under constant surveillance.

Diaspir is, of course, almost an anagram of 'despair', and despite the security and cosiness, it is a dystopian prospect. I won't spoil it for those of you who want to read the book, except to say that most of them get out all right in the end. But is Diaspir a glimpse of the near future for emergent megacities today, or will they perhaps simply be deserted as the environmental challenges become too great? Perhaps it may take a huge jolt, some form of environmental catastrophe, to break humanity out of what seems like an inevitable journey towards an unpleasant future of one sort or another? I'd like to think about these inherent urbanisation trends and issues, and explore how megacities and their inhabitants might respond in a logical way.

At one point in the novel, our hero looks down at his megacity from space; you may want to recall that the first satellite that we know about, Sputnik I, was in 1956 still twelve months away. Today, anyone can 'look' down from a vantage point on a satellite, to the coastlines, rivers, and estuaries that have provided such attractive spots for settlement over the last few hundred years, and see the 37 cities that are the homes of 10M or more people.

Indeed, if present trends continue, there will be 50 of them by 2030, and seven in ten of us will live in one by 2050.

The Greater Tokyo Metropolitan Area, over 1300 square kilometres of high tech buzzing sophistication, neon and heritage, is the largest megacity on the Earth with 38 million inhabitants, and growing about 3% or 7% over the last decade, depending on the source of your information. Definitions of exactly what is 'city', vary of course. On balance, Tokyo is not an unpleasant place to visit, but people do commute exceptional distances, mainly using a very good public transport system. Tokyo has its environmental problems too, including an ever-present risk of extreme flooding because not only is it on the coast, but on an alluvial fan at the end of a steep river: these Tokyo apartment blocks are built on massive embankments, and there is a vast pumping scheme to allow water to be pumped under the city through cavernous cathedral-like vaults, should the 'big one' arrive. To me, it felt extremely risky and I worried about the chances of a power failure as well as a flood. Megacities tend to generate megarisks.

With some 24 million inhabitants, the New York metropolitan area is the seventh or eighth-largest megacity, displaced from its premier position in the 1950s. Again, its growth rate is relatively slow, at 3% over the last decade. And like many megacities, it is dangerously close to the sea. In fact, a 3 metre or 7 metre rise in sea level, such as could be occasioned by a warming climate followed by thermal expansion of the water and collapse of the polar ice sheets, would likely wreak some devastation over a period of decades, particularly in combination with storms. Sea level is currently estimated to be rising at about 3-4 mm per year, but it does vary locally for a variety of reasons. A 60 metre rise would allow Trump Tower New York to charge premium prices for a sea view. More seriously, a rise of a metre within the next hundred years is more likely than not, and insurance companies have been sufficiently concerned to have commissioned UK consultants Arup, and the Universities of Liverpool and Birkbeck College London, to report. The implications of a 9 metre rise, such as was associated with the elevated ocean temperatures of 125,000 years ago (and similar to those today), are modelled to have serious consequences for the UK and London too, in part because of the potential collapse of the Antarctic East Sheet. A long mortgage on a house in Peterborough might be inadvisable.

London, the first city in the world to have over a million inhabitants, is not on the 'megacity' list at all according to some commentators, its spatial extent having been halted by the green belt, perhaps mercifully some would say, although with a population of 8.6 million and a growth rate twice the national UK average at 5.7% it might make the 10 million megacity threshold by 2030. Its age demographic is also interesting, with an increasing number of residents over 65 years old, combined with magnetism for young immigrant professionals. London is, according to the European Digital City Index, top city for innovation and has many other Western megacity characteristics too: the steel and glass towers, the crowded transport systems, the air pollution problems and the heady mixture of heritage and modernity. It is a place where you can see, without any irony intended, signs such as this on an office window, saying 'Heritage of Innovation' whilst its growth is still essentially steered by the pattern of investments in that were made in Victorian rail networks. A palimpsest of old and new. Turn around from London Bride, and statements such as the 95-floor Shard, fourth-tallest building in Europe, scream out about power, and symbolise the aspiration for any modern megacity to grow upwards away from its historic roots if it cannot grow away outwards, or even if it can.

Our satellite view, however, would quickly show that it is not the cities of the west that are most obvious today. Whilst today's longer standing megacities include Tokyo and New York, China has at least four, some of which have grown up at a truly extraordinary rate, planned on paper or screen almost from scratch to take rural immigrants in their millions. Shenzhen, for instance, was only a fishing village a few decades ago, and now has over 12 million people. It is a city without a history, according to the Asia Society. India too has several megacities, including Delhi, Mumbai and Kolkata. And several aspirant megacities in the Middle East have the most extraordinary novel designs, and the highest aspirations as well.

Dhaka, Bangladesh is the fastest growing megacity, with the highest population density. At some 60,000 per square kilometre (no one really knows because the Bangladeshi census tends to miss the shanty towns), it is higher even than Gibraltar (figures courtesy of the Guardian newspaper on Tuesday this week). With a population over 18 million and some half a million migrants arriving in the city from rural areas every year, Dhaka typifies the environmental challenges of many unplanned developing world megacities such as Karachi, Delhi and Lagos.

Whilst many of the megacities of the west and the Middle East are wealthy, sophisticated centres of high finance, spectacle and entertainment, more typical global megacities present themselves as sprawling, filthy, polluted, messy, overcrowded, noisy, squalid, unsafe and disease-ridden. Their transport systems seem chaotic and choking, and they are ringed (and in Dhaka penetrated, along every channel and lakeside) by vast areas of impoverished slum dwellings lacking clean water, sanitation and reliable food supplies. Soils and air are polluted by industry, vehicles and the press of humanity. The biggest megacities are also some of the most inequitable and segregated, as we see here in this image of a formerly apartheid city. The so-called 'Gini coefficient' suggests that widening inequality may be an inevitable aspect of megacity growth. But many megacities in developing areas are also exciting, energetic and optimistic places. And there is no doubt that they provide ladders of opportunity for some landless farmers to become firstly the pedallers of rickshaws, and then to move on upwards to a better life. There will be winners and losers, of course, but literacy levels are rising rapidly in Dhaka, and whereas only 50% of the total population can read, young megacity people are much more likely to have had an education. And new city centre traffic schemes are at least moving some of the Dhaka congestion further out, even if not to any leafy suburbs. Dhaka has little equivalent of London's Metroland.

So, despite becoming ever more crowded, developing world megacities continue to grow outwards and upwards in an organic and uncontrolled way. But like London, they also generate a great deal of enterprise and innovation. That is surely going to be needed if the future needs of their citizens are to be met.

There must inevitably be some environmental or other limits to this growth. If present trends continue, then something will presumably have to give, unless better urban systems can be designed and planned to be retrofitted into largely historic settings. Assumptions have to be made about the trends, in the same way that Arthur Clarke made assumptions about automation, and artificial intelligence (and the role of women) in cities, back in the 1950s, and these may prove unrealistic. If we consider Maslow's hierarchy of needs in the modern context of the megacity, then some higher level human needs could in theory be relatively straightforward to meet if the time and money is available. Some needs are essentially non-material: they do not need much space. Love and friendships, for instance, can be tenable even in crowded and otherwise unpromising circumstances. Cultures can flourish, too, and people do not inevitably become alienated and depersonalised in megacities. Communications have been revolutionised almost everywhere by the advent of the mobile phone. The technology is relatively cheap, and reaps immediate rewards, allowing people to manage their lives more efficiently and become more productive in whatever sphere they chose. Television and other digital services are widespread in megacities. The citizens of developing world megacities can not only communicate with each other, but they can and do interact across the world, as the image of 10 million Facebook friendship connections shows; although North America and Europe dominate, megacities in Indonesia, India and South America are linked on an international scale. Access to information is certainly an important requirement for personal growth and self-actualisation, but one that seems likely to be met effectively by crowd-sourcing of ideas.

Greater difficulties arise with needs that cannot be 'dematerialised', or made digital. Whilst some human interactions can be done over the phone or by videoconference, many more require people and goods to move around. Some means of transporting goods is needed. Shops and restaurants, even those with unfortunate names, need to function and people still see a need to get to them. Transport systems are amongst the most obvious areas where megacities literally can grind to a halt, as more and more people and private cars try to

squeeze through the arteries built, and indeed planned, with the needs of only a small fraction of the current population in mind.

In the west, technology-brokered solutions are increasing. Almost fifty years ago, one of the first personal rapid transit systems was developed in West Virginia, USA, shuttling people around between the formerly-gridlocked city of Morgantown and its university campus in large numbers, very efficiently and electrically. The technology was developed by Boeing, and the software to run these individual driverless cars apparently emerged from the now-obsolete Minuteman missile system. My family found it huge fun when we lived there in the 1990s – a theme park ride, twice a day. The PRT was revolutionary and it is still functioning, thankfully with some software upgrades. But we are now seeing glimmers of developments that are alleged to have the potential to transform the shape of transport in megacities. Change is occurring faster than we might ever have through possible. Never mind the 'gig' economy of deliveries on bicycles: pizza, coffee and shopping are already being delivered by drones on the ground, in the air, or both, alongside the perhaps more worthy cargoes of medical supplies. You can make your own judgement about whether this is a viable way of meeting basic megacity needs, or whether it is metaphorical, as well as literal, 'pie in the sky' but the technology already exists. On-call autonomous cars, safer than those driven by humans, are very close to being with us too, notwithstanding the challenges of insurance and being hacked. Perhaps we will have 'multi-passenger commuter drones' in a decade if Airbus is to be believed? Or personal travel pods', as in the video?

Leaving aside transport (and some of the associated noise and safety issues), I want to reflect on the other more explicitly environmental challenges of megacities. I have grouped my consideration into the four traditional clusters: earth (and growing things), fire (that is, energy), water and air. It is impossible to address all of the challenges, but here are a few.

Urban residents have to be fed, and megacities currently draw in food from vast areas around them. Most food (not all) is still grown, or reared. We are all familiar with the concept of 'food miles', and the common aspiration to minimise this for a variety of reasons such as carbon emissions and freshness, but how will this work in a future megacity? Where is the space to grow the food, not least because in older settlements soils are frequently contaminated with the waste of previous generations' technologies? Food is already being grown in some unlikely locations, such as underground tunnels below Clapham, and rooftops. Urban farming is certainly increasing in scale and sophistication, but whether it currently provides a fifth of all food, as alleged by some proponents, is questionable. There is not too much sign of it in Dhaka, where experiments with rooftop vegetable production simply attracted hordes of rats. In the west, where there may be no other way than up, experiments are being done with vertical farming, crops being produced in controlled light, nutrient and humidity conditions. Salads (again) are also being produced commercially using hydroponics, in constrained and vertical spaces. There may be some potential, though the diet may be rather restricted.

Another aspect of 'earth' is the waste material that megacities jettison as 'landfill'. Whilst recycling is growing in acceptability, and indeed in some developing world megacities almost everything is picked over and resold by the poorest people in society, there remains a problem of space either for sorting and storing, for composting organic waste, or for energy recovery by incineration. And even if recycling is growing, waste volumes are also still growing – citizens buy and throw away more as they become wealthier. Developing world megacities are drowning in rubbish, filling their rivers and coastlines with a ghastly mass of mixed plastic, paper and filth. In the developed world, we fill our sewers with 'fatbergs'. I will spare you the images.

With energy needs, the key issue is again whether enough light and heat (or cooling in some megacities), plus some extra power for appliances, can be generated locally to make buildings self-sufficient. Engineers and architects say that in theory this may be true with high levels of energy conservation (that means new buildings only), efficient solar panels on roofs and walls, and improved battery storage. Wind, tidal, wave and hydro power are generally out of range and scope in the megacity, but anaerobic digestion of organic waste and conversion to

gas or electricity might not be. Nuclear energy might not be needed after all. But there is a lot still to do with renewable energy technology to achieve this level of production, and energy infrastructure remains necessary to bring power in to megacities. Outside in the streets (and we tend to assume that there will still be streets), electric cars are presumed by almost everyone, and are developing rapidly.

Meeting water need is more challenging still. Whilst flooding is an ever present challenge in many areas, in China, 30 of the 32 largest cities, in this country of megacities, have permanent water shortages because of high levels of basic demand and pollution of local resources. Per capita demand for water increases with wealth, and wealth generally increases in megacities. The opportunities for capturing large amounts of rain or groundwater locally in megacities are limited, though not absent as planning for sustainable drainage schemes, SUDS, demonstrates in the UK. However, watersheds beyond the city boundaries must be better managed to yield and store more water, provided that this can be achieved without compromising their ability to hold back flood waters in storms, or to sustain agriculture and ecology. We do know something about this, and the role played by vegetation, rewilding of rivers, and reductions in competing demand from agriculture. This is what we mean by 'Blue Green infrastructure'. However there is no doubt that per capita demand for water in growing megacities will need to be massively reduced, and ageing infrastructure in western cities, or lack of it in the Asian megacity slums, replaced. Beyond the overall reduction in demand which may be achieved by fixing leaks or with newly designed sanitary appliances such as Propelair's revolutionary toilet, and perhaps the banning of power showers, reducing peak demand is a problem. To give an idea of the extent of the 'peak' problem, you see here what happens in a typical working week in a suburban area of the UK. Demand surges in the morning and falls away until the early evening, with minor peaks representing TV viewing schedules. The sociology of this is, I think, fascinating. The impact of a mass of people all behaving in the same way is graphically represented by water consumption in Edmonton, Canada, during the Olympic hockey final; the peaks and troughs mirror the pattern of the game. This matters because unless there are restrictions on supplies, then pipes and local reservoirs have to be large enough to accommodate two or three times the average flow.

And air quality appears to be an insuperable problem in all megacities, even those Chinese cities that are so tightly planned. NOx and SOx, particulates, and a heady cocktail of other gases from vehicles and industries that were the subject of my last Gresham lecture. Human health is inevitably compromised.

Bearing in mind these environmental challenges, how will megacities look in the future – in fifty or a hundred years' time. We are not passive recipients of the future, but have a hand in shaping it. Take the transport example, where three alternative mobility scenarios might be envisaged, depending on the way society operates.

- People get around using highly planned, green and efficient public transport
- Petrol and diesel-fuelled cars dominate, and rich people pay extra to beat the jams
- Transport is personalised, and people move in a range of small electric vehicles, souped up bicycles, scooters and 'pods

We might add another possibility, that people's ability to travel is restricted or constrained, and they choose not to do so, however unlikely that seems. All of these alternatives have been represented somewhere in my narrative this evening.

Similarly, if we move away from a single sector and begin to think about the whole megacity environment, what will that look like? For the UK, the Natural Environment Research Council and the charity 'Forum for the Future' ran a series of stakeholder workshops on this in 2016 and produced three city scenarios for the UK, entitled 'Greater Harchester', 'Market Newton' and 'Little Langbrook'. They are looking twenty five years ahead. In the first, large UK cities are politically and culturally powerful. These cities have restructured their financing and closely integrated systems at the city and regional level - such as transport, water and waste. There is a strongly utilitarian ethic that aims to provide high quality, extremely efficient mass solutions. Policy in all areas -

transport, energy, food - is structured around improving public health and lowering carbon emissions. Ubiquitous technology saturates urban environments and is taken completely for granted, giving a real-time detailed picture of the city and allowing for complex coordination of services. Data-sharing is widely accepted as a necessity for high-quality services; Big data and behavioural 'nudging' are liberally deployed to solve complex urban challenges and maximise public health and wellbeing.

The second is a high-tech, highly integrated world. The internet of things is everywhere, and virtual reality is commonplace and widely used for work and leisure. People wear devices that gather data about their health, eating habits, and leisure, and then sell this information to private companies. There are high levels of automation and correspondingly high rates of unemployment and inequality; a large section of society survives on a small basic income topped up by sporadic work in the virtual economy. Cities are private sector-led and 'pay to play' – there is huge choice in terms of products and services on offer, all with the aim of selling as much as possible. Public services are minimal.

And in the third, despite a low-growth global economy and continual low public spending, many UK communities have found a way to flourish through a philosophy of living better with fewer, more durable goods. Life is facilitated by technology but very much grounded in physical spaces; people value the ability to connect with each other in person without technology at the centre. UK cities are dense and centred around small, self-contained communities. Urban services are integrated on a small-scale and by repurposing existing infrastructure. They are often locally-run, and include everything from health to energy to food supply. Innovation is citizen-led and enabled by distributed manufacturing technologies and digital platforms. There is an egalitarian ethos, but inequalities remain – some communities are wealthy and resilient, and others lack access to resources and struggle with economic and climate shocks.

These alternatives all suggest certain things in future cities: they all have drones, they all have bicycles, and they seem to be populated with young people. All the scenarios are rather depressing, and if I am honest, rather unimaginative. By contrast, they draw on new technology in different ways, and they emphasise integration between different types of systems to a greater or lesser extent.

Can megacities be sustained, and function happily using what Will Self has called 'a hotchpotch of bike-hire schemes and superannuated hippies growing tomatoes on Brooklyn rooftops'?

My own view is that in order to support human life, megacities will need to become 'bionic'. We talk about the food-water-energy 'nexus', that area where human systems need to interact effectively. The Venn diagram shows the possibilities. Some of our technological efforts are taking us part of the way towards that sweet spot where systems are synergistic. Urban food production, for instance, is now seeing food, water and waste being managed synergistically and in a more circular way. Nutrients and heat can be recovered from wastewater, as here in this whisky distillery, which generates power as well as producing a highly marketable drink. Water companies are generating energy from sewage. There are many other examples of two systems being joined up productively and to good effect, but as yet relatively few with three or more. Melissa Sterry elegantly describes this bionic nature as 'symbiotic relationships spanning from the molecular to the metropolis in scale'. The buzz words for bionic megacities are 'smart', and 'sustainable'.

Architects, by contrast, seem sometimes to be operating in different realms altogether, with conceptions of the future that do not relate to this concept of sustainability. Here is New York, extended for an increased population, using its own waste material, for instance. Is that sustainable? Vertical forests feature strongly in architectural visions of the future, allegedly to address air pollution – as here in a drawing of a skyscraper in Nanjing (what happens in a very high wind, one wonders?), or in a future New York, where the robots (powered by tiny solar panels) seem to be about to run over the pedestrians in their green canyon and the train track runs dangerously close to the children. Or perhaps there are other habitable environments, under or on the sea, that

would reduce pressure on the megacities? The floating habitat looks, to me, rather restrictive, and pretty expensive too. But it does have renewable energy, at least. What about insinuating a few extra spaces into historic cities such as Perhaps even London could be extended, by using floating areas – a whole new meaning to 'The Westminster Bubble'.

When we look at future survivable megacities, based on the evidence I have reviewed tonight, the supporting ideas and technologies actually need to be evaluated against five criteria:

- 'Organic' cities with integrated systems such as transport, food, water, energy, waste management, and soil
- Circular systems that recycle water, other resources and nutrients
- Low energy and resource efficient systems
- Long lasting, durable systems, in physical and human terms, but also flexible and adaptable
- Resilient to sudden shocks
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In many cases, these characteristics are those that have evolved in the natural environment, so we might describe them, as do the EU, as nature-based solutions. If we cannot manage that, we may be left living as barbarians in the ruins of our megacities, much as in Arthur Clarke's later chapters.
Personally, I think technology has a large role to play in achieving these goals for megacities, and I would disagree with Thoreau when he contemplated the stresses of future travel by train at 30mph. Megacities are centres of innovation, and that's going to be needed.



Gresham College
Barnard's Inn Hall
Holborn
London
EC1N 2HH
www.gresham.ac.uk