Cite this article
Tyler N
Next-generation infrastructure for next-generation people.
Proceedings of the Institution of Civil Engineers – Smart Infrastructure and Construction,
https://doi.org/10.1680/jsmic.20.00012

Research Article
Paper 2000012
Received 12/05/2020; Accepted 20/06/2021

Keywords: public policy/social impact/transport planning

Smart Infrastructure and Construction

ice Publishing

Next-generation infrastructure for next-generation people

Nick Tyler CBE, FREng, FICE, FCIHT, FRSA, AoU, ARCM
Director, Centre for Transport Studies, University College London, London, UK (n.tyler@ucl.ac.uk)

The way in which people consider next-generation infrastructure needs to be rooted in the history of the planet and, in particular, its most troublesome inhabitant, *Homo sapiens*. This history has driven the development of infrastructure through the ages at an accelerating rate, from the incipient early cities of 10 000 years ago to the fast-growing metropolises of the twenty-first century. That history teaches people that human beings are essentially social animals and both require and crave social interactions. The need for this has been increasingly excluded from city design since the beginnings of the Industrial Revolutions and increasingly in the past 100 or so years, where the driver has been the development of infrastructure for its own sake rather than that of the everyday person. This paper proposes a refocus for urban engineering, on the concept of sociality, the propensity to interact freely with unknown others, so that infrastructure is directed to enhancing the ability of people to converse as a basic and initial form of the function of social interaction. The challenge is there, but is the infrastructure sector up to meet it? This paper proposes some initial lines of thought and ways forward to answer the challenge.

1. Past generations

One of the most common misperceptions held in relation to cities and their infrastructure is that they are built environments. In fact, the key feature of a city is that it is people, not buildings. Infrastructure (from "infra- (below, underneath, beneath), and by extension, supporting a) structure' (OED, 1989) is what supports those people and it includes, not just the hardware of roads, drains, buildings and communications systems etc., but also the 'soft' systems (including other people) that support people and society. A city, together with its infrastructure, is therefore all about people and supporting them in their quest for survival and, if everything can be aligned correctly, the improvement of their quality of health, well-being and life in general.

Since the very first cities, the sense that coming together for mutual benefit has been recognised as a good thing for supporting people. Uruk, constructed about 10 000 years ago, was constructed to support the provision of potable water to three different cultures. The cultures benefitted from the access, and the city grew to a size of 50 000 people within 3000 years. Cities were born, grew and died over the centuries since then, but the city as people know it in the twenty-first century really came into being only with the development of Manchester, the first 'modern' city, in the eighteenth and nineteenth centuries. The population of Manchester exploded in this period – in 1650, it was home to 3000 inhabitants, in 1750 it had grown to 20 000, but by 1850 it had become much larger, with a population of 300 000. The growth in population arose because of a technological change – one of the principal drivers of the Industrial Revolution, the concentration of energy, first as water power and then as steam. This concentration meant that what used to be a dispersed cottage industry, speckled through an array of rural villages and homesteads, could be utilised in a single location – a factory, for example – thus increasing the scope for production. Factories required people to work in them, so residential accommodation was needed to house these people, hence the huge growth in population in such a short time.

Cities throughout their history required support for the people living in them, and this could often be the limit to their growth. However, as they grew to a size that could not sustain itself – impossible to grow enough food within the city and its hinterland – more infrastructure was required in order to bring necessities into the city from elsewhere. A key signifier of the modern city is that it could support human life only through the artificial delivery of sustenance – imported food, water and other raw materials – all of which required infrastructure. As a result of that infrastructure, the city could become independent of its own means of support, and thus, it became totally dependent on the satisfactory provision and operation of that infrastructure. Birmingham, for example, simply could not survive without the supply of water from Wales, obtained at an immense cost to Welsh society, rural villages and people.

Infrastructure therefore shelters people from the consequences of their demand. Water on tap without the direct action of having to obtain and clean it divorces the user from the sense of how much they are using – and that neglect has meant – and continues to mean in many cities around the world – that its use is considered to be a human right. As such, unfortunately, the value ascribed to that right is often zero, priceless in the sense of bearing no price, yet incurring massive costs in its delivery. The importance of having the infrastructure to deliver that water (and of course other services, such as energy) is so high that a whole infrastructure sector is built up to support the infrastructure. However, it is all distancing the person from the consequences of their demand. Although such infrastructure can be paid for because the benefits of that energy, and thus the economic, concentration it enables, might make all well, in fact the city is built on a shifting sand. Once the economy falters – perhaps the city's

'product' ceases to be commercially viable, or another city offers a better viability to the product owner – the city can no longer afford the upkeep of its supporting infrastructure.

Without a doubt, the concept of the 'modern city' as started in the Industrial Revolution had some major flaws. Principal among these was the total neglect of the environmental consequences of people's activities. In particular, the extraction and use of fossil fuels – first coal and then oil – and the associated assumption that the emissions could be absorbed by the atmosphere and planet without limit generated the identifiable start of the anthropogenic rise in the earth's temperature, which has continued to this day. People should stop talking about a 'climate catastrophe' and call it for what it is: a 'human catastrophe'. Furthermore, much of that human catastrophe has been facilitated by infrastructure that has neglected its role of supporting people, rather than 'cities' or even 'other infrastructure'.

When the population increases beyond the capacity of the city's infrastructure, it will play out in terms of two related features: poverty and ill health. In London around the middle of the nineteenth century, the issue of sanitation arose, and caused in part by the widespread adoption of water closets, the city became a fertile base for the spread of cholera. The solution to the cholera epidemic was to separate clean and foul water, to which end Joseph Bazalgette created a huge drainage and water-treatment system, designed to take the foul water out of the city altogether. This massive infrastructure was also very expensive, and thus politically divisive. Similarly, it was clear that the housing conditions of poor people were also a major contributor to the spread of disease. The solution to this was a massive remodelling of housing, the development of housing out of the city – utilising the new railways to permit commuting and supply of goods to the now far-flung suburbs. Thus, the end of the nineteenth century saw a series of big infrastructure developments that caused immense change, in the perception of civic responsibility, the use of funds, the destruction of living accommodation, often with scant attention paid to the sensibilities of the people living in them, and a change in how people had to live.

2. Present generations

Historical decisions such as those described in Section 1 have left the present generations with an inherently unsustainable system. Those suburban railways have become a densely packed fetid horror for people commuting into and out of the city every day. The highly centralised nature of the London economy means that there are many commuters – approximately 1.5 million people cross the boundary formed by the London Underground Circle line between 8 and 9 a.m. every day. This places immense pressure on the transport system in order to provide that level of capacity, requiring expensive and complex engineering to create new infrastructure aside from, and often underneath the Victorian provision that is still in use.

Incremental changes have also added their toll. The introduction of the motor car – and the untrammelled adoption of this as the prima facie mode of transport through often dubious techniques and processes by the motor manufacturers in cities in the early twentieth century – has had a huge impact on the way cities are in the twenty-first century. Cities are designed around cars, traffic and trains, and not around people. Particularly in North America, but increasingly around the world, the road system came to characterise the city and it is often impossible to conceive of living in a city without a car, which then needs infrastructure to support it – note 'it', not the people within it – and this is part of the twentieth-century legacy.

Towards the end of the twentieth century, it started to become clear that the motor-driven approach to urban development could not be sustained on any level – economically, socially, environmentally and even in many cases politically. Starting from Jane Jacobs (1960) and her campaigns in the 1960s, the work by planners such as Edward Hall (1966) and Holly Whyte (1980) in the 1980s, and the approaches of visionaries such as Richard Sennett (2019) throughout that period (and continuing), it became clear that cities had lost their original purpose of protecting people and enabling them to survive. To make that shift from 'infrastructure' to 'people', it is necessary to think more about how people act as a social species, for that is one of the key distinguishing characteristics of *Homo sapiens*.

Genetically speaking, the twenty-first-century *Homo sapiens* is identical to its ancestors of 100 000 years ago. Humans evolved successfully for life on the savanna – their sensorial systems are being spectacularly developed for a situation with far, wide, empty horizons, softish ground, big skies. The need to feed the large brain that characterised hominids meant that under these conditions the small food sources readily available in the previous more jungle-like environment had to be replaced by larger animal sources that could not be captured easily by one person on their own. Survival thus depended on people working collaboratively to hunt and gather food supplies, and this is one of the distinguishing characteristics of *Homo sapiens* that mean that it, of all the hominids, is the one species to survive to the present day.

The characteristic of collaborative working meant that humans have worked together throughout history – even when trying to kill each other – and it is only comparatively recently that the concept of competition as a means of overriding collaboration in order to progress has taken hold. However, this does not mean that group size is a limitless function. Dunbar (1992) showed that there are limits to social group size, depending on the capacity of the brain to make connections and activities such as grooming. Dunbar set two numbers of interest in this context. The first is known as the 'Dunbar number' and is 150. This is the number of people with whom a person can maintain meaningful social relationships. The number is approximate of course. The 'meaningful' criterion means that this is very different from, and should not be confused with, the number of people in someone's Facebook contacts list or their followers on Twitter. This sets the sort of approximate size of grouping within which a person can live in a social context – perhaps it is the number of people living in a residential street, or the number of people who know each other within a neighbourhood. The other number Dunbar raises is 5. This is the number of people in a person's 'inner circle': the number of people who share deeper secrets and confidences. This is a number

initially developed from the activity of grooming in primates: grooming – gentle touching, paying detailed sociophysical attention to other members of a group – is very typical in primates, and humans, as a primate, also act in a similar way, although over time it has become ameliorated through cultural mores (holding hands, hugging, embracing and so on). It is simply not possible to 'groom' many other members of a group, and so the number becomes limited.

The significance of Dunbar numbers for this discussion is not the numbers themselves, but their magnitude. They mean that the number of people who interact with each other is in fact limited to quite a small number. The number of people in a city who coalesce is not millions, as in the megacities of the world, but in groups of around five people. In order to thrive, it is necessary to enable these small groups to thrive – the thriving of a city as a whole happens because of the thriving of a large number of small groups. In a project called 'Transforming the Engineering of Cities', it was examined the way people interpreted the sense of well-being that might be delivered by a city. Joffe and Smith (2016) found that the strongest example of this came from the situation where a person walking along a street could see someone they did not know, greet them and be greeted in return. Although at first this might seem to be a rather odd, and perhaps slight, response, deeper thought suggests that it could be very important indeed. The situation required for this interaction is one of implicit trust: 'the "other" person is not going to harm me'. Where that trust does not exist, the sense of well-being is very definitely in short supply. The city of Medellín in Colombia had lost that trust in the 1990s, and it was clear to the mayor of the time that the city would not be able to thrive until that trust had been restored. Hence, the process of restoring trust had to be in place before any other, more infrastructural changes could be made. It is for this reason that 'trust' is regarded as a principal component of the infrastructure of a city (Tyler, 2013). Trust is sensed by individuals in relation to their daily life, and even if it is sensed to be present or lacking in a city as a whole, its effect on the social life of the city is expressed through individuals and their small social groupings. The basis of this trust is what the author calls 'sociality': the propensity of one person to interact freely with another unknown person. Without sociality, trust will not happen.

Social interactions arise in the case of humans through conversation, so the exploration of trust and social grouping needs to be made in the context of conversations. The maximum number of people who can hold a group conversation is four. There are a few reasons for this. The ability of the human voice to project is not that strong, and the human ears, although highly sensitive to small sounds at great distance, being able to distinguish some sounds out of a plethora of others, they are not able to hear well enough to conduct the subtleties of conversation at a great distance. Although the human vision system has a wide horizontal field of view, the useful field of view in which detail can be easily seen and interpreted is limited to about 60°. The result of these conditions is that conversations between groups of people happen at a distance of around 1.2 m from each other. Look around a gathering of people – in a station, a street or a restaurant – and groups in conversation can be seen, but these groups will typically be four or less. Even if a group appears to be larger – say a group of six people – on closer examination the conversations in the group are between smaller subsets. Thus, to encourage a sense of well-being, it needs to be ensured that a city provides an environment that is able to facilitate conversation, trust and sociality. This means thinking about the visual, auditory, tactile, physical design of space in the city, but to provide this for small groups of people. The present approach is to be concerned with the mass movement of people – whether this is in mass public transport, private transport or crowds – but this is almost certainly at the expense of losing sociality, and thus trust. Just as in Medellín, trust needs to be built before people can begin to create a viable thriving city, and this starts with enabling people to greet unknown others, and to have small group conversations.

How could this be done?

If the starting point is to develop sociality, people need to think about that act of greeting an unknown other. From an initial sighting of the other person to the moment of 'greeting', this takes about 6 seconds. This is because the distance between two people at which it is possible to recognise that they are unknown to each other is around 10 m, and at a walking speed of around 1 m/s, they will meet in 5 seconds and pass each other in another second. During that time, features will gradually become more visible – facial expressions and so on – and the decision is made to greet, rather than avoid, threaten or run away, and updated as the two people approach each other. Hall's work states that this public distance is the outer limit of social interaction and that at a distance of rather less than that it becomes more possible to effect the greeting – maybe up to about 3 m apart. Even if somebody wants to greet someone who is 10 m away, it would be difficult to project the voice that far (an actor or opera singer has to train very hard to for them to project their voice beyond a normal conversational distance, even with an 'ideal' interior acoustic environment). The greeting itself will happen at around 1.2 m. This sequence of events indicates some interesting issues about space. The width of a residential street, for example, could be set to enable such interactions between people on either side of the street – a frontage–frontage distance of around 10–12 m would allow that, and it would be a whole lot easier if the footway widths were around 3 m each, because at that width, it would be possible for people to have a conversation on a footway without interrupting other people who want to pass along the footway. This would leave some 4–6 m for vehicles.

The distances needed to encourage sociality are driven not just by vision – the distances and spacing themselves – but by the multisensorial functioning of the human body. The human being is a massive multisensorial data collector – people receive data through many sensorial pathways to make sense of the world. The human brain is, relative to a modern computer, a slow processor, but it is hugely more effective at processing multiple different data streams in parallel. A lot of what people understand in a conversation is derived from the combination of hearing and sight – the difference between similar sounds is often only actually distinguished by sight – and the

interpretation of facial features and micro-movements adds to the interpretation of meaning. Therefore, the delivery of good acoustics is crucial to the design of urban space. This puts into context questions about materials, facades, traffic levels and noise, the delivery of visual and aural rhythms and so on, so that sociality can be enhanced to create that trust on which the thriving of the city depends. It is the embodied mind and ecological brain in action, and using these approaches – a combination of neuroscience, psychology, urban design and engineering – that will deliver the definitions of the infrastructure in the future.

3. Next generations

Brundtland's requirement of decision makers to develop sustainably – that present decisions must not compromise the future decisions of future generations (Brundtland, 1987) – carries a difficult concept within. How does society know what the future generations will need to be deciding about? For example, in the early twentieth century, the London Underground was advertised as being a way to 'commute from the suburbs', showing a carriage with people sitting elegantly in a train, reading newspapers. The reality in 2019 is one of people in a train at a density of around 4.5 people per square metre. The people designing the underground systems at that time had no idea that demand would rise to such a level, and the decisions they would have been taking then have precluded options for designers today: the development of the deep tube system in London, for example, has resulted in very small trains, with extremely limited scope for functions such as air conditioning, and no room for expansion. To expand the system now requires massive investment of completely new systems, such as Crossrail – and that will barely scratch the surface of the capacity problem on most of the Underground system. The question now is, 'what will be the future impact of infrastructure decisions people are taking now on the options available to future generations of decision makers who will be encountering whatever their problems will be at that time?' Interestingly, the 2019–2021 worldwide pandemic cause by the Covid-19 virus, shines a light on this issue.

In the work of Hall and Whyte referred to earlier, the sense of how people distance themselves in public space was shown to be observable and measurable. This has driven enlightened thinking about public space ever since. What has happened in the present situation is that physical distancing has been stipulated by public authorities, mostly on the basis of knowledge about the dispersion of droplets that have been emitted as a result of sneezing, coughing, breathing and talking. In the UK, the required physical distance is 2 m, with some recognition that actually the spread of some droplets from coughing and sneezing may reach 6–8 m, and other, much smaller ones could remain in the air for a considerable time. The challenge for infrastructure designers in this situation is that the physical distance observed and measured by Hall and Whyte, which coincided with the social distance activated by people in the public spaces, is smaller than the physical distance now being required. This has revealed what is in effect an assumption that had never needed to be stated in the Hall and Whyte models: the observed physical distance is based on the desired social distance and may thus be taken to be the same. The present situation has delaminated these two distances: the perceived social distance is now smaller than the required physical distance, thus creating an anomaly.

The physical distance required to separate people beyond the range of virus transmission is too large to facilitate sociality, but people seem to crave sociality. This has resulted in a number of phenomena, observed in slightly different ways around the world. People singing together from balconies in Italy, dancing on rooftops in Spain and clapping in appreciation of key workers in a number of cities are all examples of attempting to engage in a social activity under conditions of separation. This presents the inspirers of urban space with an interesting challenge: how to maintain and encourage sociality while protecting the physical distancing being required, sometimes with legal reinforcement, that of its nature makes sociality difficult. Similarly, the density within public transport systems – London with its 4.5 persons/m^2 is a relatively open example – the Tokyo metro can reach densities of 7 persons/m^2 and Beijing 8 persons/m^2 – is a real challenge. To reduce this to, say, 2.5 persons/m^2, which is a figure above which the density starts to reduce boarding rates at stations, but which is still way above a 2 m physical distance between people, would have profound impacts on the finances of the public transport system.

One of the issues of concern to cities in the present situation has started to emerge in Wuhan, the first major city to be affected by the virus. As the city emerges from lockdown, it is becoming apparent that people are scared of using public transport and are starting to shift to private transport, some buying cars in order to do that. This would be a disaster for much urban planning, not only for questions about sociality but also for air pollution and other responses to climate change (a challenge that has not gone away in the presence of the virus). Thus, the present urban decision makers need to make a series of deep decisions that will impact on the next generations, and they will need to make these decisions very quickly indeed.

Some initial issues of concern are as follows.

- How to rethink the way that a city works so that a more distributed system could work well, thus enabling public transport to work at a lower density and enabling many regular needs to be met by walking and cycling to nearby facilities. This means redistributing employment, shops and other activities so that fewer are concentrated in the centre and more are distributed around the suburbs. This would allow people to live and work in the suburbs, rather than having to commute into the centre every day.
- How can public transport operate feasibly with much lower occupancy than is currently considered to be economically viable? How could public transport vehicles be designed to take advantage of the lower density to enable sociality – design and positioning of seats, importance of acoustic insulation, lighting and so on being now a matter of sociality rather than density?
- Develop the communication systems to enable more remote and flexible working. The 2019–2021 Covid-19 pandemic

situation has shown what is achievable, but it has also revealed some problems. These relate to technical issues such as system capacity and bandwidth, but the pandemic has also highlighted softer issues such as family imperatives impacting on work when working at home, or how people interact with each other when not in physical proximity.

- How to understand exactly how sociality works physiologically, neurologically, psychologically, physically and emotionally, so that people can understand how to design the urban realm in such a way as to enable sociality while paying attention to the need for physical distancing (the Covid-19 virus is not going away: there is no such thing as 'post-Covid'). People have to think in the same sort of order of magnitude as those Victorian engineers resolving the cholera epidemics 150 years ago, and whose efforts are still the base of many cities' sanitation, housing and transport systems. This requires a whole new approach to the science of space and time, and it is fortunate that a new laboratory is being developed in the UK that will have the capability to study exactly these issues of how infrastructure and people interact, as part of the UK Collaboratorium for Research on Infrastructures and Cities (UCL Pearl, 2021).
- How does society change the way of thinking of all stakeholders involved in cities? It is clear that these questions are way beyond the thinking of present city leaders and those involved in planning, designing and operating cities. This will require a reconsideration of the education of professionals in city and other activities, including the science and engineering of health, climate science, energy and environment and the understanding and development of people, through social science, economics, psychology, the sciences of body and mind, the arts and philosophy.

The next-generation people are already alive – as are some of the generation to follow. The time is therefore passing very rapidly indeed. This paper is a call to action not only to the infrastructure sector but also to politicians, and others involved in the whole concept of cities and the ways in which people live.

4. Conclusions

The thrust of this paper is that people need to act now to ensure that the next generation of inhabitants of the planet will be able to have a planet to live on and a society in which to thrive. In conclusion, here is a simple list of issues that need to be taken together in this pan-systemic review of where society is now in terms of infrastructure and where it should be going.

Infrastructure needs to be designed for people in such a way that they can live at one with the planet and each other. The major thrust for that design is to design for sociality so that people can thrive through collaboration rather than through conflict. Sociality is going to be a major challenge, though, because the issues that have arisen as a result of the coronavirus pandemic have placed a set of barriers to sociality that need to be resolved as a matter of urgency. These barriers are profound and go beyond the physical infrastructure, into the finance, health, economic, educational and social infrastructures that need to combine and collaborate in order to further society in a sustainable, inclusive and equitable way.

The understanding needed to make such profound changes to infrastructure will need to be based on a different concept of how people interact with each other and the environment. This requires a model based around the concepts of embodied mind, the mind enacting responses throughout the body and the ecological brain – the brain understood as it responds to stimuli in the environment (rather than in a scanner). Thus, some of the deeper issues behind neuroscience need to enter the world of public infrastructure, for without this, people will never understand how to crack some of the more challenging issues involved in the way people interact with the infrastructure that they use.

REFERENCES

Brundtland G (1987) *Our Common Future*. Oxford University Press, Oxford, UK.

Dunbar RIM (1992) Neocortex size as a constraint on group size in primates. *Journal of Human Evolution* **22(6)**: 469–493, https://doi.org/10.1016/0047-2484(92)90081-J.

Hall E (1966) *The Hidden Dimension*. Doubleday, Garden City, NY, USA.

Jacobs J (1960) *Death and Life of American Cities*. Random House, New York, NY, USA.

Joffe H and Smith N (2016) City dweller aspirations for cities of the future: how do environmental and personal wellbeing feature? *Cities* **59**: 102–112, https://doi.org/10.1016/j.cities.2016.06.006.

OED (Oxford English Dictionary) (1989) *Oxford English Dictionary*. Oxford University Press, Oxford, UK. See https://www.oed.com/view/Entry/95624?redirectedFrom=infrastructure& (accessed 03/07/2021).

Sennett R (2019) *Building and Dwelling: Ethics for the City*. Penguin, London, UK.

Tyler N (2013) *A Vision for Cities: The Five-city Model*. Accessibility Research Group, University College London, London, UK. ARGnote vol. 1, no. 5. See http://tinyurl.com/5-citymodel (accessed 25/04/2021).

UCL Pearl (University College London Person Environment Activity Research Laboratory) (2021) See https://www.ucl.ac.uk/pearl (accessed 19/06/2021).

Whyte WH (1980) *The Social Life of Small Urban Spaces*. The Conservation Foundation, Washington, DC, USA.