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Editorial

B Urban Analytics and City Science

The Coronavirus crisis: What will the post-pandemic city look like?

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Many times in these editorials over the last 30 years have I speculated on how we might think about cities in terms of their dynamics. The central constructs in such thinking involve ways in which cities can be disrupted by new technologies, and how a myriad of networks define the way energy, materials, people and information come together to generate levels of complexity, unimaginable before the industrial revolution. This science suggests how resilient cities are in the face of unanticipated, often chaotic events, due to the fact that cities are constructed and evolve from the bottom up. A favourite model is based on the notion that if a city is conceived of as a network, then we should be able to figure out the set of cascading consequences that rapidly diffuse from some break in transmission. This relates to how we might get a handle on such repercussions if we are able to observe these networks in much more detail than we have been able to in the past. It was Edward Lorenz (1993) who in 1972, first articulated this notion of unanticipated effects or chaos in the weather, in his question 'Does the Flap of a Butterfly's Wings in Brazil Set Off a Tornado in Texas?' or more critically for cities, in the words a popular 1960s song how ' ... the lights went out in Massachusetts'. Or more to the point, how these seemingly random events in distant places like a wild life market in the Chinese city of Wuhan, suddenly throw the world into a global lockdown as an unknown virus begins to spread more rapidly than we could ever envisage.

Nothing, nothing whatsoever, could have prepared us for what has happened since the beginning of this year. I know that some researchers and public health professionals who have been modelling pandemics have argued that they were always aware of the risks but that no one has ever taken them seriously enough. Even Bill Gates (2015) has been preaching the dangers of a pandemic for years as reflected in his TED talk. But for over 100 years since the so-called Spanish flu at the end of the First World War, we have not really taken to heart the idea that everyone and everywhere might be infected by a disease that we were unable to control. I remember as a young boy growing up in Liverpool in the 1950s being somewhat afraid of various viruses such as polio and smallpox but they were fast being eradicated, disappearing by the end of the 20th century. The obviousness of what has now happened however is sobering, indeed humbling. We were able to control SARS, Ebola too and other respiratory diseases in the recent past, but the sheer virulence of the Coronavirus has taken us by surprise. The fact that we are all connected so closely to everyone else due to global travel and global supply chains has spread the disease much faster than we were able to grasp. This has revealed that our perceptions of the way the world is globally connected

lag far behind the actual reality, while the density of this connectivity appears to have grown exponentially since the Millennium.

Over the last 20 or so years, there has been some limited progress in figuring out what happens when a large network composed of tens of thousands of nodes and even more links goes down, that is, experiences some break in connectivity or transmission. We know that networks usually have a distinct structure and social and communications networks are usually composed of different clusters of nodes that reflect our competitive nature and our need to agglomerate. Such networks have gatekeepers who control key links between the clusters – weak ties – while the size of the clusters themselves are arranged according to various power laws where very often networks have giant components. Moreover, many networks are extremely resilient to attacks on their nodes or their links. There are many social and economic networks that are very difficult to bring down even if key nodes and segments are removed. In some respects, this is both the great strength as well as the great weakness of many human networks. In some networks, there is so much redundancy that it is almost impossible to bring them down, meaning stopping transmission of information between their parts, and this a great strength if what is being communicated is essential for the life blood of the system. This is easy to see if a key highway goes down through an accident. There are usually many alternative routes. But if what is being communicated is undesirable like a disease, a bad idea, or an illicit and potentially harmful drug, a network with great redundancy is not what one wants. To intervene positively to either build new links that would enable better communication or to remove links and hubs that could kill the undesirable communication at one fell swoop, then the connectivity or the density of hubs and links is all important. In the case of the Coronavirus, to stop the virus spreading one has to target the clusters where the super-spreaders of one type are located or the weak ties where another type of super-spreader exists. This can only be done by very detailed contact tracing that is expensive and will always miss some cases. Stamping out the virus in this way is difficult for it amounts to squeezing it out of the system, in its entirety. A vaccine to reduce its effects or to make the host immune is the only way.

All the examples we have of adding or removing links and hubs from a network are miniscule compared to the networks involved in the current pandemic. To stop transmission beyond the household or dwelling unit demands a total lockdown which means that everybody needs to stay at home – to self-isolate in the current jargon. This would kill the transmission of the virus to anyone outside the household but it would be akin to simply dismantling the entire network. This is not physically possible for the population must still consume the most basic necessities so what has been adopted is a lockdown for all but the category of key or essential workers. In the UK, there are about 32 million persons in employment and about 5 millions of these are defined to be essential workers. This gives some idea of the scale of the lockdown. Very roughly, we might say that this implies that about 80% of the social and economic networks of the country are currently locked down, and non-functional. It is a unique and entirely unanticipated situation and there is very little idea of what will happen next as there are severe demands for this situation to be eased so that the economy can be rebooted back to its pre-crisis levels. There are no examples in the literature of any cases where networks have been targeted in this way even in theoretical terms and thus we have little or no experience of knowing how such a network might recover.

Recover of course it will but if the lockdown were completely released tomorrow, the economy would not come back in one fell swoop. Far from it for it would take some time to reboot various industries and services. There would be differential effects related to supply chains and once one examines this in the wider global context where different nations and

cities are recovering at different rates, none of this is bound to be smooth. But parts of the economy will not come back in any case. It cannot restore itself to its former glory for some businesses will have gone broke, unemployment is bound to rise. About half of all employment is currently being unpinned at a lower level financially by government, and it is most unlikely that these workers will have saved enough to recover their former life styles, at least for a while. Recent predictions suggest that this virus will lead to the greatest economic recession since the Great Frost of 1709 – which is so long ago that it is not possible to make comparisons (Schofield, 2020). One might as well say since the Black Death, it is so unrealistic a comparison.

The biggest change however is likely to come from changes in the way we move around. Until a vaccine is found – if it is found although there is a very strong chance that something to alleviate the symptoms will be – then people will be very wary of keeping close to one another. Social distancing which implies that if we do not know that anyone within 2 metres of ourselves has the virus, we will always keep more than 2 metres from them. Many movements on public transport in cities greater than about 50,000 population have crowding at peak hours where this rule is likely to be adopted socially in a time when it will be no longer be mandatory or strongly advisable as it currently is in the UK. This is likely to lead to changes in our modes of transport. In fact for two weeks before the current lock down in the UK which occurred on March 23, I walked to work instead of using the 'Tube' and 2 weeks earlier when I returned to the UK from the US to Terminal 2 at Heathrow on February 16, it struck me that we should have been exercising much more caution especially as a plane from Beijing had just disgorged its passengers and half those in baggage claim were wearing masks. Social distancing may well be here to stay especially if the disease becomes endemic and we are unable to eliminate it which is quite possible as in the case of various strains of influenza.

Shifts in mode when people avoid public transport and resort to walking or cycling or to travelling in their own cars are likely to be a fairly immediate consequence of the pandemic and this will probably have a major effect on the amount of travel undertaken. Many more people having adapted to working from home, may well continue to do so, at least for part of the week. In fact before the pandemic during the last calendar year (2019), the UK Office for National Statistics (ONS, 2020) reported that 5% of workers worked from home all the time, 27% worked from home at some point in the year and 8% worked close to their homes in the same complex of buildings. This suggests that up to 40% could work from home if the conditions were right and if there was continued pressure to social distance. If this were the case, then the impact on transport would be dramatic.

We may well see a rise in demand for car travel, reversing the slow decline which has been happening in many countries since the late 20th century. If we see a significant increase in car usage, this could well sound the death knell for the compact city idea. During the Second World War, the idea that we should 'decentralise' our activities away from big cities took on a new urgency. Throughout the 19th century, the drive towards urban planning was based around the notion that we should return to the countryside to avoid the evils of the big city, indeed the garden cities movement and the idea of new towns reflected these concerns. And this was long before we acquired the ability to travel individually using the automobile. Indeed the history of the city in the 20th century is one of letting the city 'breath' through a decentralisation of congested activities from housing to industry to services in edge cities, low-density urban sprawl and new communities far from the central city. Combined with working from home and severe social distancing, these old ideas look increasingly attractive. During the Second World War in the UK, the strategy that emerged was based on decentralisation from the urban heartlands. The various reports which were produced for

government by Barlow, Scott and Uthwatt suggested that the industrial population should be dispersed, that to avoid a repeat of the bombing, we should live in smaller places, with industry widely decentralised and with an implication that towns should be more self-sufficient. The core of urban development in Britain in those far-off days was in fact referred to rather darkly as 'the coffin' due to the shape of the predominant industrial development in Britain in the area embracing London, the Midlands, the North West and West Yorkshire. It was this area that was largely regarded as the region of the country from which one should redistribute the population. At a more local scale, this policy came to be implemented particularly in the British new towns. Years where a degree of self-containment with respect to employment and population would minimise travel, notwithstanding it was entirely counter to the way in which our towns and cities had developed since the start of the industrial revolution.

Needless to say this policy of self-containment was impossible to implement, deeply flawed in that cities grew ever more rapidly around their edges and commuting distances became ever longer. By the late 20th century however, policies to compact the city rather than establish new towns around its edge began to be implemented such as development on brown field sites, and this was accompanied by various policies to constrain the car and reduce pollution largely through taxation and road pricing. The emergence of smart growth through policies associated with transit-oriented development came onto the agenda and before the pandemic began, the notion of a greener, more compact way of urban living was beginning to establish itself as our love affair with the car began to dwindle. The fact that as our cities grew and began to compact, the price of housing and everything else within grew ever faster and more than proportionately to our individual wealth and this a major dilemma. The pandemic will probably end all this as we strive to keep our distance from one another in many different ways, certainly in the immediate future. Much will depend on how the pandemic plays out.

Perhaps a bigger casualty of this crisis will be air travel and tourism. We have in the last two months taken to Skype, Zoom, Teams and such-like web-based conferencing systems and progress in making this experience as painless as possible has been rapid. I for one will think twice now about travelling long distances to give a talk where you barely see the place you visit and spend long hours in crowded airports waiting for planes that seem to be continually disrupted and overbooked and living in hotel rooms that are too cramped. Much of this can now be done online. Tourism too will suffer and change accordingly, not least because people will not wish to put themselves at risk but as much because we are likely in the short and medium term to be a good deal poorer, needing to rebuild our own economies. In fact, the parts of the local economy that will find it hardest to return to pre-pandemic times will be restaurants, pubs and large entertainment venues where we gather for much longer periods of time and where we are likely to be more exposed than in airports, trains stations, or at work where we have some control over our self-distancing.

It is globalisation in general that is likely to change most dramatically because so much of our world is now built around supply chains that satisfy demand that cannot be met locally. Before the pandemic, there was already a strong movement globally in many nations where the concern was with bringing production back onshore. The best example is in our health systems. In Britain, we have a good, equitable and efficient national health system. During this crisis, it has not been starved of expertise in terms of health care workers but it has been starved of the right equipment because much of it is made offshore. This will have to change just as the health care system is itself likely to become ever more significant in thinking about how we organise contemporary society. If there was ever an argument for bringing

production back onshore even though it might be much more expensive in terms of labour to do so, it is related to our public health.

That there will be a new normal, I have no doubt. What this normal will look like, in terms of cities and everything else, is still in the realms of speculation. Much is being written about this near future, but events are unfolding at amazing speed. Bringing the economy back is a critical issue in such a way that damage is minimised but once again we are in uncharted territory. In our domain, we should be able to say something about how when you lockdown an economy in the way we have done, it should come back. We need to predict the sequence of bringing jobs back to traditional ways of working and what casualties there will be with respect to the order in which they are brought back. And all this has to be factored into the virus suppression, to keeping the 'curve flat' so-to-speak and avoiding more damaging waves of infection that continue to threaten life. We may well see walkable cities emerge, we may well see much more work from home, a decline in redundant international travel, a move to produce more locally and cities built around health care. But we may see much more sprawl as people seek to get away from big cities to small towns, we may see a growth in car travel and a decline in public transport, we may see countervailing trends reinforcing each other such as working from home at much farther distances away from cities, we may see more social isolation, and different kinds of social epidemic related to changes in our health and longevity.

That the future is unknown there can be little doubt but the fact that it is in our hands to invent it is something that we need to take to heart (Batty, 2018). In the spirit of the theories and tools that we profess to research in the pages of this journal, we need to consider the myriad of networks that compose the contemporary city and work out how these will change as the pandemic is managed. Many nodes and links in these networks will change. Consider what we have said about transport. Major changes could take place in the modes of transport we use with many public transports declining rapidly, many people working from home and many supply chains being refashioned. Some networks may well disappear while new ones will take their place. How the pandemic maps onto these networks is of obvious significance but the ramifications of changes in our social behaviour will be deep and wide and the new normal that emerges will be very different from that of the immediate past. These changes will impact on every corner of our world. Suppressing the virus in one country or one city will not lead to its return to the old normal as it sits within a global network where every place will have its own behavioural response.

There are dangers too in moving to a more decentralised, isolated kind of world where crowding has disappeared and everybody lives at much lower densities. In conclusion, I am reminded of E. M. Forster's (1909) wonderful story written many years ago about what happens when such a world of isolation breaks down. In his story 'The Machine Stops', Forster paints a picture of a world that is underground, where everyone is connected by an 'internet' of sorts, where production and consumption are a strange mix of local and global, where most never venture outside and where most do not really know how such a world sustains itself. It is not quite the world that we have entered in lockdown but there are many similarities. Forster's new world was one in which an old world had been built around '. . . bringing people to things, instead of for bringing things to people', strangely prescient in these unusual times of ours. His story recounts how the world of social isolation that had become a new normal was breaking apart due the fact that the society had lost its '. . . sense of space'. He continues by quoting one his principal characters saying 'We say "space is annihilated," but we have annihilated not space, but the sense thereof. We have lost a part of ourselves'. There are many features of this world that remind us of the lockdown and the story is really all about how the machine that sustains such a world is stopping. One cannot

help thinking about our own internet in this context, and how, in the present crisis, it continues to operate. To an extent, we have avoided thinking very hard however about the sustainability of our physical networks and supply chains, particularly those providing basic needs which have become increasingly global too. Forster ends his story with the machine breaking but he does not speculate further on what kind of world will return. I will end my story too by simply asking the reader to absorb Forster's essay and his message – it is online in many places. His speculations are better than any I can reflect upon here and thus provide a sense of what might occur and what we might do as the immediate future begins to unfold.

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Unpredictability

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If I look back over 40 years of these editorials, what is striking is how new ideas about cities and their planning have emerged without premonition, ideas that at the time they were articulated had not even appeared on the horizon. When the journal was founded in 1974, the editor Lionel March and his colleagues which included myself, believed in the inherent predictability of the science that we were forging. We felt that the models and methods we were developing would enable us to make predictions about complex systems with some degree of certainty, so that we could use these forecasts to figure out how we might produce plans for 'better cities'. We were not particularly naïve in these sentiments because design was central to the role of models in planning and as many of us were trained as architects, we were conscious of our role in 'inventing the future' rather than just predicting it (Batty, 2018). Predictions and predictability were thus constructs that helped us to invent a better future, by at least steering the future away from what we might foresee as undesirable. Good predictions were judged to be essential.

Yet this certainty about the role of predictions and the need for them to be accurate has largely disappeared over the last 75 years. From the Enlightenment on, science was increasingly based on devising strong and robust theories that were improved inductively and validated deductively. Cracks do continually appear in the scientific edifice but it is these that motivate better science as theories are made ever more general and powerful. At least this is the goal. But throughout the 20th century, there has been a retreat from positivism. In 1935, Karl Popper (1959) argued in *The Logic of Scientific Discovery* that the system of scientific interest had to be entirely closed for science to be able to make accurate, hence immediately useful predictions. Popper's favourite example is the solar system whose form can be almost perfectly predicted by Newton's Laws, a closed system that to all intents and purposes could be treated as separate from the larger scale composed of other solar systems. I say 'almost perfectly' for there is always a chink in the armour of perfect certainty, in determinism, and even Popper's own theory of science is based on the notion that all we can do is falsify a scientific theory. The future is an unknown book, and this suggests that there is no such thing as an accurate prediction, anywhere, at any time. Perfect predictability is thus a norm to be aspired to but one which also enables us to determine a range of possible futures. Looking back over the last 75 years, our science has moved from a stance where we believed in 'good' prediction to a state of affairs where prediction is now 'difficult'. The recent Coronavirus crisis, almost entirely unpredictable if not in the emergence of a new virus then in its global economic and social impact of historic proportions, has turned our view about prediction into the 'impossible'. It is no longer merely 'difficult' to predict. We might assume that we can still hedge our bets a little, but our idea that small events in the shorter term might be easier to predict than larger events in the longer term, is no longer tenable.

Many people from many walks of life have come to the conclusion that prediction is impossible. In fact, we are strongly conditioned to believe that science has certainty. Our early formal experiences of it are cast in highly artificial contexts, in the laboratory where one can experience theory which is highly controlled, or as thought experiments that rely on the certainty of mathematical analysis. Our early years tend to be dominated by this kind of certainty. Even the most clear thinking scientists recognise a paradox in that our theories must be tested through their predictions but we know they will never withstand all possible tests. It is hard to break from this view. Those who still believe in the magic of science, only do so because they have not been at the forefront of reflecting on their own predictions. An increasingly number echo the author Margaret Attwood (2020) when she says: 'We live in such unpredictable times that you'd have to be an idiot to try to predict definitively the outcomes of some of the chaos and strangeness that we see developing around us.' To an extent as social change speeds up and as information technologies are continually reinvented, there is a certain logic to what she says but in retrospect, this has probably been true for all time.

Increasingly science is used to inform policy through models and this is as clear as it can be in the reaction to the Coronavirus crisis. Modelling epidemics is not generally regarded as problematic and it is one of the few areas where the determinants of how an infectious disease spreads are quite well-defined, at least in the hindsight of our knowing how an epidemic proceeds. If there is a disease where there are no deaths but one where people become infected (I), then the disease will spread through a population according to the numbers of persons who are infected by an already infected person. This contact is called the Reproduction number. If, for example, this number is *2*, meaning that each infected person passes it on to *2* of those who are still susceptible (S), hence not immune, the numbers infected will progress from the first so-called person-zero to *2, 4, 8, 16* and so on. This is a progression measured by 2^t, where t is the time at which the next group of susceptibles is infected by the disease. If we have a population of, say, 66 million, which is the current UK population, and if the infection is passed on in the next time period – the next day, say, the total of 66 million population will be entirely infected over the next 26 days. This is a very rapid spread but as soon as somebody is infected, they will spend some time with the disease, possibly initially infecting others, and then eventually become immune. At this point, they will recover (R) and no longer be part of the infected population. Thus, as the infection increases exponentially first affecting those who are exposed (E), at some point as the first to be infected recover, this will slow the progression. Eventually after the number infected peaks, this number will decline to the point where all are recovered and the virus disappears from the population. The curve of exponential growth and then decline mirrors what would happen if there were no attempts to reduce those exposed by using social distancing or self-isolation. In short, this is a pure epidemic model where the disease disappears as the population heads towards what is called 'herd immunity'. Of course in this example, there are no deaths and thus no policies which try and mitigate these by keeping deaths as low as possible.

Many features however complicate this model. First the time spent by the person with the infection being infectious as well as the subsequent time to recover, hence acquire immunity, can change the parameters of this model dramatically. The death rate is also important and thus the severity of the disease is measured by the proportions of people who recover or not, by the speed of the recovery, and by the number of susceptibles at which an infected person passes the virus on to those who they contact, in this case the Reproduction number. All of these parameters can change as the infection progresses but in the last analysis, the model is fairly tractable and if the parameters from a past epidemic can be derived from data, it can

mirror exactly the behaviour that we observe. This of course is largely because we have no obvious way of avoiding an infection other than by changing our behaviour. There may, of course, be demographic issues which divide the population into different groups of susceptibles, mortalities, and infectives. As we begin to explore such epidemics in greater detail and in different environmental and social contexts, then the pure epidemic model becomes less and less tractable and subject to increasing error.

This then is the nature of using any model to make predictions about the future which have critical policy implications. No model can be tuned to replicate an epidemic before it has run its course. There are simply too many elements of the population that need to be taken account of and as in all social systems, much of the data may never be observable, even after the event. In the case of the current Coronavirus epidemic, it is clear that the virulence of the disease was much underestimated, at first in the West where there is much less experience and social control of such diseases. In the UK, there appeared to be some sort of acceptance that this epidemic would be more like an influenza outbreak with similar rates of recovery and death. But using parameters from various cases in China relating to the Reproduction number and the length of time when infected persons were asymptomatic, it appeared that any policy of unregulated diffusion of the disease would lead ultimately to herd immunity but with massive numbers of deaths. The model was then rerun with social distancing and self-isolation built in. This was shown to reduce the number of deaths very dramatically to the point where it might be possible to squeeze the virus out of the system, and to protect the health services until the point where some sort of vaccine could be invented and manufactured (Ferguson et al., 2020).

The problem however is that such models show such dramatic differences in terms of predicting numbers of deaths that we find it hard to weigh up the evidence. In some respects, this is true of all models in any context but in this situation, we might expect our confidence in the model results to be better than economic forecasting, traffic modelling and suchlike. However, when we stand back and reflect on what we know about science and modelling, we need to grapple with an essential dilemma. George Box, the eminent British statistician, said many times that: '. . . all models are wrong, but some are useful . . .' (Box and Draper, 1986). So if we know that our models will be wrong, then what do we do about them. In short, if our science does not lead to robust predictions, how do we continue to deal with such widespread unpredictability?

The answer to this dilemma must relate to what models we use, how we use their predictions, and indeed how robust they are to a manipulation of their parameters. In essence, as all models are wrong but some are useful, we need to employ several models, not simply one. In the UK example of dealing with the virus, it is not at all clear whether more than one model was used or whether or not this was subsumed under the umbrella of using the same model under different assumptions and different parameter regimes. It is not at all clear as to how sensitive is the predicted number of deaths under different scenarios. What we have to go on are predictions made with this particular model in different situations in the past and the results are not good. For example, notwithstanding the fact that the model has been developed over a 20 year period, it has been applied to several previous epidemics where very precise predictions of the consequent deaths have been made. Ferguson's team have explored many different epidemics using their SEIR model from Foot and Mouth disease in 2001 to Mad Cow disease in 2002, Bird Flu in 2005 to Swine Flu in 2009, and then to Ebola, MERS and Zika. The predicted numbers of deaths amongst human population for these epidemics were in the tens and hundreds of thousands but when the actual numbers who die were counted, these were a very tiny fraction of the individuals involved, in fact, in the tens and hundreds. Ferguson and his

team recognise this variability and comment 'We're building simplified representations of reality. Models are not crystal balls,' (Adam, 2020). But this implies that we need many models, not one. This follows directly from the fact that our science is not necessarily robust but the way we use it should be. In some domains, such as economic modelling, weather forecasting, and climate change, such alternative modelling strategies have been recognised and developed for a number of years. In fact, counter-modelling and multi-modelling were suggested for evaluating public policies many years ago by Greenberger et al. (1976). Modelling infectious diseases clearly needs to be underpinned by similar approaches.

Many approaches to grappling with unpredictability in science do not have the resources to develop several different approaches to the same problem but in the case of disease transmission, and the policies that have been tested using the model, there has been another difficulty – the separation of 'the science' from 'the policy'. What has emerged is a strange dependence of the policy-makers on the scientists with the scientists articulating the fact that their advice is 'neutral' when it comes to policy. Much of policy seems to depend on the science but there is no recognition that this science might be flawed, is inevitably flawed, of course, if the arguments in this editorial are taken to heart. Because the policy of locking down a whole society to squeeze out the infection is so controversial, then the idea of throwing everything on the 'science' appears somewhat perverse. This whole approach is not scientific in the context of the physical and natural sciences for it rests on much more controversial perspectives related to behaviour. In fact, although this epidemic is intrinsically physical at the level of how the virus attacks the body, everything else around its transmission is manifestly environmental, social and economic and the notion of how self-isolation and social distancing affect transmission is very largely a behavioural issue. Epidemic models do not have appropriate and well-tested mechanisms to deal with such non-pharmaceutical interventions.

In these editorials, I have introduced these broader questions of prediction and predictability several times as our interest and knowledge about them have changed. We now accept that cities are inherently unpredictable in that we are unable to predict how individuals with high degrees of freedom will behave under very different conditions. We may be able to discern aggregate patterns that are generalisable and offer some possibilities for good prediction but for the most part, this is difficult and controversial. The problem with cities is that we continually invent and reinvent them thereby changing the conditions in which they operate. In terms of epidemic modelling, then the nature of how an epidemic evolves with respect to the basic epidemiology is a good deal more stable than systems that are formed by interacting ill-defined economic and social activities and individuals. Once this is put in the context of everything else that is happening in the city or society, then our understanding of an epidemic is equally confounding. As I argued in a previous editorial (Batty, 2020), the rapid emergence of an epidemic which was largely unanticipated is an example of something that we will never be able to predict, notwithstanding that we might prepare for it (Batty, 2010). It is not quite a 'Black Swan' in that we have seen them before (Taleb, 2007) but they are inherently unpredictable in any temporal context. They are predictable in the small in terms of virus transmission but hugely unpredictable in the large in the way we respond to them. As in the case of many systems, when we narrow or broaden the system and its environment, its degree of unpredictability changes.

The dynamics of change in cities exists on all scales and it has long been assumed – almost as a rite of passage – that the short term is easier to predict than the long term, largely because the short term is nearer in time to what we know in the past and the present whereas the long term is in a distant future. We know that there is likely to be more substantial change in the long term future but as we learn more about how cities change, the short term

future appears as equally volatile and difficult to predict as the long term. In this sense, there is little difference in the impact of change other than in the kind of change that occurs over different time periods. The degree of change is not a function of the time over which such change takes place. In the last half century, our focus on change has moved from the idea that systems such as cities appear to embrace it slowly and smoothly to one which is quite the opposite: that change is always volatile, never smooth and that we have to tear back the illusion that change is absorbed easily with little disruption in cities. This is rarely the case for change is masked by the inertia of the social and physical structures that we build and evolve that give the appearance of longevity. In fact these are under continual scrutiny as we attempt to adapt what we have built in the past to the demands of the contemporary present and of course to the norms and aspirations that we have for both the near and far future.

Layered on top of all of this is the notion that we have raised often in these editorials, that cities are becoming more complex as they evolve and as human populations acquire ever more technologies that continually provide them with new sets of opportunities. In this sense, nothing is predictable. The recent pandemic is likely to force us into new ways of dealing with the physical space of cities in terms of the way we connect with one another – social distancing and self-isolation may well turn into principles of spatial distancing that change the way we think of moving and locating in cities, to cities with lower densities where the local and the global mesh in ways that we have yet to invent. We may well ask the question as to why such changes have not been incorporated into cities already for plagues and pandemics are not new. But the fact they have not is simply a recognition that the world has changed, has become more complex, that our values have changed and will continue to do so. Unpredictability is now the norm. Many have said this before but we need to embrace it in ways that makes us deal with the future rather differently from the way we have dealt with it in the past. It was Arthur C Clarke (1982) who in his novel *2010: Odyssey Two* said all human plans are '... subject to ruthless revision by Nature, or Fate, or whatever one preferred to call the powers behind the Universe ...', a mantra for our time.

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