Chapter 6
Creative Destruction, Long Waves and the Age of the Smart City

Michael Batty

6.1 Introduction

One of Peter Hall's main themes in his research was the impact of technology on cities and regions. Although his early work was largely about the form and function of cities, particularly world cities, and how the planning system in Britain and America was changing the shape of cities, his first visits to the Far East energised his interest in the way cities were crucibles of creativity and innovation. From this, his interest in how long waves of technological innovation since the onset of the industrial revolution have impacted on cities led to an exploration of the geography of Kondratieff cycles and with this, the way in which new technologies destroy the old in the manner first articulated by Joseph Schumpeter. This essay reviews these ideas and Peter's contribution to them but also speculates that the Sixth Kondratieff wave which has just begun will be a culmination of the previous ones in that new information technologies will lead to massively decentralised devices implanted in ourselves and in our cities. In terms of our interest here, the Sixth Kondratieff will be the Age of the Smart City, something that Peter Hall was directing us towards.

Peter, to my knowledge, never wrote about smart cities per se although he was clearly aware of the rise of the movement that had become quite distinct and popular by the time he passed on in 2014. But what he did pursue as a major theme in his research throughout his academic life was the impact of technological change on cities that in many senses was one of his major preoccupations in charting the evolution of cities and the changing face of planning from his first writings in the 1960s. In his autobiographical essay (Hall 2015), he acknowledges several origins of this interest. From his schoolboy days, the library at his secondary school in Blackpool, England, contained Schumpeter's (1939) massive work on *Business Cycles* and his appreciation of the works of the early 20th century economic theorists

Michael Batty, Professor, University College London, UK, Bartlett Professor of Planning. m.batty@ucl.ac.uk

R.D. Knowles and C. Rozenblat (eds.), *Sir Peter Hall: Pioneer in Regional Planning, Transport and Urban Geography*, SpringerBriefs on Pioneers in Science and Practice 52, DOI 10.1007/978-3-319-28056-1_6

such as Keynes gave him a deep understanding of the importance of innovation and technological change on contemporary as well as past societies. These ideas remained, however, quite dormant in his research and writings in the 1960s and early 1970s but they positively exploded on his first visit to the Far East—Hong Kong—in the mid 1970s.

He was amazed by the dynamism of these new Tiger economies that had suddenly sprouted up, overnight almost, and were in clear evidence by the late 1960s. No one had ever thought that British colonies such as Hong Kong and the newly independent Singapore would become incubators for the world's high tech, financial services and automated manufacturing that they subsequently have become and no one ever thought that the new global economy would be fashioned, not around America, but around China. Japan was 'number one' in those days (Vogel 1979) but this was predicated on their attention to detail, and their continual scrutiny of quality at every level of their products. Japan was still a closed society in many ways and their specialisms in manufacturing were very focussed, with many areas of their economy rather backwards in terms of automated practices and business ethics.

Perhaps the best way to communicate Peter Hall's surprise at what he saw in Hong Kong is to quote him from his essay (Hall 2015) where he says: "I was totally mesmerised by the energy, the power, the achievement of the place. Most surprising for me was the achievement: expecting a third world sort of country, I found a city that in many ways was more advanced than London. And Singapore, to which I paid a flying visit, was even more impressive: it was a kind of 1960s planners' dream, a British city that never was." He continues a little later in that essay to say: "Reflecting for days and weeks after that first trip, I came to an insight that later I found reflected in the writings of Schumpeter: that the reason these societies were so successful was that they gave scope for enterprise, that is for innovation, …".

To an extent, Peter Hall's contribution to this debate is clustered around his writings about high tech and cities, particularly in Europe and North America. He did not write or research much about the Far East for one of his long term quests was to make sense of the changing economic geography of cities, particularly in Europe and the west in general. But the series of books that he wrote between 1980 and the mid-1990s reflected this interest in growth, technology, and communications that were based on ideas about innovation and creative pursuits in cities. His contributions followed three subthemes in this wider domain: books relating to growth poles which in some senses were the drivers of urban change such as *Growth Centres in the European Urban System* (Hall/Hay 1980), and those relating to high tech concentrations, science parks and science cities such as *High Tech America: The What, How, Where and Why of the Sunrise Industries* (Markusen et al. 1986) and the comparator volume in the UK called *Western Sunrise: Genesis and Growth of Britain's High Tech Corridor* (Hall et al. 1987), edited books in the series on urban form and technological change such as *Cities of the 21st Century: New Technologies and Spatial Systems* (Brotchie et al. 1992), and last but by no means least his writings on the wider theory of technological change relating to how cities evolve as reflected in his book *The Carrier Wave: New Information*

Technology and the Geography of Innovation, 1846–2003 (Hall/Preston 1988). In fact a late entrant to this grouping which did include the Far East, was his book *Technopoles of the World: The Making of 21st-Century Industrial Complexes* (Castells/Hall 1994) which went well beyond science parks, written with Manual Castells at the end of their Berkeley days. We will reflect on these writings in our appreciation which follows but before we do so, let us outline the theories associated with Schumpeter which so fascinated Hall and which drove his interest in this area particularly in the 1980s but more generally throughout his intellectual lifetime, studying and speculating on the future of cities.

6.2 Long Waves in the Urban Economy

The idea that history is cyclical betrays a highly deterministic view of evolution that is not much in accord with the empirical evidence, apart from the fact that cycles do exist although perhaps not in so simplistic a form. Nested economic cycles with different periods and amplitudes can be clearly discerned and can be measured fairly unambiguously using various economic indices but whether or not they form any long-term pattern is arguable. However business cycles can be disaggregated and focussed on cities and regions as much as they can on national and international economies. Building booms and busts, for example, which characterise the growth of all cities, provide excellent examples of one of these cycles and the question that Hall asked himself was whether or not the structure of cities and the growth of the an urban economic milieu was reflected in such cycles, particularly those which related to technology. It was Schumpeter (1939), however, who had picked up on long cycles that reflected changes in technology. He popularised the work of Nikolai Kondratieff, a Soviet economist who had argued in a series of publications in the early 20th century which were collected in his book *The Major Economic Cycles* (Kondratieff 1925, 1984), that there appeared to be long waves or super cycles of approximately 50 years in length which mirrored the rise and fall of new technologies, with the particular notion that one cycle led to another; in other words, that once a cycle had worked its way through from its inception to application (in the case of major technologies), another would begin on the tail end of the previous one. The Politburo however did not like this notion because it suggested that capitalism would always adapt and transform itself away from any long term collapse, Consequently Kondratieff who was quite high profile in the Soviet government service, was quickly dispatched to the Gulag where he died in 1938 but not before his work had been translated and picked up in the west, first by Schumpeter.

Kondratieff's and Schumpeter's discussion of long waves was put into perspective by Kuznets (1953) who massaged these ideas into a fourfold temporal structure. Each wave that began when the technology entered the market place, was a period of intense *innovation* and growth. The wave then entered a second phase called *recession* (but not our current usage of the term, more like a drawing-in of the previous boom); this was actually a kind of consolidation of the impact of the

technology. This then turned through stagflation into *depression*, which finally bottomed out into a fourth phase of *revival* or recovery. Various terminologies have been used to define this four-fold structure and the terminology remains somewhat obscure. But essentially these waves were not only technological but primarily of wider import in that they describe the economy as passing through inflation and growth, stagflation, deflation-depression, and then improvement only for the cycle to begin again. In fact Mensch (1975, 1979) mapped the diffusion of technologies that follow the usual logistic curve in the way they grow and penetrate the market onto these long waves, thus providing a somewhat richer and more complete portrayal of these theories of innovation.

There are many other cycles that differ from these long waves as well as from the standard business cycle. Rostow (1960) in his book *The Stages of Economic Growth* proposed that shorter waves were subsumed within a series of much longer waves that mirrored the way industrial society emerged through traditional pre-modern, then an era where conditions for technological take-off were set, then leading to the take-off itself which leads to mass consumption (and production). In fact Rostow's model is now quite dated although the notion of these stages occurring as much longer waves is attractive and possible relevant to the development of post-industrial society. Inside these stages can fit Kondratieff cycles while other forms of urban evolution in terms of the morphological structure of cities and regions such as that due to Vance (1990) are also consistent with the waves.

A casual interpretation of Kondratieff waves (K-waves), which is also one that is widely held, is that we are now at the end of the Fifth Kondratieff. With a period of about 50 years, this interpretation suggests the first one began around 1800, perhaps a little before and encapsulated the age of steam with cotton manufacture being the major technological improvement. The second wave began between 1830 and 1850 lasting to 1880, which was the age of railways and steel, while the third wave from 1880 to 1940 was the age of electricity and the automobile. The fourth Kondratieff, which started at the end of World War 2, was the age of information technology and the computer while the fifth wave which in started with the invention of the PC (personal computer) and networking in the late 1970s is the age of the internet and widespread application of information technologies about the person. The sixth wave which some argue is about to begin, might be termed the age of the smart city although I have never heard anyone describe it as such. Undoubtedly the technologies involved are those of the computer and communications but in many senses, this is a new wireless age where computers are able to communicate with each other through any one at any time in any place. What we call it, of course, will only make sense when we see this period of social history in hindsight.

Peter Hall himself first wrote about the Fifth Kondratieff in his frequently published commentaries in the weekly magazine *New Society* in 1981 and 1983. In fact you have to remember that the transistor invented in 1948 at Bell Labs, the integrated circuit in 1959 at Intel and Texas Instruments and the microprocessor or computer on a chip in 1971 at Intel, had only just led to the development of the personal computer and it was very unclear at the time as to the extent to which the

computer as a universal machine would come to dominate the world as it has done. Although Peter Hall like several before him defined the Fifth Kondratieff in terms of information technologies, the sheer scale of what has happened in the last 40 or more years was barely anticipated, although by then he was living in San Francisco and must have known of the Home Brew Computer Club and all else that was happening in the Valley. His two articles in the magazine focussed our collective interest not on Kondratieff waves per se but on their geography. In his autobiographical essay, Peter Hall says of his emerging and burning interest in innovation in cities and Schumpeter's contribution:

> The result was an article in *New Society,* The Geography of the Fifth Kondratieff Cycle published in 1981 and a short piece on the 100th anniversary of Schumpeter's birth, which came out in 1983. I suppose that just as parents secretly have favourite children, so authors have favourite works: these two articles, in particular the second, are my own personal favourites. I think that in the three pages that Paul Barker[1] allowed me, I said a lot about what anyone needs to know about the career and work of this extraordinarily exotic and brilliant man, … (Hall 2015: 17)

Every interpretation of Kondratieff long wave theory suggests a slightly different timing and focus of each of the five waves defined since the industrial revolution began. Indeed there are those who consider that these waves go back before the turn of the 19th century, indeed back to the Renaissance and medieval times. Indeed one suspects that one might be able to find evidence of such cycles in the classical era, in China and elsewhere although any data disappears into the mists of time. A recent and much more up to date interpretation of the Sixth Wave has been developed by Naumer et al. (2010). To do this, they define the previous five waves more generically as temporal intervals from 1780–1830 as the era of machine manufacture of clothing, 1830–1880 as the era of mass transportation, 1880–1930 as mass production, 1930–1970 as the time of individual mobility, and from 1970 to 2010 as the era of information and communications technology. Already the waves are out of synch with previous interpretations, such is the ambiguity of this kind of chartism. Kondratieff's waves are often shown as an idealised time series of related waves and Naumer et al. (2010) produce a rather a good and evocative diagram of our current understanding that we reproduce as Fig. 6.1.

The sixth period, which we have just entered, is focused on miniaturization of information and biochemical technologies, which are being used in social and medical applications in the context of institutional change, which will deal with aging, climate change and newly polarized economic structures. In some senses, I would depart from this by suggesting that the internet is increasingly dominant in this sixth wave where devices are disseminated and implanted in virtual everything that we have a concern about including ourselves and that the era of medical advance will really come into its own in the seventh Kondratieff which will probably occur somewhat faster than those in the past. In this sense, the periodicity of the cycles or waves is shortening and eventually they may collapse into each

[1]The Editor of *New Society*.

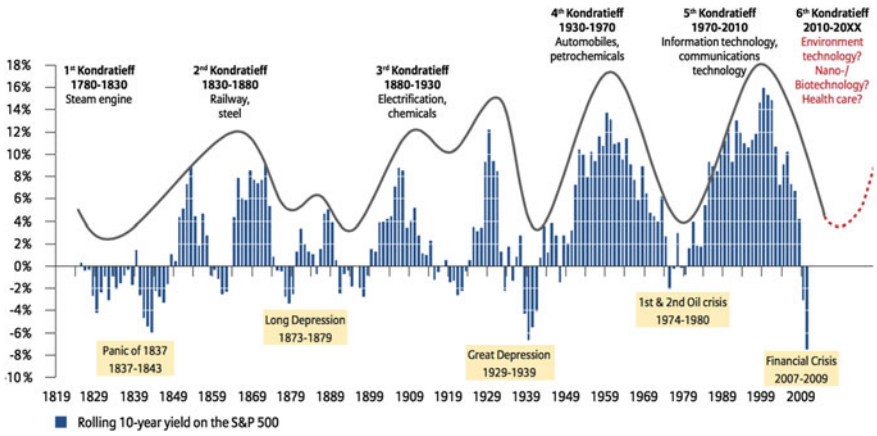

Fig. 6.1 An Interpretation of Kondratieff Waves from Naumer et al. (2010). *Source* Datastream and Allianz Global Investors Capital Market Analysis 2010

other, creating a singularity that is frankly beyond our understanding (Kurzweil 2005). But this is an area we will avoid as it remains in the realms of speculation, no matter however fascinating. Peter never wrote about this and I do not know if he was aware of its import in terms of futurologies, yet it is closely related to ideas about long waves.

There are several features of Kondratieff waves but four main characteristics stand out. Once a technology is developed, it is exploited remorselessly and eventually it peaks, ultimately dying of exhaustion or at least being incorporated into the conventional wisdom and practice of the economy of that time. Human ingenuity as it is however usually advances by beginning to exploit a new technology which is often contained in the genes of the old—just as new scientific theories and paradigms emerge from the limits of that which is pre-existing. The cycle is often dominated in its early stages by an excess of finance capital which again tends to peak as the technology matures usually leading to the third feature which is a severe recession/depression[2] which precedes the upswing in which a new technology is invented and established. During this period, considerable social and institutional transformations can take place as new technologies usually require new organisational structures.

In terms of the fifth and latest Kondratieff for which we might have a complete record and which many agree began around 1970 with the invention of the microprocessor and ended with the invention of the internet, the rapid growth and dissemination of personal computers and networking has dominated the upswing which has also led to the development of the internet in the later growth period. This was widely established in the late 1990s and this led first to the dot.com boom

[2]Enormous confusion reigns about these two words especially in Long Wave Theory. Essentially my own interpretation is that they are loose equivalents of one another.

and bust, equivalent to the period of recession (in the old language of the Kondratieff) and stagflation. In fact this was followed by the great recession which, in Kondratieff terms, is depression from which the world is slowly emerging on a new upswing with very different new technologies in personal lifestyles such as smart phones and apps and early innovations in medical technologies, AI, self-driving cars and so on. This is the food for the sixth Kondratieff that I argue here is the smart city. Or at least some part of this wave is composed of the smart city which is the development of large-scale, all pervasive and invasive computing in personal, public, and private domains and spaces.

Before we conclude this section on the approach to innovation and creativity in technologies that are reflected in cities, we need to examine in a little more detail the way we create, transform and then destroy technologies that are most clearly reflected in the built environment. Schumpeter (1939) argued that not only do long waves start with the creation of new technologies, the very act of creation contains within it the seeds of destruction of the technologies that are replaced or displaced or both. Some technologies, of course, simply become part of the background and are absorbed quickly and often painlessly although their value tends to fall. New technologies sometimes compete directly with old and the process of transformation from old to new depends on strong and fierce, often bitter competition that results in the old being destroyed often with much value within them remaining. Asset stripping is the popular phrase used in mergers and acquisitions. This is particularly true in terms of capital from whichever more value might be extracted even though it contains much intrinsic value in its current form. The best examples tend to be in areas where old technologies become automated and the amount of labour drops dramatically, as processes are computerised: iron and steel, car manufacture and such like are classic examples. These industries do not disappear but simply become leaner, smaller and more competitive, and provide space in the labour market for new technologies to thrive. So the process of destruction is always paralleled or coordinated with processes of creation.

In cities in their built environments, this is even clearer. For example the city of London—the financial quarter—has been rebuilt at least three times since the second world war in times of boom shorter than the Kondratieff for much of this has happened within the fifth wave. It is possible to see perfectly serviceable buildings being pulled down and replaced by ones which embody higher tech but also exploit densities more intensively and thus add value to the stock, reflecting the rapid changes in land values as population continues to rise and place pressure on these most accessible and attractive locations (Batty 2007). In some senses, these changes reflect changing technologies and can be locked onto the long waves that reflect technological change at a macro level. But there are many elaborations of technology that take place on much more rapid cycles and we will note these a little later for they do cast some doubt on the length of the most significant waves in the economy. However it is in the genesis of creation and destruction that lies at the heart of these long waves. Schumpeter himself drew his inspiration from Marx who argued that capitalism is so essentially competitive that new entrants wage war on those who control the current means of production and their competitive instinct is

to destroy the old in the creation of the new. In short, those with new ideas always seek to displace and destroy the conventional or received wisdom. This in fact is a truism across society in the construction of knowledge as well as human institutions. It was Max Plank who said that a new generation of science is born only when the old dies out for the old will never accept the new.[3] Old paradigms remain until those who identify with them move on.

There is one last qualification we must make about long waves. There is considerable ambiguity about the beginning and end of each of the waves in modern industrial society, which began in the late 18th century. Technologies can be easily identified in their innovation and development, but how these map onto the business cycle is harder to determine. Schumpeter (1939), like many after him, had a go at this, defining three or more cycles which nested into each other with different periodicities but when we come to look at new information technologies the picture is much less clear. Since the inception of miniaturisation of electronic circuitry that began with the discovery of the transistor in 1948, the rate at which memory and speed has increased has followed the remorseless curve called Moore's (1965) Law.[4] Every 18 months or so, memory and speed double while the cost of such fabrication reduces by half and this has gone on since 1948, which is now somewhat longer than the fifth Kondratieff. Despite the dot.com boom and the great recession, all of which are consistent with the fifth Kondratieff cycle, the power of IT has increased regardless and it shows no sign of stopping. It could be argued too that the emergence of the web and now of highly decentralised devices and apps which are intrinsic to the idea of the smart city, defy the Kondratieff and are not affected by the cycle of creation and destruction which is more of a continuous force rather than a cyclic wave. We will follow these ideas more explicitly below but first we will return to Peter Hall's application of the Kondratieff to geography and to cities.

6.3 The Creative City: Crucibles of Innovation and Incubation

Creativity and innovation go hand in hand in contemporary societies and in the last 30 years, cities have begun to be defined by their ability to foster such creativity and innovation. One of the greatest proponents of this view was Jacobs (1961) who in her seminal work—which was superficially a denunciation of the top-down US planning system which she argued was destroying the American city—explained

[3]Strictly he said: "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather its opponents eventually die, and a new generation grows up that is familiar with it" (Planck 1950, *Scientific Autobiography and Other Papers*, London, Williams and Norgate, p. 33).

[4]See at: http://spectrum.ieee.org/semiconductors/processors/the-multiple-lives-of-moores-law.

that cities brought together and focussed incredible diversity of talent. It was this variety that led to much greater innovation and creativity than could be assumed to take place in lower density, more rural and possibly poorer agrarian settings, and thus she argued that the quality of life was considerably richer in cities than outside of them. A modern rendition of Jacobs' argument has recently been presented by Glaeser (2012) who takes the argument further implying that the larger the city, the greater the diversity and the better the quality of life for its inhabitants.

Like all polemics, there is a grain of truth in this but there is also considerable disquiet in its argument. Bettencourt et al. (2007) drawing inspiration from Marshall and his definition of agglomeration economies, present evidence that the bigger the city, the greater the *per capita* wealth but so too is the greater the inequality within their urban populations and it is entirely possible that the extreme wealth associated with a very small number of persons dominates the much lesser wealth associated with a much larger number of poor people. In short, the picture concerning big cities and their agglomeration economies and diseconomies is quite confused but what does seem to be clear is that the number of creative activities grows more than proportionately as cities get bigger, especially in employment which can be measured in terms of their productivity by patents, in entertainment and highly creative pursuits in the arts, indeed in any occupation or activity that depends on highly creative talent.

Creativity is an intensely personal act and if cities represent the crucibles of invention and innovation, they are essentially mechanisms for bringing people together from which sparks will fly. It is density and connectivity then that raises the stakes in cities and it was this that Peter Hall first saw in Hong Kong in 1975. Cities are built from the bottom up and in the last 30 years, this has been widely articulated as part of complexity theory (Batty 2005). In fact economic cycles are clearly determined from bottom up action as there is no central control guiding the economy to produce such waves. Such waves are the product of an invisible hand—the product of individual creative and competitive actions that generate optimism and pessimism in the economy, and the fact that there are upswings and downswings is entirely consistent with the notion that new inventions are spurred on by positive feedback between those working on them while when the technology matures, the market adapts to their presence, assimilates them and their early promise becomes widely accepted with the initial enthusiasm and added value wearing off. This sets off recession and thence depression as things overshoot and the early promise disappears. This of course drives individual inventors and entrepreneurs to try to renew their technological edge and the search for new technologies and new markets starts the cycle over again. Positive feedbacks kick in at every stage.

Peter Hall's most significant book on the Kondratieff written in 1988 with Paschal Preston is called *The Carrier Wave* (Hall/Preston 1988) and is really a history of 'New Information Technology and the Geography of Innovation, 1846–2003' which is the subtitle of this work. In fact, his book is not really focussed on cities and regions but more on the forces of information technology from the telegraph to the personal computer that have driven the third, fourth and fifth Kondratieffs. In one

sense, Peter needed to write this book before his last significant text on these new technologies, namely his *Technopoles of the World* (Castells/Hall 1994), which does in fact focus on the geography of where such technology is produced or rather invented. What Peter's work on the Kondratieff really shows is something that others have not really focussed upon: the waves can be quite uneven geographically and this of course blurs their temporal coincidence. Hall and Preston argue that by the end of the third Kondratieff, Britain as an industrial nation was lagging in comparison to its economic counterparts. This is a hard argument to demonstrate unequivocally for the radio, TV, and then the digital computer were much in evidence in terms of British inventions during the fourth Kondratieff. Yet during the fifth, the British economy lost whatever advantage it had in new information technologies. What other nation could invent one of the world's first digital computers *The Colossus* to crack the German U-boat codes only for the ten that were on order for Bletchley Park to be broken up for scrap at the end of the Second World War before they had been delivered to the code breakers. Turing's message that such machines were universal—that they could be used to do anything that could be reduced to binary digital code and most things can—has taken a long time to take sink in. This more than anything else defined the fact that the fifth Kondratieff would barely happen in Britain as its economy headed downwards to de-industrialisation although the sixth wave shows every sign of restoring the balance.

A geography of innovation of a kind was produced by Castells/Hall (1994) that in some respects is the obvious complement to *The Carrier Wave*. This is not really a geography of how new information technology is being used as it develops during the fourth and fifth Kondratieffs but a geography of the places where new information technologies are produced—or rather invented and then produced which are often in different locations. They argue that the focal points where new IT has been invented have been in planned rather than spontaneously evolving locations but I doubt this very much and find it a strange argument. In fact, where these new technologies are produced is not in the core or inner areas of cities where earlier technologies were located. Indeed new industrial zones have been created, the classic example being in Silicon Valley, which has evolved from the bottom up, a product of massive path dependence due to a succession of historical accidents accompanied by positive feedbacks that have built many of the world's most prominent computer companies. Some nations have identified science parks and subsidised these while others have identified entire science cities but once begun perhaps with some seed funding a little like new towns and garden cities before, these initiatives have become self-sustaining. In fact what constitutes planned and what constitutes organically evolving spatial structures can be quite blurred as most development is a combination of both, neither entirely bottom up or top down.

There is nothing very specific about the locations where the most innovative ideas are produced. In fact the most basic of ideas tend to be produced almost randomly in space and time. Clusters of innovations do tend to occur in high density situations in and around the core of large cities but these tend to cluster around universities too which tend to be quite central in their location. Innovative

ideas are also generated in suburban locations, in the sprawl as well as in these dense clusters and regionally such locations tend to depend more on the general economic milieu than on specific fine scale locations per se. So for example most new IT has been produced in the south of Britain or in its biggest cities and universities, and the same is true in the United States. Insofar as these patterns are not borne out, then it is historical accidents that are the determining factors.

Peter Hall never really discussed how we use information technologies in working and living in cities and to an extent the smart cities movement is much more concerned with these kinds of issue. It matters little where such technologies are produced but how they are used and how they change our behaviour and in terms of the way cities are organised and develop, this is all-important. In Peter's quest to explain technologies and their role in structuring and enhancing the quality of life in cities, his focus was mainly on how such technologies inform and enhance the economic quality of life in cities. In fact, technologies also divide the population and some of the wider issues concerned with populations which are segregated into information rich or poor, relate to how cities are structured spatially. Peter's work is mainly on the supply of technology, on its production not on the demand for technology and they way it is used.

What I will do in the rest of this chapter is speculate a little about how I think Peter Hall might have reacted to the smart cities movement had he lived longer. I think that the movement is so profound and deep-seated, in many senses so misguided and so all embracing, that he would have begun to react and comment on its importance and impact. In one sense, he had already begun to embrace its effects in his focus on communications technologies. Reades (2016) in this volume explored many of these questions in his doctoral thesis and he was one of Peter's last students who stood astride the divide between substantive issues of technology in cities and the way those same technologies are used by ourselves to understand cities. In his chapter here, Reades articulates Peter's key approach to cities and technology when he says: "Peter did not, I think, have a lot of time for purely econometric reasoning; it was relevant principally insomuch as businesspeople and planners thought it was when taking decisions" (see Hall 1962: 169). It was, in other words, generally better to look to history for both the bigger trends and recurring patterns, as well as for the details. So history as recounted here in terms of the Kondratieff is the key and the more pragmatic usage of technology with respect to the way it alters human behaviour which is what big data and the smart city is all about is something that Peter would only have commented on when much more evidence of its meaning had become available. Just as he commented on the British planning system in his volumes on *The Containment of Urban England* (Hall et al. 1973) from a historical perspective, he would have begun the same on the smart cities movement in the near future. The fact that he did not live long enough to be able to do this, gives me a chance to make my interpretations of what he might have said with respect to the current development and applications of this technology which define what many speculate is the sixth Kondratieff.

6.4 The Sixth Kondratieff: The Age of the Smart City

In fact, Peter did talk a little about smart cities in a more popular way, although this can hardly be called research. He was well aware that computers were continually entering all facets of daily life and in this sense automating the city beyond anything that had been speculated upon in the 20th century—beyond Fordism, beyond automation (which is now a somewhat dated term pertaining to the industrial era), beyond mass production, even beyond niche manufacturing. He saw this particularly in new forms of behaviour pertaining to transport which in some senses is the heartland of the smart cities movement. In his popular journalism, he referred extensively to such technologies talking about how families of the near future will juggle travel and job locations using smart phones which are programmed to keep them on track, literally as well as metaphorically (Hall 2010). To an extent what Hall and others perceived is that these kinds of technology are really part of a seamless array of technologies that we as planners and geographers need to consider in a more integrated way than we have in the past: thinking not only about the production and consumption of technologies but how we use them to understand that same production and consumption.

It is worth emphasising this point. Peter's work on technology was very much in the spirit of economic and industrial geography, the geography of why, where and how different technologies were located with respect to their production. In this sense his work is in the tradition of location theory, which tended to deal with production and supply rather than consumption and demand. This latter focus on consumption and demand is more evident in analysis of the information economy with respect to the way we as individuals are using new technologies. As in any study of the geography and structure of the economy, there is an asymmetry between the way we study production and consumption, demand and supply with these two foci being poles of study that define our knowledge of how new technologies are invented, disseminated and consumed.

In terms of cities, there are two other dimensions that pertain to technology. In fact new information technologies first made their appearance not in the study of automation in cities or in the geography of automated products but in the use of computers for planning cities. In fact, my own work is very much in this domain and only touches on the notion of the geography of production insofar as our models reach out to include such geography in the models that we are using to simulate such form and function. While this dimension has been progressing with ever more sophisticated, ever faster models, with better and better visualisations, computer technologies are now finally being embedded into the fabric of cities. Computers began in the scientific lab, moved quickly to organisations in the 1950s for transactions processing, hit the personal and entertainment market in the 1980s, while all the time being networked in terms of remote processing and storage. Now computers have begun to be embedded into the public domain and that is where we see the advances in transportation technologies and the demand for them so cogently described by Peter Hall in 2010 in his thinking about the near future.

This is essentially our third domain with respect to geography and planning—the smart city which essentially is this embedding of computation and communications into the city so that it might be made more efficient and possibly more equitable although this is hardly guaranteed. In terms of its definition and scope, the smart city also includes questions about urban data—big data—and it extends to analytics, which at a push might include urban models of the kind that pertain to forecasting and impact analysis. The key dilemma that my own field is facing is the extent to which time frames are changing in terms of our understanding of the city due to a focus in the smart city on more routine, real time change—not a bad thing and long overdue—but something that is taxing our abilities to explain and simulate. There are also strange inversions about how we can use our technologies to study the same technologies we are trying to explain and thus in how they are changing the system of interest, the city. This new technological milieu in cities, their planning and their geography is now the focus.

The main feature that is changing our world and the world of cities that Peter wrote about is the fact that cities are becoming more complex as they evolve. In short, the subject of our interest is forever shifting and this means we have to run to stand still. This of course is social change but there is little doubt that material wealth as well as new communications technologies is massively broadening our personal and collective horizons and this is making cities harder to understand, more heterogeneous, with more complicated order and pattern as well as a multiplicity of new ways of production and consumption. The smart city is just one manifestation of this increasing complexity. What new information technologies are doing is that when embedded into the public domain—in transport, energy, and related utilities as well as the ways we access them and control them—they are generating massive amounts of data about the functioning of the city which is the 'exhaust' of real time processing. The big data that comes as part of this exhaust is highly unstructured, some of it is noise but it is giving us a temporal perspective on the city that we have never had before. Peter did not have the opportunity to rely for any of his research on the big data that comes from such real time technologies but he was aware of what was possible and what he himself needed to make sense of the future form of cities.

To a large extent, Peter's focus on future cities was related to the creative cities, to cities which were being built around new media drawing on the work of a variety of ideas from those associated with Florida (2002) to Landry (2008). In fact since these ideas began, the entire world of cities has been revolutionised by social media mainly associated with smart phones where access to all of use (who have such devices) has produced new layers of complexity in the form of social networks, either directly as through media such as *Twitter* or through web site such as *Facebook*. Peter did not write anything about this kind of media as far as I know for we are all still getting to grips with its meaning with respect to how cities form and function. Vast new data sets are available in real time that tell us where and what we are engaging with using this media but our understanding of their meaning is extremely primitive. There are many open questions as to what such media means with respect to the organisation and planning of cities and we stand at a threshold

with respect to how the future city will embrace such new technologies. It is this as much as anything else that marks the beginning of a new Kondratieff, the Sixth, which we have penned as The Age of the Smart City.

In the lecture he gave to the Balzan Foundation (Hall 2005) where he received the prize for his book *Cities in Civilization* (Hall 1998), Peter Hall ends by saying that what he wants to do is to supplement and extend his work on urban polycentricity called POLYNET that had occupied him in his last decade (Hall/Pain 2006). He wished to compile and interpret much better and more complete data on information flows. He says: "There is a parallel research agenda, impelled by the one piece of the POLYNET research that proved a relative failure. This was the attempt directly to measure the flows of information between firms and between places in such polycentric regions, by measuring both business travel and telecommunication flows—telephone calls, email messages …. Since completion of the study, however, I have discovered a rich potential source: the geography of mobile telephone traffic" (Hall 2005). It was this that Reades (2016, this volume) worked on for his doctorate and indeed this propelled Peter towards smart city ideas for Jon worked with ourselves in CASA on these issues and now has taken up a part of Peter's research agenda. I think that in a way this might have drawn my own group back towards Peter as it was slowly doing and it is to my eternal regret that our busy lives in the last few years did not provide us with the opportunity to talk about the smart city, about social media, about new forms of network and networking and the future of the city more generally. All I can do in concluding this essay on Peter's contribution to the geography of technology and innovation is speculate on what might have been.

We did in fact write (only) one paper together (Batty et al. 1974) when the idea of fares-free public transport was much in evidence and we were working at Reading University. I cannot remember the wider context but it involved the West Midlands where this idea was very much in the air. It was David Starkie who brought us together. I developed the land use transport model which essentially reduced transport costs to zero for a simple public-private two mode model of Birmingham and we engaged in some predictive modelling, not a million miles away from what we are still doing with much more detailed data pertaining to fares on public transport systems in London using RFID data, big data from the Oyster card smart card data set that we have. Our 1974 paper was hardly in the tradition of the smart city for in those days even the idea of the PC was unknown and this was still the era of interacting with computers using a deck of punched cards. But if you look back to what we did, then you will find some ideas that relate technology to model building to new policies about public transport that anticipate the smart city and its analytics (Batty et al. 1974). Clearly Peter had thought hard and long about the implications of all this for many years.

One of the key features of the role of technology on and in cities involves the ever changing influence of distance and its translation into the costs incurred to moving in time and space. Once the fifth Kondratieff really hit the modern world by the 1990s with the widespread dissemination of the PC and the development of the internet, the prospect of the 'death of distance' as popularly articulated by

Cairncross (1997) and the rebirth of Toffler's (1970) electronic cottage where everyone worked from home began to tie all these approaches to the new technologies together. What has not happened is the explosion of the city into far-flung bits but the global networks that now tie everyone together in a myriad of ways have made the world infinitely more complex as we implied above. It is this that complicates the notion that the smart city will become a seamless set of interfaces between a multitude of information technologies. In fact we can no longer discuss the production of information technologies without recourse to examining global locations, nor can we explore the behaviour of people in large cities without looking at their global connections and the costs of their interacting with others at a distance. Physical travel is as costly as ever relative to income and job type but ethereal travel—which is a shorthand for the way we interact through information—email, Skype, the web, all kinds of social media/networking—confuses the geography of the future city dramatically. In fact to study cities in the future, we will need every one of these different approaches to technology that we have identified in this section. This is something that Peter Hall would have signed up to, of that there is little doubt, and this what makes his contributions through his many books and articles of enduring value.

6.5 The Technological Future

Several commentators have argued that the sixth Kondratieff is likely to be marked by rapid technological advances in the biosciences—in medical technologies that will be key to expanding our life limits, and curing long standing diseases. But this will be built on the back of new information technologies developed during the fifth and in this sense one might think of the smart city as being just another way of characterising this change. Biotechnologies and nanotechnologies will doubtless be key to these developments and so will social media but in principle, these developments have the power to change the entire nature of the Kondratieff itself. As we have implied the periodicity of the typical cycle itself may well be shortening but in one sense, the wave is so long that it embraces several shorter cycles and in one sense, we might simply abandon the notion of the long waves and focus on merged continuous shorter ones. But at the end of the day, there can be no disputing that fact that the industrial revolution itself divides into early and late and the post-industrial and the Kondratieffs coincide to a degree with these long historical periods.

One feature of this technological future is the changing structure of demand and supply. Much of our past understanding of the geography of technology pursued by Peter Hall was focused on production rather than consumption. Increasingly the technologies of the future will be individual rather than collective; health is clearly a case in point. Already education has increased dramatically in modern cities and now the geography of education is significant—this still tends to be concentrated but increasingly education and health will be decentralised and this has profound

implications for the smart city. To an extent, the geography of future cities which Peter Hall was so much involved in will be very different, much more decentralised and heterogeneous than the cities of the industrial past. Indeed it is worth concluding with his opening remarks in his address for his Balzan prize. When talking of the mysterious nature of life, he said: "I've spent my academic life asking "How do cities work?" and I don't think that I've yet cracked my mystery either". That is as maybe but for what he has done, we are all a lot wiser of about a path best followed and we owe him thanks for the directions to the future that he left us with.

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