THE DIGITAL NEXUS OF POST-AUTOMOBILITY

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'An international survey of moral values in 1983, conducted by Gallup International in sixteen countries, discovered that the worst crime a human being can commit is not genocide, matricide, loot, pillage or even rape, but the taking and driving away of somebody else's car without their permission. It was the only value universally shared amongst the countries surveyed' - Julian Pettifer and Nigel Turner, *Automania: Man and the Motor Car*

'The car provides us with a shield and a feeling of invulnerability, a shelter for all manner of activities. We pick our noses in traffic jams, but we assume that other people cannot see us. We wind down our windows and yell at people. We

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make obscene gestures and threaten total strangers, behaviour we would not normally have the courage to exhibit in other circumstances. We can do all this because we feel secure in our inviolable territory' - Peter Marsh and Peter Collett, *Driving Passion: The Psychology of the Car*

'The new inventions and devices have been frequently used to maintain, renew, and stabilize the structure of the old order…hence the continued design of automobiles in terms of superficial fashions' - Lewis Mumford, *Technics and Civilization*

'God set a limit to man's locomotive ambition in the construction of his body. Man immediately proceeded to discover means of over-riding the limit' - Mahatma Gandi

ABSTRACT

Rapid dynamic changes in several key areas are transforming the physical geography of global regions as well as their interrelations. In this Report we set out a list of processes that we consider pose significant influence upon future mobilities, lifestyles, and social relations. We identify these as global climate change; global security and the 'War on Terror'; digital technologies and pervasive computing; and the rise in complexity thinking. This Report demonstrates how their possible combination and synthesis could impact upon mobility trends within technologically developed regions, specifically upon automobilities. Taken individually they pose significant impact; taken together they have the momentum, power, and potential to create major shifts in how socio-technical mobilities are framed. By taking automobilities, and their transformation, as the focus we outline how we conceive a possible shift occurring that would take individualised automobility use from a *series* to a *nexus* system, particularly one framed within physical/digital networks. Principally we frame these dynamic systemic changes as shifting the car system from being *autonomous* to becoming post-car *automation.* This transition would take place within a parallel shift towards increased digitisation of physical movement whereby coded environments and software-sorting systems would frame such future mobilities.

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INTRODUCTION

Many social scientists have speculated about the future, developing various scenarios of future lives. These scenarios are generally based upon extrapolations of the present, seeing some particular feature in the present as the key to how people's lives will unfold within the next few decades. Yet these are far too often predictions that rely upon linear trends rather than sets of processes that impact upon each other as parts of developing systems. Thinking the future through a systemic lens raises various significant issues: what are the various systems and their interdependencies that bring about such futures, how effective can social science be in interpreting such futures, how to avoid thinking in terms of equilibria, and whether and to what degree social science ought to be normative about such alternative futures? We suggest here that resolving these issues in the contemporary moment is essential, environmentally, economically, governmentally, socially and intellectually. The social sciences have no 'choice' but to engage with various futures, to develop 'sociologies of the future'. This is partly because there are now various methods for developing visions of futures, especially through scenario building and backcasting, which social science should analyse, draw upon and contribute to. They are attempts to imagine various future social worlds and especially how different systems are adapting to each other and co-evolving.

But the main reason to engage with these issues is because one particular prediction of the future is becoming overwhelmingly significant in terms of its implications for economic, social and political futures of life on earth. This is the thesis of global climate change and the role that an array of 'social' systems and processes has played and will apparently play in such temperature increases into the future (Stern 2006). The 'social' is intrinsic to the analysis of rising carbon emissions and temperature increases, most notably in the transport system, and the private car in particular. Global climate change is moreover not a linear system but rather a set of complex systems involving positive feedback (Lovelock 2006). These systems involve the impacts and interactions with an array of systems, natural, social, and technological. Further, that many social, environmental, and technological systems are already vulnerable to perturbations and dynamic shocks. As Homer-Dixon notes 'I think the kind of crisis we might see would be a result of systems that are kind of stressed to the max already…The best theories of revolution and civil instability generally stress that societies face crisis when they're hit by multiple shocks simultaneously or they're affected by multiple stresses simultaneously' (2006: 1).

Human and natural systems are in states of dynamic tension and non-equilibrium. Such systems are entering periods of dynamic instability. Our approach here is not to consider isolated individual systems and their disruptions but to view how various systems reverberate against each other and the impact upon larger systemic changes. In other words, it is the simultaneity of converging shifts and stresses that may create significant changes:

> Because of the synergies in the highly integrated macrosystem, the convergence of systemic stresses and climate change may produce simultaneous nonlinearities across multiple systems that risk overloading the macrosystem as a whole, creating the possibility of catastrophic failure. (Gilman, Randall and Schwartz, 2007: 17)

Dynamic changes, when taken together, not only constitute a formidable set of variables but it is more than probable that when these changes begin to converge and cross-impact a shift, or re-configuring, in system relations will occur. Such a shift may be so sudden that the processes behind its conception go unnoticed, until the new set of interrelations and interdependencies are in place and re-constituted. In this Report the trends we research will generate significant influences upon how future mobilities, lifestyles, and relations are enacted. Taken alone these processes are significant, yet when interdependent their synthesis could generate radical new social infrastructures and physical-digital relations.

In this Report we specifically focus upon the 'system' of automobility. In particular, we frame automobility within a cluster of rapid dynamic changes in several key areas that are now transforming geo-physical relations, systems, and policies worldwide. Our central thesis is that these dynamic systemic changes may shift present car automobilities into a post-automobility system in a manner that will transform the car from *autonomous* to post-car *automation*.

In this Report the argument is set out in four chapters. Chapter One – **Global Systems & Vulnerabilities** – establishes the various influential processes and frames how they comprise dynamic and multiple shifts that may affect each other in a systemic manner. Chapter Two – **Auto-Assemblages** – examines the car system as a hybrid assemblage and outlines the principle processes that may produce a potentially new automobility assemblage, a post-car system. Chapter Three – **A Digital Nexus** – goes into more detail as to how we envision the 'car' assemblage shifting from a *series* to a *nexus*. This principally involves intelligent transport systems and related digital developments becoming embedded within networked infrastructures. Finally, Chapter Four – **Post-Automobilities** – engages with social implications and examines a range of social scenarios that may be necessary for a shift to a post-automobility 'system'.

Chapter 1: GLOBAL SYSTEMS & VULNERABILITIES

Personal auto-mobilities are likely to feature predominantly in how physical-digital scapes become reconfigured and future networked infrastructures are to be both 'imagined' and 'constructed' within particular societies. It is possible that people will be increasingly incorporated into interdependent relations with environmental systems and objects, such that social-urban structures may become infrastructures of access, navigation and dependency. Central to this may be institutionalised and privatised modes of transport, providing the 'allowance for travel'. How people in these changing territories form connections 'at a distance', and negotiate social networks, may become part of a web-like nexus of arrangements that combine mobility with security, privacy with privilege, and identity with access. In industrialised countries with established road infrastructures, car-automobility is increasingly being integrated with improved networked transport management, safety technologies and support, and environmental concerns.

We approach the issue of a shift from the present car system to a 'post-car scenario' by examining adaptive processes and relations through a range of dynamic global systems. However, systems are vulnerable to rapid changes and respond unpredictably to various impacts. For this reason outcomes are uncertain and no future scenarios can be certain. In this Report we consider the four principal processes as to how the 'social' may undergo transformation to be global climate change; global security and the 'War on Terror'; digital technologies and pervasive computing; and the rise in complex systems thinking.

i) Global Climate Change: It is no longer easy to ignore how climate change is a real threat to human life and social organisation. The scientific evidence is becoming much less un certain, and the recent Stern Review (2006) emphasised this and gave the issue of climate change both economic and political significance around the world. Despite ongoing debates and contestations within national agendas of climate change, there is growing consensus about the rise in world temperatures. Global temperatures have risen by at least 0.5˚ C over the past century and this is almost certainly the product of very many different forms of social practice that raised the levels of greenhouse gases in the atmosphere (Stern 2006: ii). Moreover, these levels of greenhouse gases and world temperatures will increase significantly over the next few decades; and this rise will most certainly trigger further temperature increases as the earth's environmental systems absorb the impacts, including the possible melting of Greenland's ice cap which would dramatically change sea and land temperatures worldwide (including the probable turning off of the Gulf Stream: Lovelock 2006: 33). These multiple future processes seem to be locked in and according to Lovelock: 'there is no large negative feedback that would countervail temperature rise' (2006: 35).

The overall economic, social and political consequences of such climatic changes are already, to some degree, irreversible; this includes a reduction in the standard of living, and major upheavals in populated regions, with the impacts being felt most in poorer countries (Stern 2006: vi-vii). With business as usual the stock of greenhouse gases could treble by the end of the century and there is a 50% risk of more than a 5˚C increase in temperatures and the transformation of the world's physical and human geography through for example a 5-20% reduction in world consumption levels (Stern 2006: iii, x).

There is thus a growing consensus amongst scientists and social scientists and among many national and international governments that reducing global carbon consumption is essential and there are very substantial economic reasons for so doing. And within this overall pattern, bearing down on carbon use within transport is crucial since it accounts for one-third of total carbon dioxide emissions (Geffen, Dooley, Kim 2003). It is also the fastest growing source of greenhouse emissions, with the predicted growth of car and lorry travel within China and elsewhere throughout the world, the rapid growth of air travel, and the increased 'miles' flown by both manufactured goods, foodstuffs and friends (see Larsen, Urry, Axhausen 2006, on friendship and relationship miles). In 1800 people in the US travelled on average 50 metres a day – they now travel 50 kilometres a day (Buchanan 2002: 121). Today world citizens move 23 billion kilometres; by 2050 it is predicted that that figure will have increased fourfold to 106 billion (Schafer, Victor 2000: 171).

There are moreover potential alternatives to carbon-based systems in powering ‘cars’ at least and so reducing carbon use with regard to personal mobility is increasingly high up economic and policy agendas (Motavalli 2000; see Giddens 2007: 188-9). Relatedly, it is realised that oil supplies around the world are about to start running down. Peak oil production occurred in the US as far back as 1971 and it seems that oil production worldwide will peak around 2010 especially because of the failure to discover new fields at the same rate as they were discovered in the past (Heinberg 2005; Rifkin 2003: chap 2). Energy will be increasingly expensive and there will be frequent shortages especially with the world’s population continuing to increase in numbers. There is not enough oil and this will generate significant economic downturns, more resource wars and lower population levels. The delivery of fresh water also depends on fossil fuels and already severe water shortages face one third of the world’s population (Laszlo 2006: 28-9).At present the worldwide transport sector is heavily dependent on oil. Not only transport but the infrastructures of developed and developing nations are predicated upon the plentiful supply of oil for all areas of industrial, military, and commercial life.

In 2005 the transport sector worldwide had a dependency on oil of 98%, and this represented approximately 50% of all global oil consumption, about 20% of all energy consumption, and this followed an annual average growth rate of more than 2% (Pinchon, 2006). The inefficient internal combustion engine is principally fuelled by the primary energy sources of oil, natural gas, and coal; but these predominantly produce a combination of petrol/gasoline, diesel, and LPG. There are potential alternatives to carbon-based systems in powering ‘cars’. A move away from a carbon-based transport system is increasingly expressed as a relatively short term imperative that will generate long term savings if this can be achieved in time; there is a ‘high price to delay’ (Stern 2006: xv)[3].

In the UK in 2000 the transport sector was responsible for producing 31.5 million tonnes of carbon (House-of-Commons, 2004: 11). The UK Government 10 year plan for Transport aims to reduce this by 1.6 million tonnes by 2010. Part of this Plan

[3] Yet transport is not the direct major contributor to greenhouse-gas emissions. Power represents 24% of current global greenhouse-gases; with industry and transport sharing 14%; buildings emitting 8%; land use 18%; agriculture 14%; and waste 3% (Stern, 2006: iv).

entails encouraging the development and manufacture of cleaner vehicles that are low carbon emitters. The relationship between fuel/power and transport is then a key factor in climate pollution. Transport infrastructures and power distribution are both likely to be impacted by socio-political incentives to tackle climate change. Whilst there are a number of developments under review concerning fuel/power distribution, from a hydrogen economy (Dunn, 2001; Rifkin, 2003; Romm, 2004a) to micro-power or distributed power schemes (Alderfer, Starrs and Eldridge, 2000; Dunn, 2000), there appears little ambition amongst corporate interests to invest in energy infrastructures that move away from current paradigms of centralised production and management. Despite the need for virtually zero-energy forms of transport it will be more likely that the present individualised system of automobility will remain, not revamped or radicalised but amended and revised by a steady shift to hybrid and hybrid plug-in cars that use various combinations of petrol, gas, electricity, biomass, and similar mixtures, possibly hydrogen in the long term. The combustion engine may finally be replaced by fuel cells within two decades. It is also recognised that the event of peak oil may hit global energy markets within two decades or less (Heinberg, 2004). This would lead to resource wars and potential civil unrest. Renewable energy systems will be of huge value in the coming decades and there may be some shift towards more efficient networked infrastructures to deal with energy production/extraction, distribution, and consumption.

There is already a shift underway in the need to design and build more environmentally sustainable cities in order to house the increased flow of rural dwellers to urban centres. For example, China aims to move 400 million people, which is roughly half the rural population, into urban centres by 2030[4]. For this to become manageable there needs to be increased focus upon sustainable urban design; sustainable energy/waste management; renewable energy processes; sustainable building design; and investment in eco-city architectures. To some degree this is being implemented into existing construction projects: designs for the Chinese eco-city Dongtan currently under construction focus upon the city to be ecologically friendly, with zero-greenhouse-emission transport services, self-sufficient water and

[4] See http://www.msnbc.msn.com/id/9378521/site/newsweek/

energy provisions, and built upon zero energy building principles[5]. Similar projects need to be encouraged within Europe, the 'richer' northern territories, as well as other developing nations.

In early January 2007 European Commission chief Jose Manuel Barroso announced that it was time for a 'post-industrial revolution' in which Europe would cut greenhouse gases by 20% by 2020[6]. Despite environmental pressures over climate change this announcement was partly motivated by political fears. Europe's vulnerability as an oil importer was made clear in early January when Russia's oil/gas dispute with Belarus affected European supplies. As a move to secure European self-sufficiency Barroso stated that the EU should look towards supplying 20% of its energy needs from renewable power by 2020, with 10% of vehicle fuel coming from home-produced biofuels.

Increased public concerns over climate change and carbon emission may lead to compulsory carbon quotas being levied upon both industrial and domestic producers. In this case big businesses and private homes will, with regional variations, be forced to sign up to a carbon-trading scheme. Such a scheme is already present in proposals being currently drafted by UK ministers (Wintour and Seager, 2006), and will require those signed up to buy permits that grant 'permission to pollute'. This may be an early indicator of how pressures to cost socially peoples' behaviour will require technologies involved in the qualifying of social 'fitness' and the granting of permission/access.

ii) Global Security & the Social Management of the War on Terror:

Fears over security and safety have reached new levels in the opening decade of the twenty-first century. These are times of monitored and manufactured risk presently established around the new post Cold-War scenario. It is, in all respects, a post-millennium state of insecurity. The older and more familiar paradigms of warfare and security were based upon binaries (e.g. Democracy vs. Communism; friend vs. foe).

[5] See http://www.arup.com/eastasia/project.cfm?pageid=7047 and http://en.wikipedia.org/wiki/Dongtan

[6] See http://news.bbc.co.uk/1/hi/sci/tech/6247199.stm

To some degree this binary distinction is still maintained and played out in media and cultural discourse as Freedom vs. Anti-Freedom, or West vs. Islam. Yet upon deeper scrutiny this manifests as an asymmetrical arrangement: order/authority vs. guerrilla non-compliance. A terror suspect can therefore no longer be easily identified as 'the enemy' which requires that all civilians be categorised in a state of 'potential terrorist'. This is especially so since the notion of 'home-grown terrorist' is playing out the role of insurgency and resistance from within. This subtle shift in categorisation has seen a parallel move in the increase of the militarization of the civil sphere. By this we mean that civil space is increasingly becoming the 'battle zone' where security issues – surveillance, tracking, identification – are played out.

Most noticeably this battle zone especially occurs at transportation hubs; at epicentres where meetings proliferate and where the 'kinetic' elite are rendered static for temporary moments for the benefit of covert registration. Instances here include airports where biometrics are taking place, such as at Heathrow (BBCOnline, 2006), and where Radio Frequency Identification (RFID) tagging is soon to be introduced into passengers' tickets and luggage under a current European Commission funded research project known as Op-Tag[7]. Security threats will potentially aim to exploit the inherent fragilities of networked technological mobilities, specifically within urban architectures (WhiteHouse, 2003). An awareness of the requirements for transportation securities is likely to be a major issue within how future mobilities are framed. It is a sober reminder that

> The events of September 11th were a macabre yet subtle exploitation of the multiple and interconnected mobilities, continuously telescoping between the local and the global, that sustain global urban capitalism: mobilities of people and machines; mobilities of images and media; mobilities of electronic finance and capital. They provided the latest in a long line of dawning realisations that urban modernity, despite its promises of absolute technological and material progress, is actually utterly interwoven with fragility and vulnerability. (Graham, 2001: 411)

The infrastructures of mobility are a prime target as a security threat and that as auto-mobilities increase in complexity and speed a security-apparatus concerned with cross-border and trans-national movements will be further strengthened.

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[7] See - http://www.optag-consortium.com/

This indicates how state policies are increasingly concerned with the practical and security implications of mobility. Future policies on transportation are likely to increasingly build security concerns into the infrastructure, and these concerns are likely to be two-way: first, command and control features that monitor and regulate the users or 'mobile individuals' within the system; and second, security that deals against the potential threat of rogue attacks both from within and without. Already transportation securities are an emerging market for corporate and civil agencies in satellite observation and protection, as seen in the recent European Space Agency projects[8].

The threat of asymmetrical warfare that has built up around the 'War on Terror' implies stringent forms of social management. That these are necessary is apparently accepted, often without extensive political and/or public debate, and will be high on the agenda for how future public transactions and movements will be constructed. The contribution of 'terror security' to future automobility is significant. How this will be implemented is directly linked to the next set of processes – digitisation and new technology.

iii) Digital technologies & Pervasive Computing: technological change has, in various ways, contributed to 'mobile' lifestyles, as well as fundamentally altering how people are located within time, space, and the environment. Somewhat paradoxically though, the car is 'locked into' the industrial age of the combustion engine. Yet emerging technologised processes are increasingly dynamic as they shift relations within systems beyond the individual such that 'what matters is not technology itself, but its relationship to us' (Brown and Weiser, 1996). Developments in computerization have taken relationships in the rich 'north' away from fixed locations as in the stand-alone PC, to laptops that can be carried around, to wireless PDAs, to Internet connectivity on mobile phones. This trend in distributed computing is developing towards a shift to ubiquitous computing where associations between people, place/space, and time are being embedded within a systemic relationship between a person and their kinetic environment. This shift referred to as the 'third

[8] See http://www.esa.int/esaTE/SEMKN89L6VE_index_0.html

wave of computing' is that of 'ubiquitous computing, whose cross-over point with personal computing will be around 2005-2020' and may become 'embedded in walls, chairs, clothing, light switches, cars - in everything' (Brown and Weiser, 1996). Brown and Weiser envisioned that the 'social impact of embedded computers may be analogous to...electricity, which surges invisibly through the walls of every home, office, and car' (1996). Within a decade of this pronouncement, computing evolved from fixed locations of access to an increased wireless presence. And it is predicted to become more ubiquitous in ways that will dissolve it *into* physical surroundings, architectures and infrastructures. Such pervasive computing is expected to make itself almost invisible, forming complex interdependencies of information flows as part of an information-immersive environment (Greenfield, 2006). Such an integrated system of person-information-environment would accelerate temporal differences between multiple sites of information and have significant implications for what it means to be mobile, and for notions of social presence.

Ubiquitous computing will, in the rich 'north', be part of the social and natural environment as sensor microprocessors are lodged in the environment, buildings, and household objects. Greenfield considers this to be, in one form or another, an inevitability, and refers to this ubiquitous computing (ubicomp) paradigm as 'everyware': 'Everyware is information processing embedded in the objects and surfaces of everyday life...the extension of information-sensing, -processing, and -networking capabilities to entire classes of things we've never before thought of as "technology"' (Greenfield, 2006: 18). Although we cannot say whether this is an inevitability these developments foresee a potential future environment where social relations are enmeshed within an enveloping field of information that may exert a strong influence upon not only how people travel but also whether they *can* travel, and *when*. The result being that 'where everyware is concerned, we can no longer expect *anything* to exist in isolation from anything else' (Greenfield, 2006: 128). The era of pervasive computing is forecast to be built around developments in three key areas: costs; Internet infrastructure; and agent based computing (Sharpe and Zaba, 2004).

It is expected that core components will become cheap enough to allow most things to be connected and digitised. Then it will become feasible to connect both animate and inanimate objects online. This will also be determined by developments in Internet infrastructure. Internet standards that are the backbone to the World Wide Web will go through radical upgrades that will allow much greater functional capacity and expand on the current Internet infrastructure. This will include developments such as the semantic web, grid and distributed computing, and more widespread peer-to-peer applications. This in turn will impact upon the rapid growth in digital interactions and interrelations and will greatly expand the complexity of design protocols and programming. This will necessitate the need for agent based computing and autonomous agents to instigate interactions within the pervasive computerised environment. If these developments are successful, and this is still not certain, then this will facilitate the emergence of complex physical-digital architecture with potentially significant effects for mobility.

The accelerated growth towards more complex interrelations and interdependencies within digitised physical-digital scapes and architectures leads to the next set of significant processes; namely, the development of complexity science.

iv) Systemic Complexity Thinking: Complexity theory, as a development from chaos theory, has emerged as an approach for analysing non-linear processes. Specifically, how components of a system through their dynamic interaction 'spontaneously' develop collective properties or patterns that are not implicit within, or at least not implicit in the same way, within individual components (see Urry 2003: chap 2 for a fuller account). Complexity investigates emergent properties, certain regularities of behaviour that somehow transcend the ingredients that make them up. Complexity thinking transforms scientific understanding of far-from-equilibrium structures, of irreversible processes, and of non-Euclidean mobile spaces. It emphasises the nature of strong interactions occurring between the parts of systems, with often the absence of a central hierarchical structure that 'governs' and produces outcomes. These outcomes are both uncertain *and* irreversible.

One of the most influential developments to have contributed to a self-organising systemic theory, and to the complexity sciences, is Prigogine's theory of 'dissipative structures'. His work (1980; Prigogine and Stengers, 1985; Prigogine, 1997) on dissipative systems showed that open systems existed far-from-equilibrium and sustained themselves through maintaining energy flows, thus shifting from entropic reactions to negentropic ones. Systems in states far-from-equilibrium, it seemed, increased in complexity through an internal generation of networks by using a through-flow of energy from an external environment, while constantly maintaining a dynamic state of stable order. How the open-system responds shows whether it adapts to new circumstances in terms of growth, or whether it collapses. A nonequilibrium system, Prigogine observed, 'may evolve spontaneously to a state of *increased complexity*' (1997: 64). This increase in the complexity of a system is a successful utilisation of the energy influx that, at times, is created by the disturbance itself. Complexity then appears to be a process whereby open-systems self-organise their dynamic interior networks in response to its environment.

The pluralistic character of the complexity sciences enables it to function within various disciplines since 'there is as yet no single science of complexity but, rather, a number of different strands comprising what might be called the complexity sciences' (Griffin, Shaw and Stacey, 2000: 85). The interdisciplinary approach of complexity thinking is central to framing how various components of a system through their interaction 'spontaneously' develop collective properties or patterns. However, because of the complex interdependencies of systems it is almost impossible to predict what would be the appropriate means of effecting change. There are just so many unintended consequences across time and space of economic, social and political innovation; and these consequences themselves engender further adaptive and evolving system consequences. And not all changes.

Abbott argues that while change is the normal order of things and indeed many assessments of contemporary social life emphasise the increasingly accelerating nature of profound changes, there are certain systems that get stabilised for very long periods of time (2001). They are path dependent. Causation flows from contingent events to general processes, from small causes to large system effects, from historically or geographically remote locations to the general (Arthur 1994; Mahoney 2000). Path-dependence means that the ordering of processes through time significantly influences the non-linear ways in which they eventually turn out decades or even centuries later. Path dependence is a process model in which systems develop irreversibly through a 'lock-in' but with only certain small causes being necessary to prompt or tip the initiation of the original 'path'. Such small causes are mostly unpredictable, difficult to foresee although in hindsight they appear explicable in terms of how they tipped the system into path dependent patterns. Lock-ins mean that institutions matter a great deal as to how systems develop over the long time. Institutions, using this term very broadly, can produce a long term irreversibility that is: 'both more predictable and more difficult to reverse' (North 1990: 104).

One system that is remarkably stable and unchanging is that of automobility with close to 600 million cars currently roaming the world's highways (Urry 2004, 2007). And this is so even though a massive economic, social and technological maelstrom of change surrounds it. It is a modern day Leviathan: 'automobility stretches its six fingers – production, possession, pipelines, projection, pressure and power – to tighten its global grasp upon humankind' (Latimer, Munro 2006: 35). Such locked-in institutional processes are extremely difficult to reverse as billions of agents around the world co-evolve and adapt to it and build their lives around its strange mixture of coercion and flexibility (see Urry 2004, 2007). A systemic and 'complex' understanding of relationships and networks will be essential, we argue, to how future automobilities are constructed.

Automobility, viewed through the language of complexity, can be seen as a self-organising, non-linear system (see Dennis, Urry, 2007). It incorporates a complex assemblage of cars, car-drivers, roads, fuel supplies and distribution, and a huge array of novel objects, technologies and signs that cars both presuppose *and* call into existence. This system of automobility stems from the path-dependent pattern laid down in the 1890s. Once economies and societies were 'locked in' to the 'steel-and-petroleum' car, massive increasing returns resulted for those producing and selling those cars and its associated infrastructure, products and services (Arthur, 1994). And at the same time social life was irreversibly locked in to the mode of mobility that automobility both generates and presupposes. This mode of mobility is neither socially necessary nor inevitable but seems impossible to break from.

The effects of the petroleum car over a century after its chance establishment show how difficult it is to reverse locked-in institutional processes as billions of agents co-evolve and adapt to remaking that system across the globe (see Sheller and Urry 2000). The remaking of the petroleum car into a co-evolving system of interdependent agents and relations has formed, over time, a complex assemblage that 'constitutes' the car. It is our suggestion that the future of automobility may involve a shift from a car series to a nexus system as we discuss below.

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This sketch of four key trends provides a framework upon which to begin assembling post-car futures (Dennis, Urry, 2007). Before bringing all the developments together it is necessary to examine the networks that are likely to form the core processes impacting upon the 'car' in coming decades. In this respect we refer to automobility as a hybrid auto-assemblage.

Chapter 2: AUTO-ASSEMBLAGES

'Automobility' is a hybrid assemblage, of humans (drivers, passengers, pedestrians) as well as machines, roads, buildings, signs and entire cultures of mobility with which it is intertwined (Thrift 1996: 282-84). What is key is not the 'car' as such but the *system* of these fluid interconnections since: 'a car is not a car because of its physicality but because systems of provision and categories of things are "materialized" in a stable form' that then we might say possesses very distinct affordances (Slater 2001: 6). It is necessary in any consideration of future automobility to frame this discourse within a 'system assemblage'; a web of material interactions and networks that position the possibility for movement and constitutes an embedded environment that hosts the user. Whilst automobility is a system in which everyone is *coerced* into an intense *flexibility*, it also enforces certain relationships of dependence within the temporal, spatial, and geo-physical constraints that it itself generates.

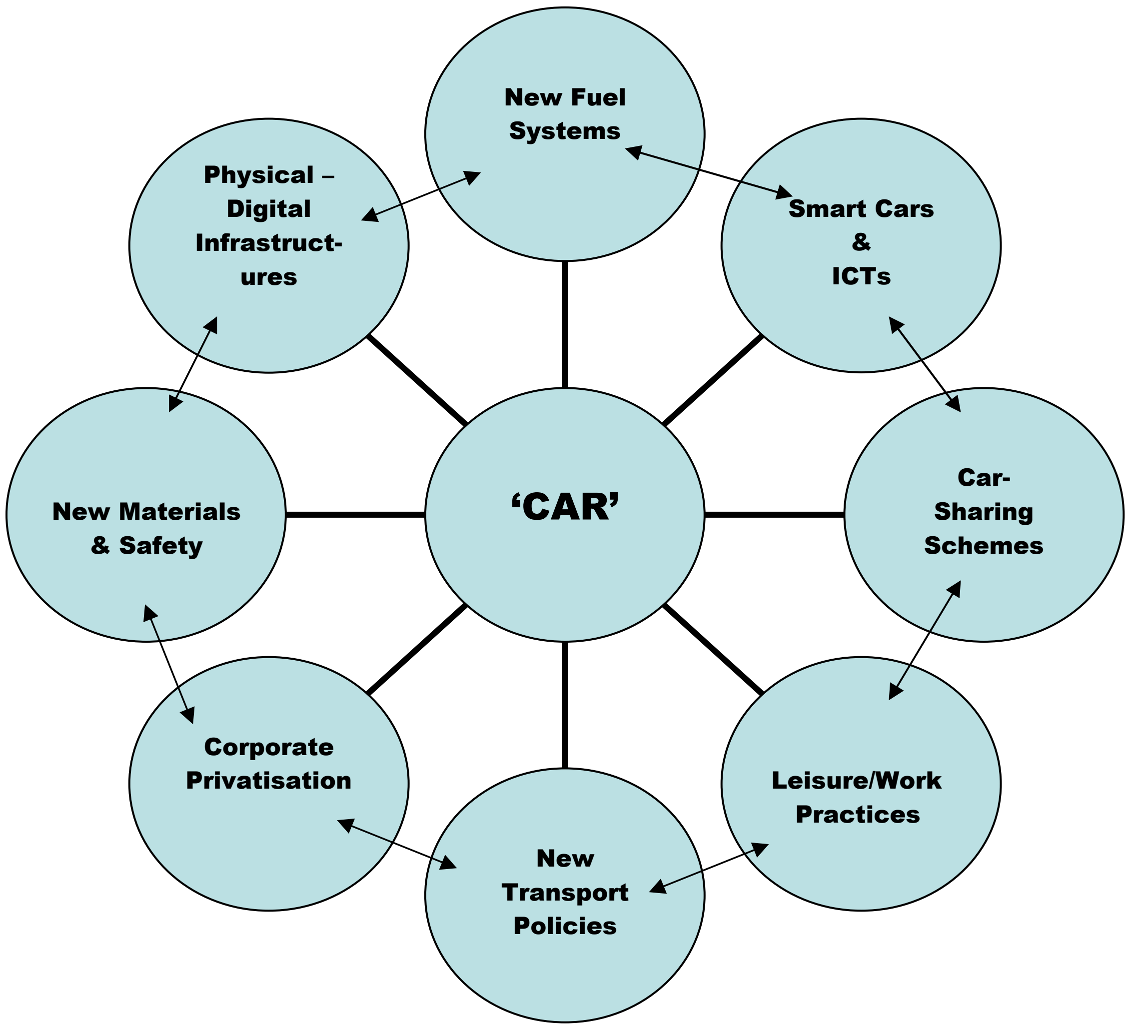
The car we might ironically say is the 'iron cage' of modernity, motorised, moving and privatised that encases an individual within specific static structures whilst producing the democratic desire for flexibility that only the car system can satisfy. Yet in order to cope with the 'mass' take up of individualised automobility, a systemic assemblage of artefacts and support was required and developed. This assemblage is, we argue, set for change due to the processes previously outlined. The current automobility system may undergo a shift involving the changes occurring within the 'mix' of relations that have formed around the current car system.

The so-far unchanging structure of the current car system is what Mumford refers to as a cultural pseudomorpth, a concept borrowed from geology (1934). In geology, a pseudomorph is a: 'mineral compound resulting from a substitution process in which the appearance and dimensions remain constant, but the mineral which makes up the chief component of the compound is replaced by another. The name literally means False Form'[9]. In cultural terms Mumford describes this as 'new forces, activities, institutions, instead of crystallizing independently into their own appropriate forms, may creep into the structure of an existing civilization…In city growth, for instance,

[9] Definition supplied by Wikipedia, http://en.wikipedia.org/wiki/Pseudomorph (accessed 14/02/07)

electric and gasoline transportation has increase the congestion which was the original result of the capitalistic concentrations of coal and steam power' (Mumford, 1934: 265).

However, there are some technical-economic, policy and social changes that may be laying down the seeds of a new automobility assemblage for future transportation vectors. If they develop in the next decade or so they will contribute to a new mobility paradigm that sees a 'post-car system' embedded into irreversible digitised network infrastructures that will embed 'movement' into *ordered flow* and *managed passage*. These changes include *new fuel systems* including batteries, hybrid cars powered by diesel and batteries, and hydrogen or methanol fuel cells; *new materials* for constructing 'car' bodies that will be many times lighter; *'smart-car' technologies and communications* that are embedded within and coterminous with forms of transport; the *de-privatisation* of the car through extensive car-sharing, car clubs and car-hire schemes; and shifts in *transport policy* away from predict and provide models, including new costing methods. Below is a diagrammatic representation of this new 'car' hybrid assemblage:



We turn now to address some of the principal processes that may come to realise this potentially new automobility assemblage, a post-car system.

i) New Fuel Systems: It is apparent that cleaner fuels and more efficient engines will be needed in order to shift away from the dependency upon fossil fuels. Such dependency is not only detrimental on the environment and climate but also sustains resource wars and ethically corrupt geo-political operations and strategies. Realistically, however, it is difficult to assume that fossil fuels will continue to power the majority of individually driven cars (House-of-Commons, 2004). Alternatives under development include biofuels; hybrid vehicles; electric batteries; and hydrogen.

Biofuels - fuel alcohols (ethanol/methanol) - can be produced from a range of crops, such as sugar cane, sugar beet, maize, barley, potatoes, cassava, sunflower, eucalyptus, etc (Salameh, 2006). Two countries that have developed substantial bio-fuel programmes are Brazil (ethanol from sugar cane), and Russia (methanol from eucalyptus). The worldwide production of ethanol in 2005 has been estimated at 37 million tonnes, 80% of this being used as fuel (Pinchon, 2006). The largest producer of ethanol is Brazil at 37%, with North America at 36%, Asia at 15%, trailed by Europe at 2% (others are 15%). The production of ethanol for fuel grew 15% 2000 - 2005, with worldwide ethanol fuel use in 2050-2100 estimated to be around 33% of total fuel usage (Pinchon, 2006). Currently China is engaged in biofuel plant construction and has already established the world's largest biofuel ethanol facility at Jilin (Salameh, 2006). By the end of the decade the two largest major ethanol producers will be Brazil and the US. A Biofuels Research Advisory Council report *Biofuels in the European Union: A Vision for 2030 and Beyond* concludes by suggesting that by 2030 the European Union should supply up to 25% of its transport fuel needs by clean and CO2-efficient biofuels (BRAC, 2006). Although biofuel usage cuts down dependence upon foreign oil imports, and is a cleaner, more environmentally friendly material, there are many significant problems. The main argument against biofuel production concerns the availability of agricultural cropland. For example, for either the US or Europe to replace 10% of their present transport fuels with biofuel using today's technologies would require up to 40% of cropland (Salameh, 2006) – an unsustainable amount. Therefore, the BRAC report on future European biofuel usage (BRAC, 2006) recommends securing safe and consistent biofuel imports as well as developing possible alternative biotechnology programs. Biofuels may be significant in increasing future energy securities, yet research is still needed to engineer biofuel not dependent upon plantation. Research in this direction is developing biofuel alternatives from bacteria, such as microbial energy conversion (Buckley and Wall, 2006). Here, microbial energy technologies 'employ microorganisms either to manufacture fuels or to generate electricity directly through the breakdown of organic materials' (Buckley and Wall, 2006: 3). Another biofuel manufacturing process is to use cellulosic energy crops, such as switchgrass, poplar, and other fastgrowing plants. This use of 'next-generation' cellulosic biomass feedstock could potentially alleviate the stress placed upon the standard agricultural land crops (Worldwatch, 2006). The shift towards new fuel technologies may influence an engineering shift away from the combustion engine towards hybrid fuel cells, and even lithium batteries.

Hybrid-electric vehicles (HEV) are seen as the most promising alternative in the short term to fossil fuels. HEVs employ a hybrid engine that combines regular petrol-combustion driven mechanical drives with battery driven electrical drives. Usually the HEV uses the petrol part for long-range driving and acceleration, switching to battery-electrical power assistance for cruising and short-range urban city driving. HEVs batteries do not require constant recharging as in electric vehicles as they rely on both a long-life battery cell and recharging via the vehicle's kinetic motion and braking. Car manufacturer Toyota has captured a niche in the HEV car market with their Prius model, and their range is soon to be expanded. Several manufacturers are now entering the HEV market with high-profile 'green' cars, noticeably GM and Ford. HEVs are also considered a 'safe bet' should future fuel cell vehicles fail to become a commercial prospect (House-of-Commons, 2004).

A variation on the hybrid-electric vehicle (HEV) that is gaining favour is the 'plug-in hybrid' car, referred to as Plug-In Hybrid Electric Vehicles (PHEV). PHEVs are grid-connectable Hybrid Electric Vehicles that are said to typically consume 50-90% less of any kind of conventionally used fuel. The PHEV is the basis for a viable Vehicle-To-Grid (V2G), Distributed Generation (DG) vision, whereby the car can be plugged back into the grid when not in use not only to recharge but also to return some of its unused energy during peak demand, for which the owner can be reimbursed. In this way credit can be earned which also encourages non peak-time driving (Hawken, Lovins and Lovins, 2002). This peer-to-peer grid connectivity mirrors the web-like infrastructure of the Internet and allows for distributed participation. It is similar to Rifkin's peer-to-peer vision for a hydrogen economy. It is claimed that 'Electric-drive vehicles, whether powered by batteries, fuel cells, or gasoline hybrids, have within them the energy source and power electronics capable of producing the 60 Hz AC electricity that powers our homes and offices'[10].

Currently research is being undertaken to produce lithium-ion batteries that are cheaper and more efficient than present car batteries. MIT is one of the leading research institutes currently developing these alternative batteries. The MIT's new

[10] See http://www.udel.edu/V2G/

lithium battery contains manganese and nickel, which is cheaper than the regularly used cobalt (Trafton, 2006). MIT researchers have modified the battery so that the lithium ions are capable of carrying the battery's charge and making battery recharge up to 10 times faster. However, the process still needs to be made cheaper before it can be commercially produced on a large scale.

Perhaps the most-touted alternative to fossil fuels is the hydrogen fuel cell and possible shift to a hydrogen economy (Rifkin, 2003). The hydrogen fuel cell car is considered by some as the 'dream ticket' for the clean car of the future. A UK government white paper on transport places the timeframe for hydrogen fuel cell cars as 2020 (House-of-Commons, 2004). However, GM have publicised how they hope to be producing fuel cell cars by 2010 that will eventually be powered by hydrogen. Fuel cells promise a clean car future and near-zero road emissions. Fuel cells, which convert energy from a chemical reaction, produce electricity similar to batteries. Unlike batteries, fuel cells never need to be recharged and will produce energy for as long as the fuel is provided. These cells are expected to convert hydrogen into electricity, once storage and distribution problems are solved.

Whilst hydrogen is an attractive option, currently the 'costs of producing hydrogen from renewable energy sources are extraordinarily high and likely to remain so for decades' (Romm, 2004b:3). Others estimate that '"renewable hydrogen" will not be available for use by fuel cell cars for 30 years' (House-of-Commons, 2004: 17). There is also the issue of infrastructure. Two key issues for infrastructure involve where the hydrogen is produced, and what form it is stored onboard the hydrogen vehicle. It may be necessary to develop a whole new delivery infrastructure as hydrogen, being highly corrosive, has the potential to make brittle current gas pipelines, thus requiring a new infrastructure of pipelines to be established using suitable materials. Similarly, Heinberg notes that 'we need a solution now, not decades from now' (Heinberg, 2004: 129). In this respect, hydrogen has been seen as a problematic short-term strategy, as well as unproven for the long term (but see Rifkin, 2003).

ii) New Materials & Car Safety: Steel is still not an efficient material from which to manufacture a transport vehicle. The weight ratio needs re-modelling since at present the car 'needs only one-sixth of its available power to cruise on the highway and severalfold less in the city. The result is a mismatch not unlike asking a three-hundred pound weightlifter to run marathons' (Hawken, Lovins and Lovins, 2002: 27). It seems likely that the developments in new materials will see a shift to smaller, lighter, safer, and smarter cars more suitable for being fitted into networked infrastructures of code and digitised connectivity. This would greatly facilitate the ongoing drive towards 'Intelligent Transport Systems'.

Due to environmental concern it is likely that there will be a forced shift towards cars at least in the 'north' that are part of a recyclable 'system'. The European Union proposed a goal of recycling 85% of vehicle components and converting 5% into energy by 2006. According to new European Union legislation, by the year 2015, 95% of vehicle components will have to be recycled. This may signal a move towards systemic thinking in terms of industrial manufacture and materials. Industrial and social flows may be forced to act as in ecological flows - in self-reflexive and recyclable processes, rather than in wasteful, linear flows. Too much energy is being wasted within the car itself – through heat dissipation from the engine, exhaust, tyres etc. Environmental materials will be paramount with future infrastructures; this is likely to be headed by innovations in architectural city design that hybridise modern nano-materials with natural, environmental materials, ethics, and bio-mimicry. Industrial ecology is a paradigm that favours how this assemblage may form. The concept of industrial ecology shifts industrial processes from linear systems, in which resource and capital ultimately become waste, to feedback processes whereby waste is injected into recyclable inputs for new processes[11].

The global car industry is heavily researching vehicle materials that could provide weight reduction without sacrificing safety. Research on the 'hypercar', which uses advanced polymer composite materials (Hawken, Lovins and Lovins, 2002), is one example where materials are at the forefront of design and fuel efficiency. Other technologies include aluminium and nanotechnology which may make possible carbon-based fibres 100 times stronger than steel and at one-sixth the weight (US Department of Transportation, 1999: 4-5). Also there may be increasing production of

[11] See http://en.wikipedia.org/wiki/Industrial_ecology

much smaller micro-cars (rather than 4-person family-sized cars) for crowded urban spaces (Urry, 2007). Examples of such micro-cars include the Mercedes Smart Car, the Nissan Hypermini, Nice's Mega City, and the Reva G-Whiz.

It also seems likely that new players will emerge in the transportation construction market, such as electronics software companies as they integrate their products into hybridised cars. Recently Microsoft teamed up with Ford Motors to provide in-car communications, presently dubbed 'Synch', although this is still in pre-production. With the increase in the use of sensors, future 'automobiles' may resemble computers with wheels rather than cars with chips. Such cars will cross-over into being driven more and more by software than by hardware, and adaptable learning autocars will either have the advantage or be a necessity in order to integrate into the software transportation assemblage. Computer-embedded materials/components may also be designed to interact wirelessly with informational systems. Smart-car technologies will accelerate the merging of cars into 'virtual' territories that will allow them to be *intercepted* from external sources whereby material updates will be provided wirelessly from manufactures such as in-car software upgrades via car-to-dealer communications. Researchers on the 'Dynamically Self-Configuring Automotive Systems' (DySCAS) project aim to design an intelligent car that can 'self-diagnose and ultimately self-heal its own faults, update its own computer devices and interface with a drivers' mobile phone' (Online, 2006). These component systems, comprising 'smart materials', will download their own engine management and re-configure their performance and safety without driver interference. These are the latest designs in autonomous safety systems.

Traffic management could also form part of a possible hybrid car-assemblage. Private contractor Qinetiq, formerly the Defence Evaluation and Research Agency (DERA) which was a part of the UK Ministry of Defence (MoD) until July 2, 2001, is working with the Highways Agency to develop new fibre-optic sensor systems to track and measure road usage in order to improve traffic flow. These systems are designed to integrate with the Motorway Incident Detection and Automatic Signalling (MIDAS) network which establishes traffic flow and real-time road messages[12]. Similarly, ITIS

[12] See http://www.e4engineering.com/Articles/296541/More+go+with+the+flow.htm

Holdings Plc[13] has developed a unique system for the collection and analysis of traffic information, working with UK governmental and corporate bodies. They collect information from traffic offices around the UK and combine this data with their real-time 'Floating Vehicle Data'[14] (FVD) to provide travel time forecasts and real-time traffic updates. ITIS now operates an extensive road management sensoring system that incorporates, not only on-the-road monitoring vehicles (FVD), but also an array of fixed sensors that include CCTV, microwave, acoustic, infra-red, and electronic inductive loop magnetic fields[15]. This information is then commercially provided for road management schemes and policy projects. A similar system is in operation in North America where state-owned vehicles – such as governmental and emergency services – carry sensoring devices that record weather information, traffic congestion, and road speeds. This data is then wirelessly transmitted to the state Condition Acquisition Reporting System (CARS) to be used for immediate traffic management[16].

These developments in vehicle software embodiments and traffic safety management could be crucial in providing secure mobility features that will form a core aspect of the Intelligent Transportation Systems (ITS). Fundamental to ITS will be the development of *telematics*, which includes wireless technology, vehicle tracking and navigation assistance, and car-to-car communications (Bell, 2006).

iii) Smart Cars – Intelligent Communications: As previously noted trends in pervasive computing will increasingly embed information within architectural places/spaces and moving objects. This information will be digitised and released into networked locations, forming communicative relations between cars, roads, and the environment. This could represent a major shift in how car mobility is reconstituted: as a networked system rather than as separate 'iron cages', as a potentially integrated *nexus* rather than as a parallel *series*. This could produce a shift from the modern divided traffic flow to what Peters terms the organic flow in which all traffic

[13] http://itisholdings.com/index_flash.asp
[14] Floating vehicle data – 'technology for the collection, analysis and forecasting of journey times using speed and location data directly from a sample of vehicles as an alternative to fixed roadside sensors' - http://itisholdings.com/whatfvd.asp
[15] See http://proddev.itisholdings.com/worldcongress/
[16] See http://news.nationalgeographic.com/news/2004/05/0521_040521_smartcars.html

participants are able to survive and co-exist, aided by new kinds of communications regulating the system as a whole (2006). Such networked communications will be central to how the current car system based on self-directing autonomy may shift over to a post-car 'nexus' system of increased digitised automation and management.

Various research developments and projects get included under the general umbrella term of Intelligent Transport Systems. One of these, Advanced Vehicle Control Systems (AVCS), refers to 'any vehicle or road-based systems that provide increased safety and/or control to the driver'[17]. These have already been positioned in the motor car in terms of braking, suspension systems, and steering systems. However, more sophisticated preventative and safety technologies will become available in the short to medium-term. These will include Lane Assist and Intelligent Speed Adaptation (House-of-Commons, 2004). Longer-term collision avoidance systems are also under development. PReVENT[18] is a European automotive industry activity, co-funded by the European Commission, that aims to develop car safety technologies such as in-vehicle systems that are capable of assessing both external road conditions as well as the driver's own state. INTERSAFE, the largest PReVENT sub-project, focuses on implementing in-vehicle sensors to avoid collisions at intersections. These Advanced Driver Assistance Systems (ADAS) include in-car driver-navigation assistance systems; vehicle-tracking radar systems; lane-departure systems; and road-collision sensors[19]. Similarly, Adaptive Integrated Driver-vehicle InterfacE (AIDE)[20] incorporates in-vehicle information systems with environmental monitoring sensors to create a human-machine driver interface for more secure driving. The European Commission's involvement on this – Advanced Driver Assistance Systems in Europe (ADASE) – aims to introduce and implement active safety systems by (i) harmonising and communicating active safety functions; (ii) identifying technological needs and focussing on essentials; and (iii) preparing architectures, roadmaps and standards.[21]

[17] Summary document titled 'Overview of Future Trends' – see http://www.transportvisions.org.uk/documents/pdf/V2030-15_Overview_of_Future_Trends-24Apr02.pdf
[18] See http://www.prevent-ip.org/
[19] For publications see - http://www.prevent-ip.org/en/public_documents/publications/
[20] http://www.aide-eu.org/
[21] http://www.adase2.net/

A corresponding EC transport project, situated within the 'i2010: European Information Society 2010'[22] proposal, considers the 'Intelligent Car' as one of the 3 flagship initiatives. The *i2010 Intelligent Car Initiative*[23] aims to research intelligent vehicle systems which utilise radar detection systems; hands-free autonomous systems; 'CarTalk' inter-vehicle communication; and in-vehicle emergency communication systems such as eCall (EU, 2006). Communicative network infrastructures are being designed as part of the future visioning of a new kind of post-automobility system within Europe.

These vehicle communication and safety technologies seek to extend beyond the individual car unit to connect with other 'cars' in the immediate vicinity, in a car-to-car communication network that forms a *nexus* that transcends the present car *series* system. Rather than cars operating in Euclidian geometry, a pre-complexity approach, non-Euclidean mobile spaces will be opened up through networked communications operating in real-time between cars in transit, similar to swarm behaviour. *Swarm Intelligence and Traffic Safety*[24], a project under development at CalTech by Yizhen Zhang and Alcherio Martinoli, is based upon complexity notions of how natural systems aggregate[25]. The aim of such safety technology is to take some degree of autonomy away from the driver so that response-reaction times can be quickened under such automation. In other words, the cars take on some of the responsibility in communicating their presence to other cars similarly to how people signal their presence to others within a social context. A new development by a German research project envisions a peer-to-peer network for vehicles on a road passing data back and forth (Ward, 2007). Likewise, the 'Car 2 Car Communication Consortium'[26] is a non-profit organisation set-up by several European vehicle manufacturers for researching and developing road traffic safety by means of inter-vehicle communications. Already 'Audi, BMW, DaimlerChrysler, Fiat, Renault and Volkswagen have formed the Car-2-Car Communications Consortium to seek consensus on standards for dedicated short range communication (DSRC) communication' (Bell 2006: 148).

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[22] http://europa.eu.int/information_society/eeurope/i2010/index_en.htm
[23] http://europa.eu.int/information_society/activities/esafety/intelligent_car/index_en.htm
[24] See http://www.cnse.caltech.edu/Research02/reports/zhang1full.html
[25] And see Michael Crichton's novel *Prey* for more on swarming.
[26] See http://www.car-to-car.org/

Longer range communications will be supplied by orbital infrastructures in the form of satellite networks. Europe, in a move to divest itself of dependence upon the US military GPS system, will move to the Galileo satellite radio navigation system[27]. The European consortium behind Galileo also involves China, India, and Israel. The objective of the system is to ensure it has interoperability and compatibility with the US GPS system. Negotiations with the Russian Federation are also ongoing to agree on co-operation strategies with the GLONASS system[28]. Galileo is due to become operational in 2008 yet is currently 2-3 years behind schedule. The Galileo system is based on a constellation of 30 satellites in constant communication with ground stations in order to provide information on vehicle location, real-time navigation, speed control, and potentially pay-as-you-go cost tracking. As part of the assemblage we expect to see ground networks embedding vehicle transport into systemic communication infrastructures. Overall, this will include short range car-to-car communications merging with cellular and radio frequency identity (RFID) transponders interfacing with satellite and state transport data systems (see Bell 2006). Once Galileo becomes operative it will facilitate a tremendous shift in how transport mobilities and infrastructures are managed. It should not be underestimated how the power of the Galileo satellite radio navigation system will contribute to shifting present transportation structures into a digitised network infrastructure.

On a more localised scale it is likely that in-car multimedia platforms and interactive communications will be designed *into* the driver experience. This may include such applications as personalised displays with wireless Internet connections for accessing the Web and emails on the move, and for video conferencing (this may initially only be for passenger access, yet this may change depending upon the degree of driver-automation). With digital wireless access such activities as online transactions, home-office-car computer synchronisation, and schedules/meetings can be managed whilst on the move, making the 'smart' automobile more of a mobile-office thus efficiently utilising traffic time. Similar proposals were stated in the UK Foresight report under the scenario of 'Perpetual Motion' which considered a future of high-density urban sprawls set against relatively low-density suburbs. In this scenario 'Everyone is plugged into the grid and is 'always on', always in touch, and ready, willing and able

[27] See - http://ec.europa.eu/dgs/energy_transport/galileo/index_en.htm
[28] http://ec.europa.eu/dgs/energy_transport/galileo/international/cooperation_en.htm

to travel using clean forms of energy' (Foresight, 2006a: 10). Technology innovation is likely to lead to increased flows of personal information and communications 'on-the-move', with 'always-on' being a required feature by a majority of business travelers. This may further the development of automobiles that are connected in 'real-time' to events and environmental changes. These technologies not only are planned to improve road safety records but also to signal a shift in how communicative networks in future automobilities will be augmented. Increasingly the environment is being brought into the networked infrastructures of transport so that the car of the future may be less an individual unit than today and more a networked object. 'Smart' vehicles may come to form part of a constantly communicating web – or *nexus* – of information; as coded network-nodes moving through pervasive digitised 'space'.

Already transport/social environments are shifting towards increased convergence in coded space (Thrift and French, 2002) and embedded intelligence:

> we treat embedded intelligence as an abundant resource, having almost zero marginal cost, that will be deployed throughout society. This goes hand in hand with the continued expansion and development of the online world as we already know it. It is this availability of a pervasive computational mesh that makes intelligent infrastructure systems possible. (Sharpe and Hodgson, 2006: 10)

Such a 'computational mesh' will be served by sensors that are decreasing quickly in size, cost, and capability. Already they are being used in a range of applications from environmental and agricultural monitoring; personal health monitoring; and embedded in mechanical components such as airbag sensors (Sharpe and Hodgson, 2006). These micro-electromechanical systems (MEMS) will 'increasingly be built into more powerful and tiny computational devices that can network together to create a dense mesh of sensing and computational power. A smart road in the future will be able to create a whole sensory "world" for vehicles that travel on it' (Sharpe and Hodgson, 2006: 12). Research is also making progress into nano-electromechanical systems (NEMS) that will enable environments to be made 'smart' at the nano scale. When this is achievable, the networked infrastructures will be pervasive and invisible to everything but the sensors. This direction will open up the environment to the possibility of 'smart matter' (Sharpe and Hodgson, 2006).

The intensity of such networked systemic flows will be increasingly mediated through software, which creates complex forms of automated spatiality (Thrift and French, 2002). The architecture of the surrounding environment will thus form a part of the intelligent networked infrastructures that will allow mobilities through coded spaces, as discussed in depth later. This shift will have been made possible through the processes already stated: growth in digital technologies; rise in complex, systemic thinking; the need for secure spaces; and the necessity to move away from individualised and *unrecorded* forms of mobility that are contributing to climate degradation. Such a re-configuration of existing infrastructure systems will be expected to lead to increased capacity, greater efficiency; increased safety and security; decreased environmental impact; and an improved longevity. A recent UK Government research programme on 'intelligent infrastructure systems'[29] stated the benefits of improved and 'intelligent' infrastructures would be:

- Increased automation
- Proliferation of information and communications technologies such as sensors, microprocessors, GPS and RFID tags
- Increased and improved communication and connectivity
- Greater integration between different transport modes
- Increasingly attractive, efficient and reliable public transport
- Potential changes in the nature of travel
- New energy technologies, e.g. hydrogen fuel cells

(Foresight, 2006b: 40)

The development of such infrastructures requires networks, control systems, built-in resilience, transportation hubs/nodes, pervasive software, and regulated forms of social management. Also of concern is the potential of national transportation systems to be transformed into a westernised form of centralised control obsessive with security and stability mediated through digitised networks of surveillance and

[29] http://www.foresight.gov.uk/Previous_Projects/Intelligent_Infrastructure_Systems/Index.htm

management (Network, 2006). Concerns of privacy may well be lifted onto a wholly new level – an era of post-privacy where access through mediated spaces requires giving up privacy; to submit details of personal information in order to gain *passage of access.* We return to these issues later. We now discuss how 'smart cars' are facilitating an increase in the sharing of the space of the car.

iv) De-privatisating the car: New 'smart' technologies are enabling how people can flexibly share, schedule, and access de-privatised cars being offered by the rise in car-sharing car clubs. The offer of flexibility within the increasing need for sustainable practices encourages the demand for urban car-sharing schemes. Already there are significant moves to de-privatise cars through car-sharing, cooperative car clubs and smart car-hire schemes (see *inter alia* Hawken, Lovins and Lovins 2002; Motavalli 2000). Even by 2001 six hundred cities in Europe had developed car-sharing schemes involving 50,000 people (Cervero 2001); prototype examples developed in La Rochelle (Liselec), in northern California, Berlin, and Japan (Motavalli 2000: 233). In Oxford there is the UK's first hire by the hour car club scheme named Avis CARvenience. There are various other car clubs such as CityCarClub, Car Plus and Carshare. Two US car sharing companies are Flexcar and Zipcar, yet in the United States it is estimated that there are just over 1,000 shared cars in all (Rosenthal, 2007). One of the largest single companies, Mobility, is well-placed within Switzerland, and currently has 60,000 members and 2,400 cars, whilst in the Netherlands Greenwheels is experiencing increasing popularity. Car-sharing clubs usually involve smart-card technology to book and pay, with flat monthly fees and a pay-as-you-drive costing. The ease and flexibility to book a car on the (mobile) Internet will be attractive to many potential users.

In the past few years car-sharing has also become more significant in Switzerland, Germany and the Netherlands, where it has been commercialized by a small number of companies (Rosenthal, 2007). As urbanised centres face increasing residential parking problems, as well as congestion, cities in Europe, North America, and Asia - from Singapore to Turin to Minneapolis - are turning to car-sharing practices on a commercial scale. In January 2007 the European Union held a conference in Brussels to promote car sharing. The Report stated that 'We see a big potential for European cities', estimating that 'at least 500,000 private vehicles could be replaced in Europe by car sharing' (Rosenthal, 2007).

More unique and customised forms of participatory car services are also appearing due to the use of Internet capabilities. One of these in the UK is 'Peasy – Car Parking Made Easy'[30] which is an online site for people to book – or offer – car parking space within the United Kingdom. Peasy's mission statement is 'to provide a platform to enable people to travel to locations more efficiently and easily through enabling the spread of information and utilising underused resources'[31]. This type of scheme works similar to an online marketplace where people can also offer their own parking spaces for strangers to use and can enter negotiations over price based on short-medium-long term requirements. Peasy also advertise that 'Homeowners can also sign up and offer their underused driveway, garage or secure parking space for rent, thereby earning a significant additional monthly income'[32]. Such services make it easy for people to participate in distributed schemes and certainly make for an attractive financial incentive.

A similar online service is currently being offered for residents of New York City (soon to be expanded to Brooklyn and Boston) through Hitchsters[33]. Hitchsters.com is an online service that connects travellers so they can share taxis and split the cost to and from a local airport. The site claims that 'In many places taxis are the most convenient form of transportation between metropolitan centers and airports, but they are expensive, too. The *hitchsters.com* matching system (patent pending) makes riding in a taxi more affordable, more environmentally friendly and more fun'[34]. Hitchsters allows prospective taxi-sharers to look-up a co-rider on an online notice board or to leave their information. As soon as a share becomes available the person is contacted by both a text message to their mobile phone as well as an email giving first name and mobile number of the co-rider to contact. As an added security the company states that it preserves the phone number of all successful matches in case of disagreements. Gender specific co-riders can also be specified.

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[30] http://www.peasy.com/Home.aspx
[31] http://www.peasy.com/About-Us.aspx
[32] http://www.peasy.com/About-Us.aspx
[33] http://www.hitchsters.com/
[34] http://www.hitchsters.com/allabout.htm#about

It is developments in these areas of innovative de-privatisation schemes and organisational technologies that, we argue, may likely form a more visible addition to car mobilities and which will be significant for how auto-networks are constructed within a post-automobility scenario. Also, such schemes are not only restricted to urban areas. For example, in the UK in rural areas car-club schemes have been initiated by The Countryside Agency in order to mobilise community members whilst reducing private car use and ownership (Countryside-Agency, 2004). Such car-clubs have been established in Cornwall, Devon, Wiltshire, West/North Yorkshire between 2002 and 2004.

These developments reflect the general shift in contemporary economies from what Rifkin terms 'ownership to access' as reflected by the delivery of many services on the Internet (2000). This could potentially favour the increasing payment for 'access' to travel/mobility services rather than the owning of vehicles outright. One important consequence is that if cars are not domestically owned then the coops or corporations providing 'car services' would undertake both the short-term parking and especially the long term disposal of 'dead' vehicles. The former would significantly reduce the scale of car parking needed since vehicles would be more 'on the road', while the latter would radically improve recycling rates (as demonstrated in Hawken, Lovins and Lovins 2002). Overall with improved digital management and securities it is possible to propose within post-automobilities a notable shift from cars as owned and driven by individuals, to de-privatised vehicles owned either by cooperatives or corporations and 'leased'. This change may itself be reflected within newly emerging transport policies. Car drivers who retain the use of their private car for urban journeys are likely to be impacted by how digital systems will individualise their movements and costs.

There is little doubt that transformations in the transport sector are seen as being urgently required. A constant flow of governmental reports in most societies demonstrates this. Re-structuring future mobility forms are high on various policy agendas and are part of a potential post-car assemblage.

v) New Transport Policies & Costing: This Report considers that a shift from the present car 'system' into a post-automobility 'system' will entail a noticeable move away from predict and provide models in car transport which were based upon increased mobility as a desirable good towards new road schemes developed by engineers. These new road schemes, we argue, will be embedded within the emerging practical discourses of digitisation, sustainability, and security. New road schemes are also likely to be networked within other systems and routes of travel. One example is the EU project *The Trans-European Transport Networks* , TEN-T:

> By 2020, TEN-T will include 89 500 km of roads and 94 000 km of railways, including around 20 000 km of highspeed rail lines suitable for speeds of at least 200 km/h. The inland waterway system will amount to 11 250 km, including 210 inland ports, whilst there are a further 294 seaports and some 66 airports. (EU, 2005: 7)

'New realist' policies involve many organisations developing alternative mobilities through integrated public transport, better facilities for cyclists and pedestrians, advanced traffic management, better use of land-use planning, real time information systems, and a wider analysis of how transport impacts upon the environment (Vigar 2002). In particular, we see 'western' transport policies increasingly influenced by alternative models of transport such that of Curitiba (in Brazil). This model involves separating traffic types and establishing exclusive bus lanes on the city's predominant arteries. As a result there is a safe, reliable, and efficient bus service operating without the hazards and delays inherent to mixed-traffic bus services and with fewer delays to car routes. And there is the densification of development along these bus routes. Over a thousand buses make 12,500 trips per day, serving 1.3 million passengers. And there are five different types of buses operating in Curitiba including a new 'bi-articulated' bus on the outside high-capacity lanes. Bi-articulated buses - the largest in the world - are three buses attached by two articulations and capable of carrying 270 passengers.

Similar transport innovations are under development in Guatemala City; Pune, India (launched December 2006); Bangkok; Santiago, Chile; and Lagos, Nigeria (April 2007) (Transport-Innovator, 2007). Such developments may help to ease some of the inner-city heavy traffic as car drivers will be encouraged to use these modernised and efficient bus services. The city of London, UK is already investing in a new fleet of energy-efficient buses, including several hydrogen powered buses. However, the pattern of ‘public mobility’, of the dominance of buses, trains, coaches and ships, has been irreversibly lost because of the self-expanding character of the car that has produced and necessitated individualised mobility based upon instantaneous time, fragmentation and flexibility. Hence the need for urban areas to invest in some form of car-share and flexi-hire schemes.

Incoming transport polices in regions of dense urban infrastructure are likely to increasingly turn to digitalised transport management in order to re-configure and re-construct the type of systems that will surround individualised car mobilities. It is expected that a ‘post-automobility system’ will be embedded in a range of networks that will qualify, quantify, and calculate cost, to an unprecedented degree for the post-car user. From car insurance to road pricing and car emissions, the road user may be subject to continual monitoring and individualised cost restraints and responsibilities, if they choose to be ‘on the road’. ‘Intelligent’ road usage requires educating the car driver to make ‘smarter’ individual choices about when to travel and how to make those journeys. Car ‘performance’ is likely to become more enmeshed within management systems that favour capacity, safety, security, and data-basing. This will entail new ways of privatising and costing road use that will be presented in terms of supporting the car users’ ability to make smart decisions on where and when to drive.

Car insurance will increasingly move over to a ‘pay-as-you-drive’ scheme which has already been rolled out in late 2006 by Norwich Union. In this scheme customer cars are fitted with a data box that gathers information on mileage, time of travel, speeds, direction, and from this information the customer will be billed accordingly as an individualised driver. Police authorities have also expressed a wish for these technologies to be openly used as the data stored by vehicles can provide important evidence in the event of crashes and other road accidents (House-of-Commons, 2004). Norwich Union believes ‘the technology should be used to monitor, encourage, and ultimately reward behavioural change’ (House-of-Commons, 2004: 42). Factors behind the push for individualised ‘behavioural change’ will be, as stated, environmental and security concerns. This may be supported by a carbon ‘credit card’ system for personally monitoring carbon expenditure while travelling (Wintour and Seager, 2006). Policies may be enforced to monitor also the privileging of access as the physical-digital infrastructures increasingly regulate social practices of mobility and movement, which may invariably lead to inequalities (Graham and Marvin, 2001; Graham, 2002; 2004a).

New transport policies likely to come into effect in future decades will take into account security issues requiring systems for identity recognition. Also included will be measures to tackle general crime such as theft; this may involve remote immobilisation. Electronic Vehicle Identification (EVI) allows for the identity of a vehicle to be read and recorded remotely. This will be promoted as providing security against uninsured, unlicensed, and untaxed driving; thus ensuring that all road users are legitimate and protected, safeguarding against unregistered drivers. However, once these measures are accepted in the public domain they may pave the way for more draconian policies. Already the Association of Chief Police Officers and the insurance industry have expressed a desire for electronic identification that extends to drivers through biometric recognition systems (House-of-Commons, 2004: 43). Such a system may involve in-vehicle biometrics that checks the driver before permitting car use, such as in deterring those with above acceptable blood alcohol levels. The Association of Chief Police Officers and the motor industry are also developing a technology that will allow for external third parties to enforce remote immobilisation of stationary vehicles in the event of criminal misuse and illegal behaviour (House-of-Commons, 2004).

The transition to a low carbon economy will likely see rises in fuel duty in the short-term to fund these transport changes in infrastructure and systems, and to provide disincentives to ‘improper’ drivers. Managing supply and demand in future transport will be crucial if the transition to more intelligent infrastructures is not to be chaotic. Without sufficient changes journey times may increase on both urban and rural routes, with increased congestion during peak travel times. Issues of concern here are road space allocation which may lead to prioritising journeys into essential and non-essential movements, as well as freight movements. This suggests that

> The management of the highway transportation system in its totality will become highly automated and increasingly real-time…New technologies will allow for real-time pricing of transportation facilities to increase efficiency, make better use of spare capacity, and reducing congestion delays. This will be supported by systems that dynamically control and advise traffic on the network to maintain traffic flow without adversely affecting the local environment. (WSP-Group, 2003: 9).

Transport policies for the future are shifting towards providing capacity, safety, security, and data basing. This can be achieved through intelligent network infrastructures that interact with road vehicles and their users. Whilst this may appear as leading down the road to a 'control society', it may be an unintended outcome of how these technologies have become enmeshed within social practices. It is presently unclear whether these digital technologies will be used for benefit and gain or as part of clandestine and covert strategies.

Thus, car mobilities may become transformed from a *series*, or sequential platform that is only loosely connected to a social fabric of people, objects, environments, information, and mobility, into a *nexus*. This *nexus* will construct automobility futures into complex assemblages of networked structures, both natural and digital, that will combine individualised and social components into a multiplexing arrangement of interconnectivity and embodied movements. We refer to this as a transition to *the digital nexus of post-automobility*.

Chapter 3: A DIGITAL NEXUS

The processes previously outlined within the auto-assemblages chapter constitute the changes that may possibly facilitate a shift from the present car 'system' to a post-automobility 'system' which this Report terms as a *nexus.* The central feature of this *digital nexus* is the arrangement of interconnecting physical/digital networks. The new 'mobility paradigm' for studying social phenomena considers the material changes brought forth through merging connectivity as physical and digital networks that are being made and remade at increasingly accelerating speeds (Sheller and Urry, 2006). This paradigm also examines how technological infrastructures will enable people to be more individually mobile in physical-digital space whilst forming increased small world connections and dynamic networks 'on the go'. This provision can be met by the development of existing technologies of communication into newer technologies that will facilitate interfaces between a person and the physical-digital space through which they seek transit. The UK Foresight report on intelligent information systems stated that

> The rapid development of new technologies in areas of location, communications, sensors and control are providing and will continue to provide ways to better achieve current policy objectives and to enable the evolution of new policies which reflect changing social, economic and environmental circumstances. The application of Information Technologies (IT) can revolutionise the way that people and goods move by reducing travel times, operating costs and environmental impacts, and by improving accessibility. (McDonald and Li, 2006: 1)

In this section of the Report we describe in more detail some of the digital innovations, specifically the digital infrastructures, which may help to shift towards a *digital nexus* system of post-automobility.

Technologies that relay information, such as sensors and road cameras, are part of the early networked infrastructure that may lead to more distributed and pervasive computerised environments. This scenario of pervasive computing may be conceived as a form of ambient intelligence; a rich sensory web of data that, by 2050, could facilitate the flow of exabytes of data every second. One report foresees the following scenario:

> This data flow within the infrastructure will far exceed what humans are processing. Automated vehicles all communicating with the smart roads and with each other and back-end services will create a completely new information environment within which intelligent infrastructures can be built. The delivery of this sort of rich, deep and intense computational power over the network, known as grid computing…will take many standards and systems to make these things work between organisations and across the many technologies needed. (Sharpe and Hodgson, 2006: 13)

Research into these standards and systems is already at the advanced stage[35]. Grid computing is also one of the critical drivers towards autonomous agent based systems. Other critical drivers include the semantic web; peer-to-peer computing; ambient intelligence; autonomic computing; and complex systems. A major EU Co-ordination Action report – 'Agent Technology Roadmap' - defined the agent-based approach as

> an agent is a computer system that is capable of flexible autonomous action in dynamic, unpredictable, typically multi-agent domains. In particular, the characteristics of dynamic and open environments in which, for example, heterogeneous systems must interact, span organisational boundaries, and operate effectively within rapidly changing circumstances and with dramatically increasing quantities of available information, suggest that improvements on traditional computing models and paradigms are required. Thus, the need for some degree of autonomy, to enable components to respond dynamically to changing circumstances while trying to achieve over-arching objectives, is seen by many as fundamental. (Luck, McBurney, Shehory and Willmott, 2005: 11)

This definition is close to how transport may be defined, as people and goods moving through systems of dynamic yet ordered spaces in flexible autonomous action. Other reports consider autonomous agents as being of great importance to intelligent transport infrastructures:

> As we make this transition to agent-based systems, we discover ourselves to be in a completely new area, where we become interested in the way that collections of quite simple agents can exhibit 'emergent' properties that enable them to act together in powerful and adaptive ways. Ant colonies are a classic example, where complex foraging activities emerged from individual actions.

[35] See the Global Grid Forum - www.ggf.org

> When these ideas are mapped onto the components of our infrastructure – network switches, for example – we can start to talk about 'self-healing' infrastructure systems (Amin, 2001). Agent-based approaches can also be used for very powerful simulations of the real world, helping us to understand flow patterns under different conditions (Sharpe and Hodgson, 2006: 14)

As stated at the outset a complexity approach to understanding systems and networks is one of the key processes in the transition to a digital nexus of post-automobility. Autonomous agents are designed to develop emergent properties as they act together within intelligent surroundings.

The possible move to increasingly intelligent surroundings (referred to as 'ambient intelligence') is considered to be an emergent feature of pervasive, ubiquitous computing, or 'Everyware' (Greenfield, 2006). A transition to greater programming power may be the stage marking the move into an embedded environment of connectivity whereby objects, places, and spaces will be invisibly – and often wirelessly – linked to an intelligent network or Web. Once the computing power and grid is in place it can be employed and expanded upon at marginal cost, making intelligent infrastructure networks possible and sustainable. Such an environment, if it materialised, would drastically alter the material and social fabric of the world people inhabit and move through. The ambient vision describes an environment of potentially thousands of embedded and mobile devices (or software components) interacting to support user-centred goals and activity, and suggests a component-oriented view of the world in which components are independent and distributed. At this stage much of the communication will be conducted machine-to-machine as digital infrastructures organise and manage a multitude of systems, thus pushing many processes into the background and out-of-sight.

Whilst this is a technically feasible scenario it does not take into account how social practices will adapt and/or appropriate particular socio-technical devices. By taking a complex systems approach to these developments we emphasise how systems often manifest unforeseen and unpredictable consequences. The shift towards embedded digital infrastructures will almost certainly not be a smooth transition as systems often react in a non-linear manner to changing environmental conditions. The ambient/intelligent environment is thus expected to be dynamic and to rely on constant feedback mechanisms, making it necessary for autonomous agents to be employed for processing and maintaining complex systemic computational management. The scenario is that autonomy, distribution, adaptation, responsiveness, and so on, are key characteristics of these processes, and in this sense they share the same characteristics as agents (Luck, McBurney, Shehory and Willmott, 2005: 23).

Multi-agent systems which are self-programmable and self-adaptive can be employed within networked infrastructures to compute complex processes and to manage highly complex transportation systems, as well as to model simulations. The complexity of the expected digital organisational management will require that multi-agent algorithms work independently and efficiently. To maintain and sustain this increased density of control an interdependent network of computerised systems will be crucial (Beniger, 1986). Computational capacity at this level will be necessary in order to handle the increased information and data flows created by the linking and connectivity of smart vehicles. Data will need to be processed, analysed, and formatted at unprecedented levels. Already the UK's rail industry has a data warehouse in excess of 12 terabytes (10 to the power of 12) of travel data from ticket sales (Sharpe and Hodgson, 2006). Data within complex networked infrastructures will have to go beyond the stage of storage into efficient utilisation and management. Both hardware and software will need to pass through further developments before the scenarios above are likely to be realised. It is not enough to envision increasing information flows and digitisation if there is not the practical capacity to effectively organise and manage these flows. For this reason, the path of future automobilities is not guaranteed or inevitable.

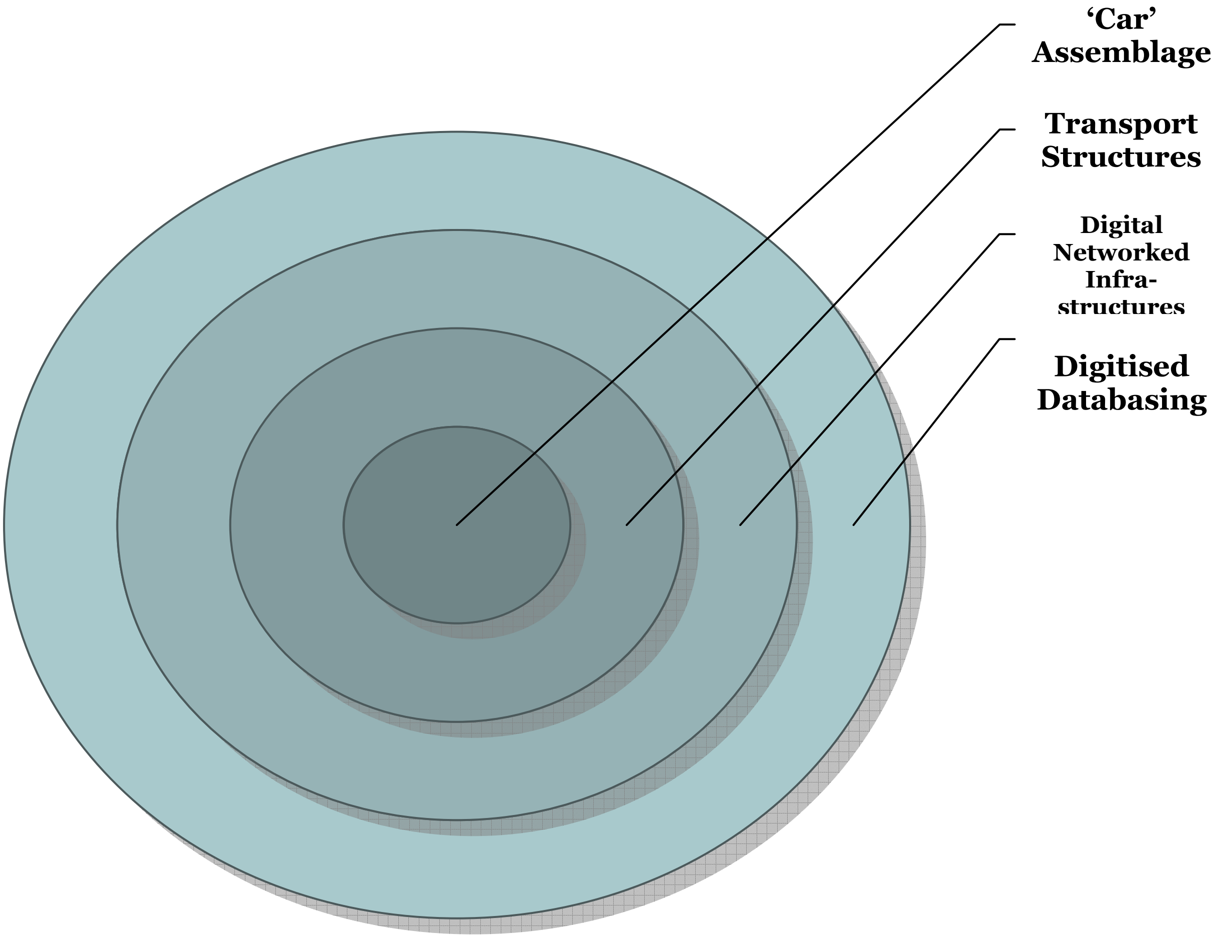
The Foresight Report (Sharpe and Hodgson, 2006) outlines four dominant ideas for their envisioned future: Personal Mobility; Cyberspace; Smart Flows; and Urban Environment. The report outlines a contrast in the mindsets from 20th century to 21st century paradigms, including the following key terms: 'Micro mobility – ultra-personal systems; Low-emission transport; Smart vehicles; Smart stuff; Industrial ecology; Adaptive intelligent infrastructure; Telepresence; Motes; RFID; Fuel cells; Agents, policy and market-based control; Complex adaptive systems; e-hubs; Web services; Data mining; and Sensor mesh' (Sharpe and Hodgson, 2006: 20). This list is similar to many key features that we see becoming part of the digital nexus of post-automobility. Also in similar fashion to the Cyber-Urban Ecology report we consider the dominant areas of automobility futures to be based upon personal mobility; cyberspace; smart flows; and urban environment. However, rather than separate them into ‘dominant’ and yet ‘complementary’ ideas as the report’s authors do, we see them as being mutually inclusive within the digital networked infrastructures we discuss here. In other words, personal mobilities, intelligent informational flows, digitised and coded spaces (ambient environment), and urban scapes (physical environment), may well become meshed into a multi-levelled yet pervasive field that will encapsulate, construct, and conceptualise the ‘social’.

If the transition is successful intelligent networks of the near-future are likely to become essential additions to physical architecture and urban spaces, just as most ‘new technologies’ have been additions to existing technologies, reinforcing the continuing need for newer technologies to exist alongside the old (Edgerton, 2006). As the aftermath of the Industrial Revolution saw an explosion in physical urban infrastructures - improved streets to handle greater traffic; streetcar and rail transportation networks; utility and communications networks (Kern, 2000) – so the digital revolution has piggy-backed onto these existing infrastructures to form what has been termed a ‘city of bits’ (Mitchell, 1995). The meshing of old and new technologies brings with it its own uncertainties and thus a ‘digital nexus’ should not be taken for granted as an efficient ‘machinic’ complex. However, this Report views the older physical transportation infrastructures in technologically developed regions as integrating with digital structures such that ‘the continued integration of the digital and physical infrastructures and the successful adaptation of transportation agencies to a new hybrid infrastructure will require significant institutional and organizational adjustments' (Cluett, 2004: 112).

A key factor in facilitating the integration of digitisation into infrastructure ‘is a set of trends that make IT more affordable, reliable, and powerful than could have been imagined a few short decades ago' (Zimmerman and Horan, 2004: 11). The integration of these infrastructure networks are dependent upon one another, creating interdependence in their flows and resilience that enhance capacities. Zimmerman has observed that ‘the extent of these dependencies appears to be escalating, and that results in interactions among the systems and produces effects upon environments that are difficult to predict. Integrating these services can improve the performance of the infrastructures' (Zimmerman, 2001: 97). It is important to bear in mind that increased system interactions will invariably incur their own unpredictable and uncertain outcomes. This is likely to be one consequence of greater interdependencies.

Such infrastructure interdependencies will increase uncertainties in the complex ways they form socio-technical interactions. It could be said that both global and local flows and interconnections have formed a praxis of *dependency infrastructures*: by this, we mean that complex interrelations in flows of information and organisation have formed systemic dependencies whereby effects do not occur in isolation but rather the system is responsive and open to local/global perturbations. Modern technological urban cities have become machinic complexes of spaces and flows of production, distribution, and consumption; they merge the industrial and civil into socio-technical hybrid systems. Such hybrid systems are formed from transport, energy, media, and other mobilities that are linked into intelligent infrastructures. The cities and urban spaces of developed, and in some cases developing, regions are becoming computerised constructs, increasingly invisibly coded and ubiquitous, especially so in rich societies in the ‘north’ (Graham, 2004b; 2005). We argue that it will be these digital *dependency infrastructures* that will enable/permit, or block/refuse future mobilities. Here we view post-automobility as playing a key role in how the physical landscapes and spaces in urban environments are being re-configured in relation to digital hybridisations of complex efficiency and control.

Below is a diagrammatic representation of the *digital nexus of post-automobility:*



We envisage that transportation networks will demonstrate how a physical world of movement and mobility can be deeply embedded within a digital, computerised environment, and in which neither exists separate from the other. Physical and digital connections will form hybrid linkages that are pivotal to a developing symbiotic socialisation that places symmetric encounters/movements with asymmetric mobilities and networks. Urban architectures will increasingly engage with this fluidity and adaptation to complex and dynamic arrangements and relations between physical-digital situated convergences. The term *transArchitecture* has already been coined by Marcos Novak to signify a 'liquid architecture that is transmitted across the global information networks; within physical space it exists as an invisible electronic double superimposed on our material world'[36] . In a similar fashion Mitchell, in his

[36] See http://framework.v2.nl/archive/archive/node/notion/.xslt/nodenr-127479

'City of Bits', terms the combination of physical structures in urban spaces with electronic spaces and telematics as 'recombinant architectures' (Mitchell, 1995).

Terms such as 'information age' and 'network society' are becoming out-dated as in some cities physical-digital and socio-technical processes are merging into cross-referenced environments. Latham and Sassen refer to these as *digital formations* that identify 'a coherent configuration of organization, space, and interaction' (2005: 10), whereby organization is the ordering of practices and relations among actors. Interaction is the flow of exchange and transmission among actors; and space is the electronic staging of the substance and social relations at play (Latham and Sassen, 2005).Since these configurations require a social context Latham and Sassen term these formations as *sociodigitization*:

> what is rendered in digital form is not only information and artifacts but also logics of social organization, interaction, and space...the character of digital formations depends on the social relationships, practices, institutions, and organizations that feed sociodigitization (Latham and Sassen, 2005: 17)

From this it can be said that 'the digital infrastructure is exerting profound and very complex forces on the transportation infrastructure and travel patterns that are only partially understood at this time' (Cluett, 2004: 111). Complex social systems are in some places increasingly becoming rendered as sophisticated technological artefacts, linking horizontal and vertical mobilities into flows of information and digital database-isation that coordinate, facilitate, or block passage. Infrastructure networks serve as physical assets, as mediating channels that constitute the networked character of modern societies.

The concept of urban space is becoming, or has become, a misnomer: where once space denoted emptiness, it now connotes a coded environment. Thrift and French referred to this transition as the automatic production of space:

> software has come to intervene in nearly all aspects of everyday life and has begun to sink into its taken-for-granted background...here we point to software's ability to act as a means of providing a new and complex form of automated spatiality...what we believe we are increasingly seeing is the automatic production of space. (2002: 309)

These environments are expected to form part of the mesh of intelligent transport systems discussed previously. Software will become as crucial to mobility as sheer physical capacity. Urban structures then will serve as data nodes that will increasingly construct modern technological spaces as inter-textual zones (Thrift and French, 2002). Such a functional calculative background based on complex flows of coded systems will merge and share data with increasingly pervasive digital infrastructures and databases. However, these calculable measures and technical strategies will, by sheer necessity of rendering multiple complexities efficient, be shifted onto the intelligent transport systems that may be brought ‘on-line’ to coerce automobilities into manageable systems.

We now turn to examine a range of social scenarios and ‘manageable systems’ which, to greater or lesser degree, may be necessary for a shift to a post-automobility ‘system’.

Chapter 4: POST-AUTOMOBILITIES

What would a future society be like that was able substantially to slow down carbon impact and the rate of increase of global temperatures? In the Stern Review the kinds of 'behavioural changes' that are necessary to mitigate climate change are weakly described partly because of an individualistic model of 'society'. The Review lacks any coherent sociology of the future (2006). It does not apply systems thinking to 'society' and to the multiple social practices that make up and constitute everyday life especially as those lives might be experienced in a few decades time. Yet if we think such processes through the notion of systems then it is clear that only some exceptionally powerful systems could offset those tendencies that are currently moving the whole earth towards unstoppable global climate change. The positive feedback loops implicated in climate change will need to be confronted with an enormously large and powerful set of alternative social-physical systems.

A major consideration in any social forecasting is how publics respond to the issues involved. Climate-related change, environmental disruptions, and security/terrorism fears are currently high in public agendas. These issues are consistently part of current media as well as political debates and policy. Public awareness of these matters determines not only the response to the circulated facts but also to the perception of the threats and dangers that surround these issues. Bearing this in mind there are likely to be socio-cultural changes and adjustments that reverberate from these concerns. The other pair of processes - digital technologies/pervasive computing and a rise in complex systems thinking – are less publicly visible and are more likely to affect changes imperceptibly at first, or through indirect means. Since the 'green debate' has now become the leading public policy for the UK political parties (as well as within certain other countries) it is likely that some new policies will emerge to reflect these concerns, such as taxing and carbon restrictions. These policies may have some effect upon the social practices of travel and personal consumption. We now examine various social scenarios that may be necessary for a successful shift to a post-automobility 'system'.

i) Travel and Consumption: The rise in public consciousness over climate changes and the foreseeable emphasis upon individualised carbon emission tracking, such as a carbon 'credit card' system for personally monitoring one's carbon expenditure during travel (Wintour and Seager, 2006) and possible carbon trading, may affect how people take their travel-leisure holidays. The UK is currently leading the way in placing a 'green tax' onto such activities as flying in order to discourage Britons from taking multiple holidays amidst a strong growth in low-cost budget airlines. This may affect those with homes abroad, with large families, or low-waged from taking more than one or two annual trips abroad. This could result in a growth in UK mainland tourism. Over the coming decades it is also expected that the rise of Asians as tourists will be significant. Also, that long-haul travel worldwide will increase at an expanding rate (Gilman, Randall and Schwartz, 2007). The result of this is that many more people will be travelling to see much more of the world than before, unless newly implemented international policies and taxes discourage this. Not only will this trend impact upon climate change concerns but also will configure into transportation. In spite of the increased proliferation of information communication technologies these will not yet make physical travel obsolete. ICTs may replace some functions of work travel, to varying degrees, yet is highly unlikely to replace the need for social interactions such as visiting family, friends, and for leisure (Sheller and Urry, 2004; Urry, 2002). Even those destinations specialising in eco-tourism – such as South American and African destinations - may be hit by regional changes such as species disappearance, climatic variations, and concerns from eco-tourists over travelling exceptionally long distances. Under current concerns even eco-tourism is turning out to be bad environmental policy (Monbiot, 2006). Increased financial burdens over 'green tax', coupled with concerns over climate change, may also affect domestic travel and shopping habits, especially if greater taxes are placed upon automobile use.

To facilitate the shift towards a 'nexus' we expect that travel journeys will increasingly be designated into priorities such as higher priority for work rush-hour and children to school and lower priority for shopping and social excursions. These designations will be signified by individual costing of routes and times. In some quarters this may influence more people to work from home via ICTs, as well as affecting business travel. Similarly it may cause some to consider moving their homes to more competitively priced regions, further away from high-priced congestion routes. Shopping is also likely to be affected, with more people turning away from public spaces towards the privacy of their own home. Already in the UK there has been an increase in home deliveries, both in retail and food shopping with the large supermarkets all showing a healthy rise in home delivery. Telematics in transportation infrastructures provide new and improved efficiency in the ways services such as these can be delivered to people in their homes. Many delivery services already implement Radio Frequency Identification (RFID) devices into their products, examples being Wal-Mart and UPS who have spent billions of dollars between them to construct a supply chain of tracked goods from manufacturer to consumer. With increased efficiency in the purchasing, tracking, and receiving of consumer goods it is expected that home online shopping will be a strong growth area (Salzman and Matathia, 2006). Such changes in habits may help to ease traffic along particular congested routes at peak times, as well as shifting the routines of social engagements and physical encounters.

The development in car-sharing and car-clubs, as previously discussed, has aimed to initiate the shift from private car to car-access as part of travel-sharing schemes. Ongoing urban and rural travel management organisation and strategies are needed to be introduced in order to prepare for the re-configuring of car regulations as envisioned for post-automobilities. As well as changes to urban physical/digital infrastructures, social policies should also take into account how residents can manage sustainable travel arrangements. This would need to include more detailed arrangements such as residential parking; whether houses are built without parking spaces; and relative distances to strategic travel points/centres. The shift to a potential digital nexus of post-automobility entails that changes be made to expand the availability, flexibility, and convenience of public transport, and that action be taken in order to provide better amenities to encourage changes to travel habits as well as increased public amiability towards forms of shared and public transport.

Some cities in Europe and North America have been experimenting with bicycle ride-share schemes for localised journeys as well as to facilitate the movement between different city public transports. Cities such as Lyon, Stockholm, and Portland, have taken influence from Amsterdam and have introduced bike kiosks around the city for members to pick-up and use. Generally the cycle-club member pays a minimal annual fee (around 10 euros/$15) for a smart-card that they can swipe at a bike kiosk. Bikes are then rented for up to 2 hours at a time with the first 30 minutes free, then paying for each subsequent 30 minute use (Karni, 2007). A similar scheme is soon to be introduced into areas of New York, with 100 bikes to be placed in each designated neighbourhood. In the summer of 2007 Paris is introducing 1,450 new kiosks which will provide an extra 20,000 bicycles to be scattered throughout the city (Karni, 2007).

A similar new service – termed 'Bicing' – has just been introduced in March 2007 to Barcelona. The 'Bicing' scheme entitles subscribed users to use any of the 1500 available bicycles located across the city's subway and train stations[37]. This service also has a yearly membership fee (6 euros) and provides a smart-card to enable users free use for the first 30 minutes, charging 30 cents per subsequent 30 minutes. This service is used in combination with a network of city public transports that includes energy-saving trams and environmentally friendly subways. The Bicing homepage online provides real time information on bicycle availability by station, city maps, pick-up and drop-off points, bicycle friendly roads and membership information. Since it began operating in March 2007 Bicing has already attracted over 3000 users[38] and provides residents with alternative travel facilities for short-distance localised urban journeys. Alternative mobility schemes such as this and overall improvements to residential travel will be important for shifting towards forms of future networked mobilities.

A 2005 report for the UK government Department for Transport by the Transport 2000 Trust put forth the following recommendations for improving residential travel:

- Reducing the need for car use with benefits in terms of reduced traffic, congestion, air pollution and accidents;
- Improving accessibility and travel choice for reaching local facilities;

[37] http://www.bicing.com/ - For English see: http://www.barcelona-on-line.es/noticies/noticia.asp?idIdioma=2&idPublicacio=1976
[38] http://www.citizen-ecosystem.com/garden/2007/4/8/bicing-barcelona-sustainable-public-transportation.html

- Improving public transport provision for people in nearby developments because of the increased economies of scale;
- Increasing scope for child-friendly housing layouts with fewer roads, vehicle movements and parking areas;
- Complementing nearby travel plans, and possibly even assisting them in achieving more ambitious initiatives;
- Improving access by the wider community to the residential development by sustainable modes of transport;
- Representing good practice and providing an educational tool to help change perceptions about the convenience and benefits of not using the car where alternatives exist;
- Achieving more attractive environments that contribute to regeneration and renewal initiatives;
- Increasing marketability of the development as more households seek to change their travel behaviour. (Addison & Associates, Lilli Matson and Newson, 2005: 8)

Significant here are recommendations for changing housing layouts to assist a shift in car use; educational tools to educate car users; and to make sustainable practices more profitable for the users, with induced benefits. If these changes could be implemented for more localised travel use, then a digital nexus system could be an operational strategy for extended private car travel plans whereby digitised control and management would be required for handling and monitoring complex traffic routing. One scenario that describes more localised and integrated mobile patterns of travel and communications is labelled by the UK Foresight Programme as 'good intentions' (Foresight, 2006a)[39].

This 'good intentions' scenario would constitute a re-configuring of social architecture of technologies and practices. As we have discussed, such a break will be made possible by inserting and combining digitised information *within* systems of movement. In this scenario neighbourhoods will foster 'access by proximity' through denser living patterns and integrated land use. People will live in denser, much more

[39] We adapt somewhat the Foresight scenario here. Details are drawn from Dennis, Urry 2007.

integrated urban areas that will maximise co-presence. Such redesign would 'force' people to bump into each other since their networks will overlap. This scenario would involve carbon allowances as the new currency that is allocated, monitored and individually measured so constraining much physical mobility. Much of the time physical travel would be replaced by modes of virtual access which will effectively simulate many of the affordances of physical co-presence (see Urry 2007: chaps 8, 11). The 'good intentions' scenario is a world in which climate change awareness constrains personal mobility and forces stricter community forms of co-presence, although this effectively ostracises rural dwellers. Also, strict programs of surveillance would be required to restrict people's movements according to their carbon quotas, and intelligent cars would monitor and report on the environmental cost of each journey (Foresight, 2006a). There are some similarities between this scenario and the current designs for the Chinese eco-city Dongtan currently under construction. Dongtan has been designed to be ecologically friendly, with zero-greenhouse-emission transport services, self-sufficient water and energy provisions, and built upon zero energy building principles[40].

The post-automobility scenario does not foresee such strict containment of mobilities but rather an increased systematisation of car mobility rendered within various factors and/or constraints, such as time and route of travel. This means that the context is very different from when French engineers in the 1980s were developing Aramis which promised the advantages of the car – point to point service, no transfers, comfort – but within a public transport system (Latour 1996: 34). This innovation 'failed' but this was prior to the digital revolution. Physical transport has been mostly a matter of engineering possibilities but it is now increasingly 'smart' and this changes some futures.

Personal transport, if it is to shift towards a nexus system, will not be so much transformed through radical re-designs of the unit of mobility, but through the flows of mobility and the embedded *rites of passage* through mediated spaces, including issues of rights of access. 'Smart infrastructure' will be needed to facilitate this embodiment and will require 'cars' also to be 'smart', as discussed earlier. This

[40] See http://www.arup.com/eastasia/project.cfm?pageid=7047 and http://en.wikipedia.org/wiki/Dongtan

development will lead to car navigation becoming increasingly automated with less driver-input. To reiterate, future mobility will be where one is allowed access through mediated spaces that require giving up some privacy through having to submit details of personal information in order to gain access. This may be within the 'north' the only solution to increases in congestion, road usage, and climate and security fears. We refer to this as a post-privacy era. Paradoxically, the transition to distributed and networked infrastructures will necessitate more centralised regulatory measures. The implications here for personal privacy are unambiguous.

It is innovations in 'smartness' that will be one of the preconditions for moving rapidly towards networked mobility systems and the post-automobility scenario. However, a development in the 'smartness' of transport may increasingly shift the car system from a *private space* to one of *privatised space*.

ii) From Private Space to Privatised Spaces: Computer software is already being utilised to cross-reference information databases with communications networks on an automated basis in order to discern queuing and congestion times for premium and non-premium customers (Graham, 2005). Callers are thus categorised and 'privatised' through social-sorting software in telephone customer service practices. In this context physical location influences the priority status of the caller and their access to services. It will only be a small yet 'logically rational' step towards prioritising road users according to location, route, travel necessity, time, and financial status. What we envision as an alternative is a new era of *social-sorting* of post-automobilities through intelligent digital infrastructures that will emerge first in richer and more developed markets. Graham's term for this style of social coded space is 'software-sorted geographies' in which selective access is organized 'through particular topological spaces within sociotechnical systems through which actors have to 'pass' in order that the system actually functions in the way that dominant actors desire' (Graham, 2005: 564). Without these coded assemblages and techniques, much mobility will be rendered inconvenient, if not impossible. For example, levels of road pricing may designate 'high demand urban corridors' that are designed for specific traffic and premium road space, with access to these 'e-highways' being technologically enforced (Graham, 2004a).

The social implications of ‘software-sorting’ may be significant for creating fractured, or tiered, privatised automobilities underneath the seemingly smooth scapes of surface flows. For a post-automobility system to function, access to road space would likely shift to become a privatised and priced commodity, dependent on users having the technology standardised in their cars, and the resources, such as finance and flexible time, to engage with the mobile nexus of individualised yet networked travel. Such travel and mobility infrastructures will need to be interconnected with datastructures which in turn will provide the framework for the corporate privatisation of cities, roads, and cost quantified movement. It may be that post-automobilities will be constructed around further social inequalities and a ‘splintered urbanism’ (Graham and Marvin, 2001).

The days of the automobile being the gateway to ‘unfettered’ freedoms and a spontaneous release and ‘get away’ are surely numbered. This concept of the car is likely to be no longer sustainable in dense urban regions given the increase in car users, and the foreseeable increase in road congestion problems in city areas and privatised routes. The sheer complexity of integrated issues, from individual user rights, individualised pricing schemes, car security, identity validation, etc, will require complex systems of informational databases and coded spaces. We argue that this necessitates a move into datastructures as a dominant form of social-sorting within which mobilities, including automobilities, will be negotiated and ‘permitted’.

Datastructuring, based on the codification of space with database referencing, will be required to transform how movement is enacted through socio-technical systems. Locations and precision routing will be necessary to re-codify the user/traveller/driver within digital time-space coordinates. This is not to imply that codified mobilities will become a forced practice of coercion, or that such social passages will necessarily be uncomfortably noticed by the general legitimised user. The organisation of complex mobilities, and in-built strategies of marginalisation, may be rendered as ‘normalised’ social practices, ever ubiquitous and seemingly rationalised as tools of convenience, efficiency, and effective management. Or, as Graham argues, 'In the medium term it is possible that the language of rights of access and movement may even be replaced by one of provisional mobility where people need to demonstrate in detail why movement and access is necessary on a continuous basis' (Graham, 2001: 415). The digital nexus of post-automobility, as we envision it, will require greater attention being paid to complex systems of rights of access sensitive to securities, intrusions, and threats:

> Digital technologies necessarily play a key role in efforts to enhance surface transportation security through enhanced communication and data exchange. Increased attention is being directed to vulnerability and risk assessments, threat detection, deterrence and prevention, monitoring, human factors perspectives on security, emergency response planning, and training (Cluett, 2004: 100).

In order to ‘enhance’ transportation routes interdependent with security and digital systems we foresee the likely necessity for the rise in private corporations that will emerge to oversee efficient management and control. The privatisation of information, as has already occurred with private credit database companies such as Experian[41], is set to become an area of commercial growth. As ‘knowledge innovations’ grows into a sizable commercial sector, the post-automobility nexus may necessitate an embedded digital network that involves credit/financial data flows that will be fundamental to legitimised movement, in terms of access to routes, car tracking, operational telematics, real-time information flows, and security systems. Similar to how toll-roads in Europe have been developed by the private sector the physical/digital convergence of transport management is likely to be developed by private corporations following capitalist strategies. As profits are central to how corporate institutions run civil enterprises this is likely to spur development of automated and computerised management systems.

This supports our claims, as outlined in this Report, that the shift from a state of automobility to one of post-automobility will involve a parallel shift from autonomy to automation. Intrinsic to the move to increased systemised automation is, we predict, the involvement of corporate growth in the privatisation of spaces; both spaces of movement as well as spaces of information and legitimate mobility. Issues around information privacy, surveillance, and controlled access may not only be centralised by state bodies but is likely to be dispersed amongst a range of private and civil bodies. Central to this is the efficient sharing and cross-referencing of

[41] See http://www.experian.co.uk/

information and data between institutions and their various databases. Emerging physical/digital infrastructure systems, if they are to be successfully adopted, need to be operationally convergent with information communication technologies. Importantly, they need to be integrated into existing social, organisational, and policy systems.

Again, it is important to emphasise that social and urban practices are not determined by technological change in some linear fashion but, as complexity demonstrates, involve unpredictable and often dynamic interplays between multiple forces. This may be in part responsible for talk of a 'paradigm crisis' in urban planning and policy-making (Graham, 1999) as ideas that were useful for planning the 'industrial city' leave little space ‘within these approaches for forces of human agency or urban and telecommunications policy-making at the local level with which to alter the apparent 'destiny' embodied in the telecommunications-based development of a city' (Graham, 1999: 13). What this ultimately implies is that if there is to be an increased convergence of physical and digital infrastructures as part of the privatised social and urban experience in technologically developed regions, then there also is required a parallel development in policy and planning initiatives. Cluett notes that 'transportation organizations lack the skills, training, and often the vision to deal with the demands and opportunities provided by the emerging digital technologies' (Cluett, 2004: 108). Thus, such systems are likely to favour a move towards a privatisation of operation, management, and administration of digital spaces.

We consider that complexity thinking will become significant in shaping knowledge of how networks and systems are privatised, in a way that highlights the dense interrelations and non-linear interdependencies. The future of socio-technical systems, including that of transport, will be increasingly interdependent upon a range of processes. To remain effective such systems must increase in efficiency, organisation, and profitability. This requirement is likely to give rise to what we are terming *dependency infrastructures*. By this we state that increased technological interdependency will be a rational and logical outcome from an ongoing development in increased informational processes and requires the need to control and organise these flows, both efficiently and profitably, as illustrated by James Beniger (1986). The future scenario of a post-automobility nexus is ‘not a deliberate form of oppressive control but an institutional - bureaucratic obsession with function, with the smooth flow of goods and services, and with efficiencies of movement and transactional fluidity' (Wood and Graham, 2006: 182). In other words, mobility requires its own digitalisation as a means of mediating its own organisational principle. These organisational and social interdependencies will thus require their own in-built resilience and security.

iii) Issues of In/Security: None of the processes, analysis, or outcomes set out in this Report suggests that all is set in stone and systems are forever. Using a complexity analysis on current socio-technical trends, possible future(s) seem either poised between a breakdown of current systems and networks through the multiple feedback loops of global heating, threats and insecurities, or a world where a tipping point shifts towards an increased integration of physical/digital systems and networks that work to 'securing' many mobilities and especially the car system, and 'securing' peoples within multiple panoptic environments. Whether 'breakdown' or 'breakthrough', each scenario may then involve many and varied internal inconsistencies, disruptions, and incompatibilities. Neither route is likely to engender a fine-tuned outcome, nor will the transformation be a smooth one. If there is to be a 'breakthrough' to something resembling a post-automobility nexus then we can expect a catalogue of disturbances whilst dynamic processes and systems are updated, developed, and implemented. Security, insecurities, risks, threats, and failure may still provide much of the background to such a transition. One of the reasons for this is that any future society(ies) must bear the legacy of the twentieth century. And the twentieth century saw a series of path dependent mutually adapting systems being set in motion and becoming 'locked-in' far beyond their capacity to deliver a sustainable future, most strikingly within the high energy society. Some of the implications of these path dependent systems are now manifesting in asymmetric disruptions, such as the current geo-political 'war on terror'. Global security and the 'War on Terror' was one of the dynamic processes set out at the beginning of this Report.

Shortly after September 11th 2001 the White House administration requested a report on the vulnerability of critical infrastructures to terrorist attack, including transportation, energy, utilities, financial, informational, leading to the publication in

February 2003 of *National Strategy for the Physical Protection of Critical Infrastructures and Key Assets* (WhiteHouse, 2003). The collapse that followed on the heels of the September 11th 2001 infrastructure disruption served as an important lesson. We have also previously outlined that the fear of in/security will further necessitate individuals being rendered as informational subjects – or data-subjects. The socially coerced submission of private details will need to accompany the post-automobility shift. This will entail a compromise in individual autonomy if smooth passage is required. Yet despite such compromises it is foreseeable that this will lead to what Dutch architect Rem Koolhaas has termed the 'kinetic elites' (Graham, 2002). The 'kinetic elites' are those who, because they travel extensively, often on business, earn bonus points and airport privileges, and are allowed faster access and passage. This can be exemplified by the United States Immigration and Naturalization Service (INS) *Passenger Accelerated Service System* – known as **INSPASS**[42]. INSPASS was a program that ran during the late 1990s until its demise in 2002; its purpose was to facilitate and fast-passage the entry of pre-screened low-risk travellers through immigration and customs at airports. By 1999 the scheme had 70, 000 participants with plans for the program to be expanded (Graham, 2002). However, due to post 9-11 security concerns INSPASS has since been replaced by **NEXUS**, a cross-border initiative solely between the US and Canada. One of the security factors that may have to be built into a post-automobility nexus is the classification of travellers into low-medium-high risk categories as part of their 'mobile identities'.

Security concerns may construct social discourses around the pre-screening of mobile individuals, with privilege access being granted to the so-called 'kinetic elites'; or rather, the time-poor cash-rich and those deemed 'low-risk'. This notion of a kinetic elite 'is leading to an increasingly coded or software-sorted society and 'splintered' urban landscape characterized by highly differentiated mobilities' (Wood and Graham, 2006: 178). The security implications that will loom over social systems are likely to force strategies of control and containment upon movement within more complex and interrelated social systems. Such containment policies are likely to aim towards control over both predictable and unpredictable events – the containment of complexity and insecurities – that can be viewed as also coming close to strategies of

[42] See - http://www.foreignborn.com/visas_imm/entering_us/4frequent-traveler.htm

social sorting. Such strategies as these are likely to facilitate the shift from autonomous mobilities to automated post-mobilities.

However, a shift from autonomy to increased automation, whether via coercion or consensus, may not be a smooth transition as complex systems often react in a non-linear manner to incursions, additions, and perturbations (Gladwell, 2000). The consequences of such a move cannot fully be appreciated or planned for prior to implementation. This is generally the case when technologies are appropriated into the social fold. Whether or not there will be a social privacy-backlash can not be known at this early stage. Another unknown factor is the overall effective functioning of the digital apparatus. High risk technologies inevitably incur their own 'normal accidents' (Perrow, 1984), as well as the hypothesis that people are not naturally well-equipped to deal well with involvement in complex systems (Dorner, 1996). It is important to note that 'when IT is incorporated into the design of infrastructure systems for high performance, it can beget new problems with infrastructures and create unintended consequences' (Zimmerman and Horan, 2004: 3). Coupled with the constant security/terrorist threat against core infrastructures, this makes the issue of resilience and resistance a major concern that will need to be taken into consideration if a digitised post-automobility nexus is ever put in place.

In this context it is necessary to question the resilient nature of a post-automobility nexus, and also whether digital infrastructures will create their own resistance, such as social resistances to privacy intrusions as well as to terror threats. Social resistance to new technologies and alternative social customs have a history. As Edgerton notes, 'Resistance is required. In choosing one technology, society was necessarily resisting *many* 'old' and 'new' technologies' (2006: 9). An important aspect in the resilience of such networks will be how vehicles within the digital nexus can manage secure and efficient transfer of data and information across all the relevant access points within the multi-nodal network infrastructure. As in complex systems, dynamic stability is maintained and sustained if there is an effective flow, sharing, and utilisation of material, energy, or information. Thus,

> Questions are raised about the costs of acquiring and processing the data, determining which data are most important, data quality

> assurance...data storage and retrieval, and how the information can be controlled and security maintained. (Cluett, 2004: 110)

Not only the security of data is at issue here but also the ability to handle and effectively process the huge amount of data/information generated by these new systems of mobility and control. Clearly, software advances are as important as hardware developments here. And just as digital software must coordinate with the physical hardware, so too must digital technologies be effectively appropriated into social practices and everyday mobilities. Despite the opening up of digital spaces the need to have physical and localised existences will continue. The link between digital spaces and lived daily urban experiences must be retained and sustained and built upon rather than replaced. Key questions in this regard must necessarily ask 'how can sustainable, successful and truly beneficial telematics applications be socially constructed in real world situations and in real cities? How do we translate this technological potential into sustainable applications that actually meet the day-to-day needs and demands of a largely urban society?' (Graham, 1999: 29). These questions, and more, are an unavoidable and inherent part of the move, and learning curve, towards a possible digital nexus of post-automobility.

The general position we have taken in outlining our vision of a post-automobility future combines an increasing awareness of issues such as climate change and global security, tied in with an emerging digitisation of place, space, and movement that signifies a shift towards complex embedded technologies that construct social bodies within a panopticon of surveillance and access. What this suggests is that in order for a person ‘to move’ they may need to compromise their privacy in order to access the digital infrastructures. In this post-privacy scenario, as we term it, this may alter how a person coordinates their movements and work/leisure engagements. Whether this will entail a significant shift in behaviours remains to be seen.

CONCLUSION

We began this Report by stating that rapid dynamic changes in several key areas are transforming the physical geography of global regions as well as their interrelations. We initially set out a list of processes that we considered posed significant influence upon future mobilities, lifestyles, and social relations. We identified these as global climate change; global security and the 'War on Terror'; digital technologies and pervasive computing; and the rise in complexity thinking. Through this Report we have expanded upon these to demonstrate how their possible combination and synthesis could impact upon mobility trends within technologically developed regions, specifically upon automobilities. Taken individually they pose significant impact; taken together they have the momentum, power, and potential to create major shifts in how socio-technical mobilities are framed. By taking automobilities, and their transformation, as the focus we outlined how we conceived a possible shift occurring that would take individualised automobility use from a *series* to a *nexus* system, particularly one framed within physical/digital networks. Principally we framed these dynamic systemic changes as shifting the car system from being *autonomous* to becoming post-car *automation.* Furthermore, this transition would take place within a parallel shift towards increased digitisation of physical movement whereby coded environments and software-sorting systems would frame such future mobilities.

The latter part of this Report examined some of the social and political conditions that would help facilitate this shift to a post-automobility nexus. We stated that policies such as a carbon 'credit card' system and possible carbon trading may be implemented to affect how people take their travel-leisure holidays. Also, various 'green taxes' may be applied in countries in the 'rich north' to discourage those activities that use heavy fuel consumption. Social policies are likely to emerge that reward sustainable practices and punish 'offenders'. Further, we emphasized that transport mobilities will require greater management control and efficiency which in turn will foster a move towards increased privatisation of transport schemes as well as privatising personal information into corporate databases, with private credit database companies such as Experian having responsibility over who can travel. All these changes point towards a physical infrastructure of travel that is moving into digitally embedded networks that will monitor, allow, and navigate a majority of future auto-mobilities. Into this there will be considerable changes in localised and residential forms of transport, as yet unrealised. The social and political conditions required to engage in a systemic shift into a post-automobility era have not yet been fulfilled. It is likely that public discourse in such areas as climate change will considerably speed-up these processes.

Over the past few years there has been a significant increase in the debates surrounding the multiple sciences of climate change. Although the scale and impact of future temperature changes are still much debated and, especially in the US and certain developing societies, contested there is growing consensus (as captured and reflected in Al Gore's movie *An Inconvenient Truth*). The scientific evidence is overwhelming, and the recent Stern Review (Stern, 2006) gave the issue economic and political credential. The pressure is most certainly on to change those social habits most damaging to the environment. Undoubtedly, this concerns the nineteenth-century combustion engine motor vehicle. As we described at length there are a range of changes underway that affect the whole car assemblage, from new fuel systems, to new materials, software, transport policies, and smart-car telematics. This hybrid auto-assemblage can be seen to be, in some ways, a reaction to multiple impacts ranging from consumer awareness, political shifts, changing markets, developing technologies, geo-political uncertainties, etc. Moreover, the next couple of decades – according to Stern the key period for combating climate change – are likely to be globally shaped by other system developments that are going to make it possible for particular regionalised socio-technical environments to move towards a digital nexus vehicle model. Into this mix we emphasise the global security situation, specifically the 'War on Terror' and related threats. Fears over security and safety exist at a high level in socio-cultural discourse as well as in the mainstream. It is, in all respects, a post-millennium state of consistent in/securities.

Mobility by its nature represents a moving target, and as such moving targets imply a visibility as well as leaving traces. With more and more mobilities tied up with electronic mechanisms and architectures, not only are more traces being left behind, but also more opportunities for critical infrastructure attack (see White House report, 2003). This may be our own double-edged sword - a Sword of Damocles - social systems have constructed in their push towards increased integration, interrelation, and efficiency. A catch-22 situation is arising that tightens mutual dependencies within a machinic complex; we refer to this as the rise of *dependency infrastructures*. The increased technological developments in computing and software power are helping to establish complex flows of coded systems that may one day merge and share data with increasingly pervasive digital infrastructures. We argue that it will be these digital *dependency infrastructures* that will enable/permit, or block/refuse future mobilities.

Somewhat ironically, the more movement there is, the more the dependency is between individual freedoms and infrastructurally managed restraint. These are times of monitored and manufactured fear presently established around emerging insecurities. In a post-privacy era, access through mediated spaces will require giving up a degree of privacy; to willingly submit potentially extensive details of personal information in order to gain *passage of access.* For example, the UK Government's ID card scheme will contain and integrate 49 separate pieces of personal information and yet it will have little effect in preventing certain categories of terrorist attack[43]. Its introduction has been highly controversial in part because it is based upon a low trust model of the population in which everyone is deemed a potential terrorist. However, the introduction of new technologies is seldom smooth and these multiple impacts are likely to affect mobilities in the short to mid term in a non-linear and unpredictable manner. Thus, it is important to consider how future mobilities, and the 'auto-mobility machines' are organised as a system or set of systems from the vantage point of complexity theory.

The necessitated individualised mobility based upon instantaneous time, spatial fragmentation and coerced flexibility (for much detail, see Urry 2007: chap 6) is seen by us to be potentially shifting from a *series*, or sequential platform, into a *nexus*. This *nexus* may see future automobilities constructed into complex assemblages of networked structures, both natural and digital, that will combine individualised and social components into complex interconnectivities. We refer to this as a transition to *the digital nexus of post-automobility*. Whatever any new system will be like, it will

[43] http://news.bbc.co.uk/1/hi/uk_politics/4630045.stm, accessed 20.03.06. ID cards will have to be applied for if one is seeking a new passport.

substantially involve a focus upon individualised and flexible movement that automobility has brought into being during the ‘century of the car’.

However, for there to be individualised and flexible movement within a digitised automobile nexus there is a Faustian bargain to be struck. And we suggest that this new Faustian bargain has implicated humans in a new embrace, this time with countless digital code and databases. The digital databases that will form the software-pumping hearts of the emerging physical-digital infrastructure convergences by necessity will lock humans within these interdependent ‘databasing’ systems. This ‘dance with the digital’ will signify a post-privacy era in a process of submitting one’s privacy through databasing what had previously been private to each self. Socio-technical progress as implied by the richer ‘Northern’ territories suggests a dependency upon the more extensive *and* intensive ‘database-isation’ of each self. Our argument is that the only way of taming the utterly dominant car system and hence producing a step change in the significance of mobility machines for global climate change is through the conversion of the car system from a series to a nexus system.

Such a development represents a major transformation of the nature of the ‘individual self’, including the threat to the ‘freedom’ to walk, drive or move unnoticed through various environments. However, such a freedom is already transformed through the consequences of the global war on terror as well as the global war on international crime networks. And developing such a model will be significantly contested for both its cost and for its negative effects upon human rights, but this is in a period in which worldwide there is already a hugely heightened ‘securitisation’ of individual selves. So life goes on and indeed extensive co-presence through travel would be still achievable for many, but only because each individual self is tracked and traced and this enables the individualised car-system to tip into a nexus, organic vehicle system (for the enduring significance of co-presence in relationship to travel, see Urry 2007: chap 11).

It may appear that our conclusions offer a stark and ‘dark future’ for not only mobility but social relations in general. Are we ‘predicting’ a dystopic digital Orwellisation of self and society, with more or less no movement without digital tracing and tracking, with almost no-one within at least rich societies outside a digital panopticon and with a carbon database as the public measure of worth and status? Maybe. Yet possible future(s) are just that: they are possible. By taking a complexity approach to these developments we are reminded that system futures often manifest unforeseen and unpredictable consequences in the face of change. This Report examines those changes and marks the paths and patterns that may manifest. We are all in the business of an uncertain future, especially so in these present times. We are all also in the business of imagining sustainable futures.

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