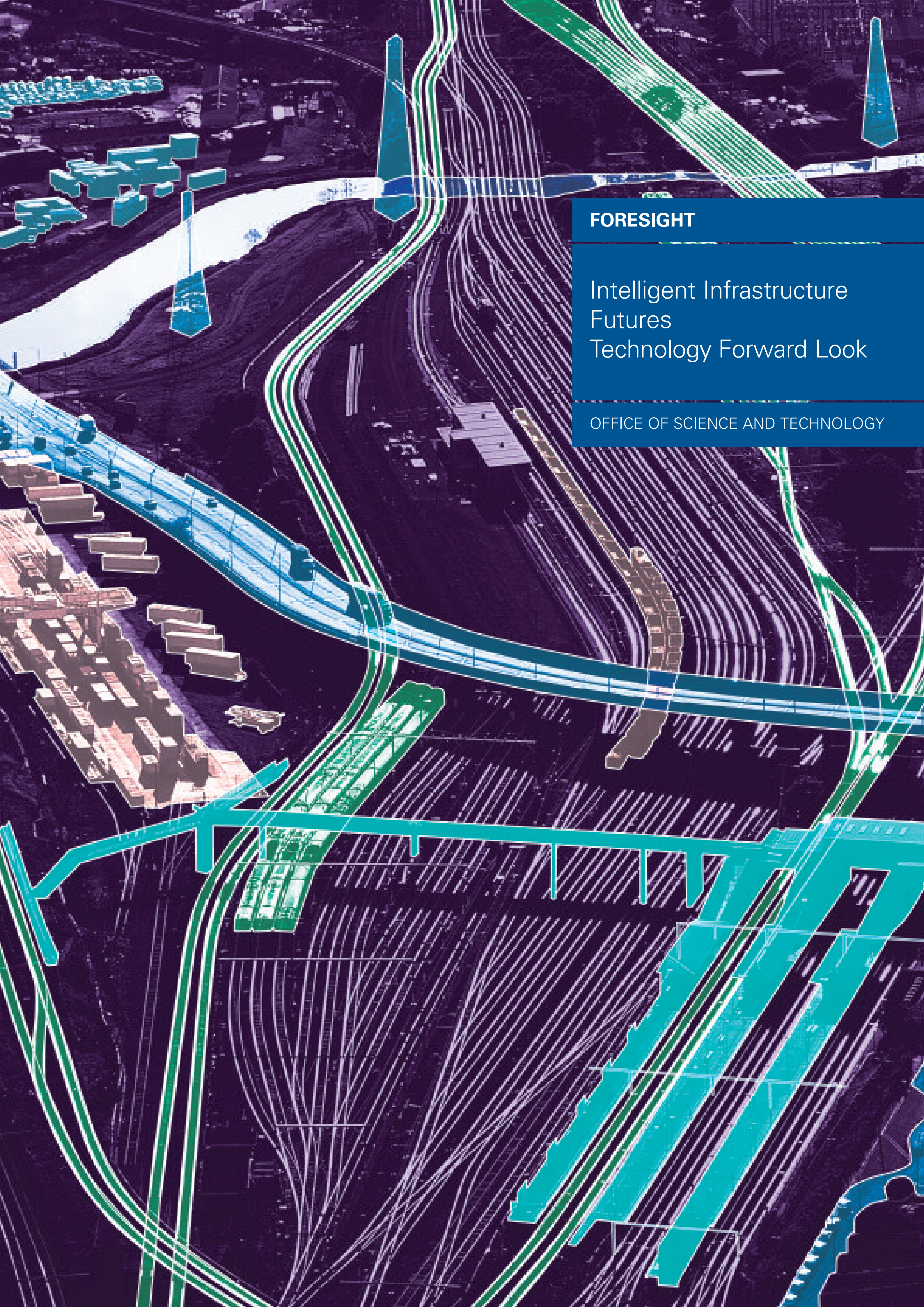

FORESIGHT

Intelligent Infrastructure Futures
Technology Forward Look

OFFICE OF SCIENCE AND TECHNOLOGY

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Technology Forward Look

Towards a Cyber-Urban Ecology

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Contents

Overview

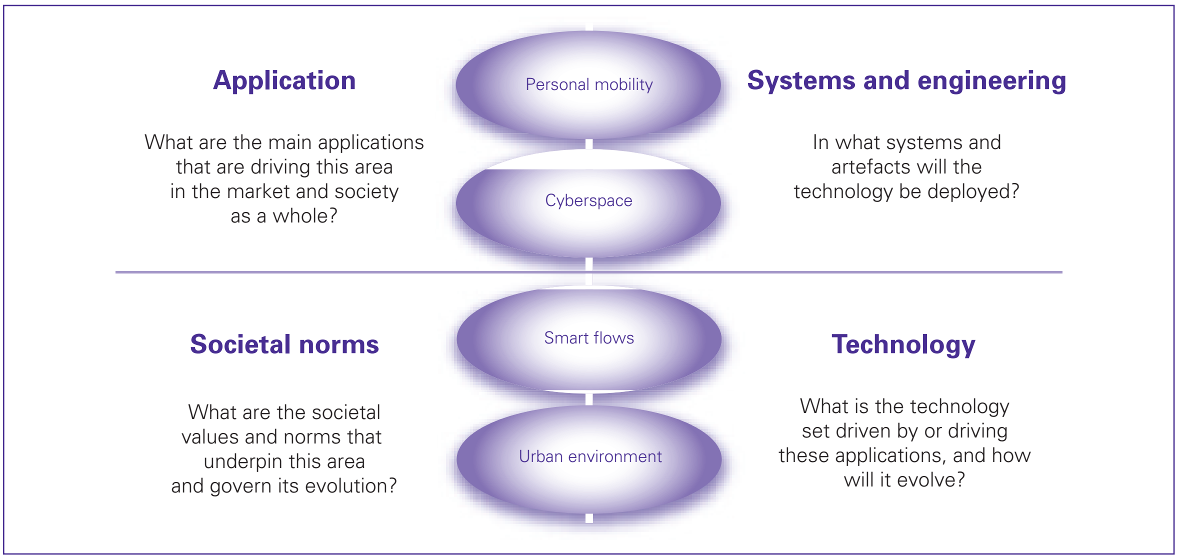
The Foresight Project on Intelligent Infrastructure Systems set out to explore how science and technology could, over the next 50 years, be used to deliver infrastructure for transport, and its alternatives, that would be sustainable, robust and safe. The project considered the three central aspects of sustainability – economic, environmental and social.

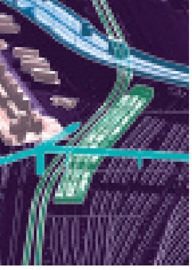
The project looked at the issues in three ways:

- Leading researchers were commissioned to write state-of-research reviews that set out where we stand now and what research could deliver for us now. The state-of-research reviews covered areas as diverse as artificial intelligence and data mining through to how information affects our choices, and the psychology of travel.
- A set of scenarios was produced that provide a range of credible and coherent pictures of the technology we might invest in and how society might react to those investments.
- This *Technology Forward Look* reviews current roadmaps for the development and application of the technology, and considers how that technology could be applied in the longer term.

This forward look therefore sits between the research reviews and the scenarios and provides a way of organising the discussion of the technology and how it influences scenario outcomes. This has been done by looking at the way the development and deployment of technology in society is typically organised around fairly stable and long-lasting assumptions about how we want to use it; and what making the next generation 'better' means – whether faster, more reliable, less polluting, or whatever. This is illustrated in Figure 1 which also shows the four main topics that were identified as providing underlying structure to the scenarios:

Figure 1: Evolution model applied in this *Technology Forward Look*





Personal mobility Our freedom to travel how, when and where we like, under the increasing constraints of energy, congestion and pollution.

Cyberspace The relationship between virtual and physical spaces, and how this relates to the places where we live and work.

Smart flows The global system for managing flows of materials, goods and energy, and how this relates to sustainability.

Urban environment How our approaches to the movement of people and things influence the configuration of the places where we live.

The purpose of this *Forward Look* is to support the scenario exercise by helping to organise the huge breadth of research materials in a way that makes it possible to think about them. It does this in three stages:

Part 1: A discussion of how we need to organise our thinking into three horizons: in the short and medium term, we can use technology roadmaps to look ahead; for the 50-year period, we need to use an envisioning process.

Part 2: A high-level view that signposts the key IIS technologies, built on existing research materials and roadmaps for Horizons 1 and 2.

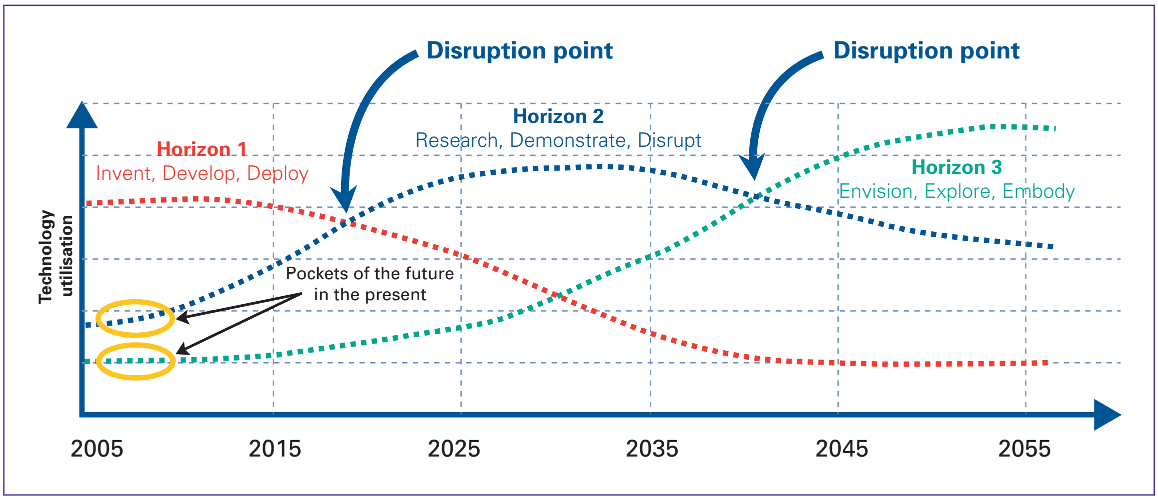
Part 3: A discussion of how the four topics might shape the 50-year future of Horizon 3.

Part 3 sets up a contrast between our current mindset and an alternative view dominated by concerns for sustainability. That view highlights the choices available to us in how we conceive and apply technology. This is not intended to be a prediction, plan, or roadmap: it is a thinking tool to throw light on the choices we might make and approaches that might warrant analysis in more detail.

Part 1

Three horizons: What can a technology forward look do?

Figure 2: Three horizons in anticipating technology developments

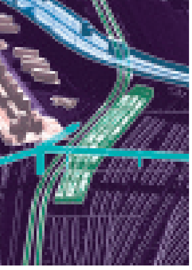


A challenge to be faced in this look ahead is the project time horizon of 50 years, which takes us well beyond the 15–20-year outlook of even major technology roadmapping exercises. To tackle this, the IIS project structured its analysis around three horizons, and these each provide a distinct way of thinking about technology.

Horizon 1 – Invent, Develop, Deploy

This horizon, about a decade into the future, covers the roll out of new, but understood, technical capabilities to solve problems and address opportunities within the dominant socio-technical systems of the present day. It may still involve significant levels of new invention, but of the sort that experts in the field consider to be well within known art or its extension. A lot of the 'smaller, cheaper, stronger, faster, smarter' types of invention lie here.

For example, the well-known Moore's law predicts that we will see the number of components on chips doubling every 18 months or so. The law, which is really a description of a shared intent of the semiconductor industry to meet self-imposed targets by planned invention, is broadly mapped out in the industry roadmap.



Horizon 2 – Research, Demonstrate, Disrupt

This time horizon, looking some 25 years into the future, is the domain of research, invention and market disruption. At any time, you can look at the programmes of major university, government and industrial research labs, assemble groups of experts and build an informed picture of what we probably can and cannot do. This is the centre of gravity of the typical major technology roadmapping project.

Alongside what we can predict, major effects in this horizon come from the emergence of successful new models of technology use that disrupt the status quo. In the IT industry, these disruptions come along every decade or so. It is worth noting that, even when the general trend of innovation is clear, its actual form can be unpredictable. The emergence of the World Wide Web is a good example. In the late 1980s and early 1990s, every major computer company and government had its vision of a connected world and information utility, and was spending large amounts on Research and Development to bring it about. Major research projects were developing a sound understanding of many of the key concepts of distributed computing. Yet the invention of the Web did not flow directly from these programmes. It arose through an inventive step that reconfigured the whole approach, drawing the industry resources around it, and allowing much of the preceding work to find its place in the new model.

Another pertinent example is the recent Defense Advanced Research Projects Agency (DARPA) Grand Challenge for self-guiding vehicles. The challenge was for vehicles to navigate a 132-mile course across the varied terrain of a desert without any human help during the journey. In 2004, none of the entrants got further than 10 miles. In 2005, five vehicles completed the course. The prize has been awarded. The challenge is over. There was not (and still is not), one roadmap for autonomous vehicles. Instead, there is a field of endeavour pursued by a broad community that is testing, in a Darwinian sort of way, many approaches, from which a coherent class of systems is gradually emerging.

In this horizon, discoveries can occur at any time, redefining the whole sense of what is possible. These can then work their way through to new classes of systems and applications. Suppose room temperature superconductors and cold fusion had both turned out to work the way first thought – we would now have a very different technology landscape.

The validity of the forward look for Horizon 2 rests heavily on the peer-reviewed scientific research and the associated culture of research proposals and Grand Challenges. The IIS research reviews are primarily written in this mode.
This document also refers to relevant industry roadmaps such as the Foresight Vehicle Technology Roadmap.

Horizon 3 – Envision, Explore, Embody

'When an elderly and respected expert tells you that something in their field can be done, they are usually right, when they tell you it cannot be done, they are usually wrong.' Robert Heinlein (1973) *Time enough for love.*

When we attempt to look over the horizon of known science and beyond many years of unpredictable invention, what can our look ahead still do for us, and what sort of test of validity is appropriate?

First, if something does not contravene known natural laws, and we really want it, we can try to accomplish it. The use of nuclear fusion for energy is an important case for the current project. Those in the field have a programme of research, and we can construct an outline roadmap for what would be required to engineer commercial systems.

A contrasting example, very relevant to any project considering the prospects of systems with intelligence, is the vision of the 'singularity'. This has been defined in many different ways, but the core idea is that within 50 years we will cross a fundamental discontinuity in history, created by the technological invention of smarter-than-human intelligence. This is much debated, but various dedicated and knowledgeable people hold the notion, and the idea informs the direction of their own work and that of their organisations (e.g. www.singinst.org).

These examples both illustrate that when we reach beyond the known, our 'map' is a commitment to a goal or outcome with some general resources, rather than a pre-conceived plan – just as an exploration of unknown territory has to be. The effect of such a vision is the way it configures the use of resources now in making the initial steps. We can include these visions in our uncertainty map for the construction of scenarios. Such an exercise can legitimately include anything that can be imagined and that would have high impact, with particular significance to those where large resources are already committed to the goal by researchers.

These types of visions have their fulfilment firmly in the future – you cannot use nuclear fusion energy until someone has invented a way to harness it. However, there is a second sort of vision, the one that is embodied in real systems and activity now, with a goal of long-term change. Here, the intent is to bring the future into the present in such a way that it draws research and invention around it in pursuit of new goals – such a vision puts us on a different path. A decision to switch an island totally to clean energy, to living in an urban community without cars, or a commitment to organic agriculture, are examples. These are pursued as societal goals that influence the direction of technology development.

This takes us back to the model of socio-technical systems in the previous section. At any time, society has many Horizon 1 systems that are locked in, and to which resources are allocated to make them better, whatever 'better' means in terms of the social norms around them. Horizon 3 systems are those that are envisioned, explored, and embodied in real-life situations, and which compete for a mainstream role in our future. Many of these will fall away, but some will succeed in their niche, and will attract resources and grow to become the new mainstream.

The term 'pockets of future in the present' is used for these sorts of visions. If you look around, you will find people already living out these futures now, sometimes carving out a place on the margins of society where they are free to experiment. Or, as William Gibson said, 'the future is already here, it just isn't evenly distributed.' Such visions are the stuff of scenario thinking. Here, validity derives from them being plausible, relevant and not violating current knowledge in any arbitrary way. Instances of people exploring sustainable living and car-free models are especially relevant to this project.

As the quotation on page 5 suggests, in Horizon 3 thinking, it is unwise to rule anything out just because we don't yet understand it. This imaginative freedom means that we cannot ground such visions in technology evidence in the ways possible for Horizons 1 and 2. Scenarios are neither 'right' nor 'wrong'. Their primary purpose is to help us see our current situation in a variety of ways and help illuminate the choices available.

IIS three horizons

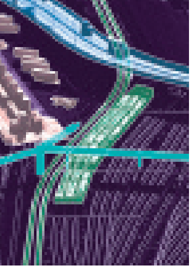
This technology forward look is primarily concerned with Horizon 2 and 3 thinking.

In Part 2, we look at Horizon 2 and synthesise material from the project research reviews and related material into a high-level view of the main technologies that underlie the scenarios.

In Part 3, we look at Horizon 3 and explore what could influence the outcomes of the different scenarios. Our starting point is that the research reviews, project workshops and scenario exercises all demonstrate that the indefinite extension of 'life as usual' is highly vulnerable to the growing constraints of energy availability, pollution and congestion. This is true even when all the capabilities of an intelligent infrastructure are taken into account. In fact, we find a significant danger that by wringing more capability out of our existing systems we may fail to tackle more fundamental issues. Such dangers are illustrated by the sorts of collapse explored in the Foresight scenario, Tribal Trading.

When we look at what influences the outcomes of the scenario, we therefore find it is not so much the availability of any particular technology that matters, but the ways in which we use the emerging capabilities.

This component of the report is therefore intended to help inform thinking about how future applications of technology might come together around a major transition to more sustainable models. In doing this, we are moving to a scenario 'back-casting' approach, in which we try to imagine a desirable state and see what could bring it about. Part 3 therefore sets up a comparison between today's systems and a single instance, derived from the scenarios, of how the future might look. This is not a prediction, plan or roadmap; it is a thinking tool to throw light on the choices we might make and the approaches we might analyse in more detail.



Part 2

Horizon 2: Emerging capabilities

To ground the discussion of the longer term, we first sketch out the main Horizon 2 technology capabilities that underlie the scenarios, as found in the published research and Foresight literature.

Three contextual drivers

Taking a very high-level overview of the scenarios, we can see that our 50-year horizon is concerned with three fundamental technology drivers that are particular to our time: energy, materials, and ambient intelligence. These are called 'contextual' drivers in the language of scenario thinking, because they describe major trends in the overall environment which are not within the control of the organisation that is the focus of the scenario exercise – in this case the UK – even though it might have some influence over them.

Energy

'Energy will inevitably become less available and more expensive than it has been for the last few decades. The change will be permanent. Adapting to this scenario while maintaining the UK's standard of living will require fundamental changes in the way we produce and use energy. All sources of energy will be required.'

Loughhead (2005)

The scenarios include the possibilities of major societal overshoot in energy use, with demand outstripping supply, followed by major societal disruption. So, in this technology forward look, we treat energy as a constraint, and push as far as possible on the responses that would create resilience in our societal systems.

Materials

'The volume of materials flowing through the industrial system into the human economy worldwide is now at roughly the same scale as the flow of materials occurring naturally through global biogeochemical processes.'

Tibbs (2000)

The environmental footprint of human activity is growing rapidly. This statement by Hardin Tibbs indicates that we are already beginning to match natural processes in the scale of material flows we have created. As the world's population grows further, and as the developing world moves towards the same consumption patterns as the developed world, we have to look at what it means for these flows to be sustainable. Volume of flow need not in itself be a problem, but problems arise when many of the effects are left as externalities to the market and have negative environmental impacts. So, as for energy, we explore the idea of a transition occurring in the 50-year period from predominantly linear flows from the environment, through the economy and out into the environment, to cyclic flows which eliminate the externalities.

Ambient intelligence

The third major trend is the deployment of digital processing widely into the environment – what is variously called ambient intelligence, ubiquitous computing, the Internet of things, or just 'smart' technology. Just as the World Wide Web was a one-time transition in the technology landscape, bringing information into a globally integrated system, we are just at the start of another one-time transition, linking up *things* through embedded intelligence and communications.

Most of the world's computing power is already embedded invisibly in the things around us. The personal computers, music players and other gadgets are just the tip of the iceberg. They probably represent no more than 1% of the computing power we have deployed around us. A typical car today will have at least 20 microprocessors and a host of other electronics.

Over the coming decade, this embedded processing will allow any and all of the objects around us to connect to the power of the global Web. On the one hand, the embedded power puts huge amounts of processing power just where it's needed, in sensors and actuators that help to prevent collisions, for example. On the other hand, the link to the Web allows any object, however humble, to be visible over the Web to any applications, and to link into the power of the Web as an information utility to call up any resources needed.

In this forward look, as we move to Horizon 3, 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.

General overviews of this trend are available in the previous technology forward looks for the Foresight projects on Cognitive Systems and Cybertrust and Crime Prevention.

Emerging IIS capabilities

In this section, we put to one side detailed analysis of the user values and societal assumptions that drive these developments and look at where the natural agenda of science and engineering is taking us. In the section on Horizon 3 we return to the underlying social values and look at how these might change and shape the scenario outcomes.

Low emissions and energy-efficient transport

The IIS project is concerned with the movement of goods and people by all forms of transport – road, rail, air, sea, walking, cycling, etc. – and with how the technologies used for them, and the pattern of use between them, can be made sustainable in the long term. Rather than try to cover the huge field of transport technologies here, we only want to place them in the high-level context of the scenarios and point to more detailed reviews.

From the perspective of the IIS scenarios, energy efficiency and emissions of transport are major concerns in the long term:

- Transport was responsible for 25% of carbon emissions and over 50% of oil use across the world in 2003 (IEA, 2005).
- Most transport emissions are due to road travel, but air travel was projected to grow 200–300% between 2000 and 2030 (DfT, 2003).
- 'Middle-income' countries, such as China, India, Brazil and Mexico, are moving towards the levels of automobile and aviation use in developed countries.

The IIS and related research reviews (Köhler 2006, Owen 2005, Foresight Vehicle 2004) all indicate that we can expect major progress in improving the energy efficiency and lowering the emissions of transport, though aviation presents a particular challenge. However, as the reviews by Köhler (2006) and Banister and Hickman (2006) both bring out, these gains are not sufficient in themselves to create sustainable patterns of use. We also need to manage the demand side. The optimistic view is that, if we can put the possibilities of low-emission energy-efficient transport together with more intelligent patterns of use, we will be able to achieve sustainable models suitable for the whole world.

Adaptive intelligent infrastructure

The power of distributed intelligence is that we can blur the boundaries between personal and mass transit. In this way, we can give each many of the beneficial characteristics of the other: cars and lorries can move safely and efficiently by being 'platooned' on high-throughput roads, personal rapid transit vehicles can come to my door, personalised with my choice of music, and then blend back into the mass switching system. The movement of goods becomes the movement of 'smart assets' – things that can have sophisticated controls of their own to carry them through the world, letting them operate in real-time markets, to move to where they are needed most. While we cannot map out the shape of this world in detail, the following headings call out some of the main technical strands that are dealt with more deeply in the IIS research reviews.

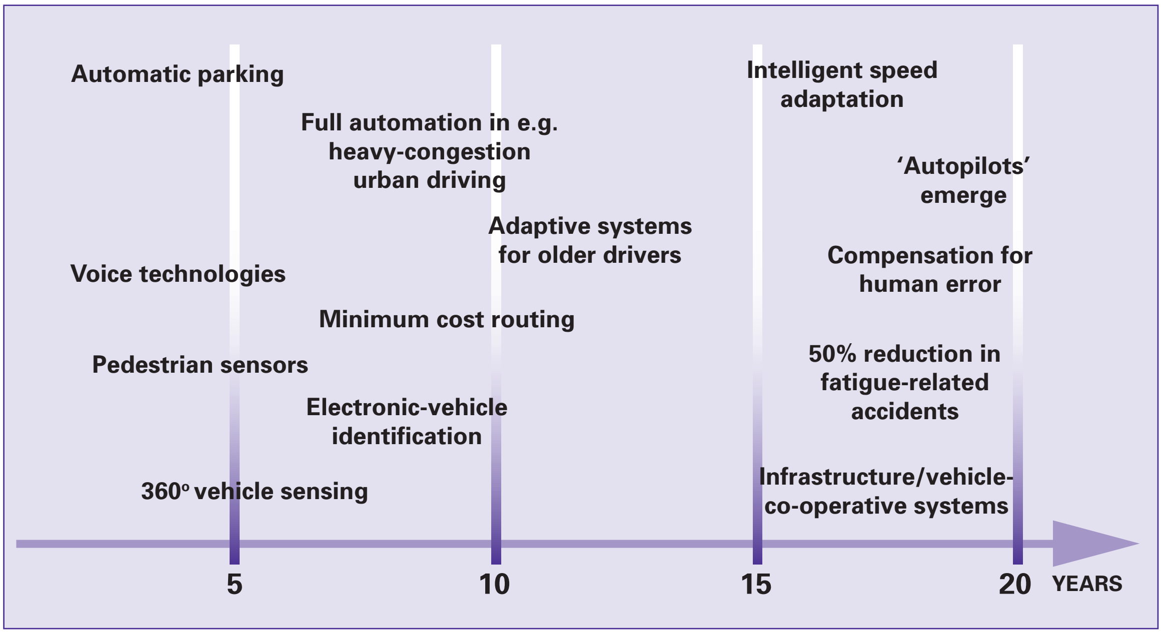
Smart vehicles

'…Now we need to teach them (smart vehicles) how to drive in traffic.'

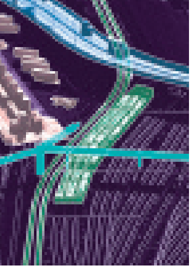
Bradski (2005)

The Foresight Vehicle Technology Roadmap provides a very detailed industry roadmap of smart vehicle technology for everyday travel (Foresight Vehicle, 2004). This goes out to 20 years. Figure 2 picks out some of the main capabilities anticipated:

Figure 3: Foresight Vehicle Technology Roadmap: main capabilities identified



During the course of the IIS project, the DARPA Grand Challenge for autonomous vehicles took place in the US. Vehicles designed and built by five of the teams successfully completed a 132-mile route over desert terrain, featuring natural and man-made obstacles in under 10 hours without human intervention or assistance (Bradski, 2005). DARPA's primary goal is to encourage the development of technologies for military purposes. But the achievements illustrate just how rapidly this area is moving. Looking out to 50 years, it is realistic to expect that our vehicles will be providing us with very high levels of automatic control under overall human guidance.



As the roadmap shows, an important complement to smart vehicles is the design of the road infrastructure. At the moment, there is a sharp distinction between infrastructure for mass transit systems, which can make significant use of automated control, and roads, which assume that human sensory–motor systems are in full control. We will move away from this distinction as smart infrastructure co-evolves with the smart vehicles. By the end of Horizon 3, we can reasonably expect that we can hand over as much control as we like to vehicles that travel on smart road systems throughout urban spaces.

Sensors and smart materials

The size, cost and capability of sensors is decreasing quickly. They are now rapidly entering all sorts of applications in environmental monitoring, agriculture, personal health monitoring and so on. Sensors can be put together with processing and valves, gears, motors and other mechanical components, all embedded in a semiconductor chip, to make what are known as MEMS (micro-electromechanical systems). Car drivers already benefit from the use of MEMS for airbag sensors. Automatic control of tyre pressure is another emerging application that will take a mundane task and automate it, much to the benefit of driver safety. MEMS are being explored to create wing surfaces that can be shaped in real time leading to much greater manoeuvrability and efficiency for aircraft.

MEMS are already cheap enough to be used for simple tasks like this. They 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.

The research community is well into the research phase for NEMS (nano-electromechanical systems) – doing all these things at the nano scale. By the end of Horizon 2, we can expect such technology to be combining with new models of nanocomputation and new smart materials to open up fundamentally new engineering possibilities for the capabilities and efficiency of smart things. It is this overall direction that causes some researchers to characterise these possibilities as 'smart matter'.

More generally, any object can, in the future, either have embedded processing and communications, or link up to the online world to obtain the computation power it needs. Already well under way is the development of the next generation of smart radio-frequency identification (RFID) tags that are replacing bar codes and will allow any object to be identified to the infrastructure by wireless, and power-less, interrogation. This infrastructure includes a numbering scheme that means we can number individual instances of things – '*this* can of soft drink' – not just general classes. Once things can link up in this way, they can combine their own intelligence with that of the infrastructure in whatever way is needed.

See research reviews on pervasive tagging (Tully, 2006) and materials (Guthrie, 2006) for more on these directions.

Information grids and utilities

As we populate the physical world with smart stuff, we will simultaneously be building the data and information utilities that can handle all the data they produce, and provide a myriad of ways to analyse and use it. Today, the UK's rail industry already has a data warehouse in excess of 12 terabytes (10^{12}) of travel data from ticket sales. Looking ahead it is hard to get a grip on the numbers in any way the human mind can comprehend. At Bristol University they are talking about the Exabyte Challenge:

'One exabyte (10^{18} bytes) is a rough – and probably conservative – estimate of the size of everything ever written, composed, filmed, painted, or in any other way 'recorded' by humans. By 2010, virtually all of this vast amount of data will be online. Most of us will be able to access it from our homes, our mobiles and other kinds of wearable devices.' (Flach, 2005)

As we create the sensory rich web of things, by 2050 exabytes of data will be flowing around every second. 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, is the subject of major industry investment in the necessary standards. Different sectors of industry will be served by both generic services (such as global positioning systems (GPS)) and deep, sector-specific services such as environmental data.

It will take many standards and systems to make these things work between organisations and across the many technologies needed. Information on these is available at the Global Grid Forum (www.ggf.org). Grid computing is already evolving in deployed systems, and so will have gone through at least two more major cycles of computing industry change, driven by the underlying computing technology, as we enter the period of the third horizon.

Complementing the Foresight Vehicle Technology Roadmap, a picture of how today's ICT is being deployed in intelligent transport systems in the UK can be found in ITS (2004).

Agents, autonomy, and adaptive systems

When you set the climate control or cruise control in your car, you give an artificial system a goal and some permission to control something on your behalf.

As long as we set the goals, and understand the scope of the permissions we have granted, we are happy with this way of interacting with things.

With more capable 'systems', we employ much higher-level commands – just watch a sheepdog being given instructions by the shepherd. In computing, this approach to delegating is known as an 'agent-based approach' and is a major area of research that has emerged over the last decade.

As defined by a major EU Co-ordination Action, 'an agent is a computer system that is capable of flexible autonomous action in dynamic, unpredictable, typically multi-agent domains, with especial emphasis on situations where the agents come from many different organisations, so have different controlling authorities' (Luck et al, 2005). This definition can also stand as the definition of transport – people and things moving through the natural world in well-ordered ways – so 'agents' are of great importance to intelligent transport infrastructure.

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. 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, for example.

In the financial world, trading is now routinely carried out by a combination of human traders and automated software programs. This is driving forward research into ways in which trading algorithms can be embedded directly into agents to provide notions of market-based control (Cliff and Bruten, 1998). These capabilities need not be used only in the obvious notions of trading, but might be used between smart vehicles to allocate a slot opening up in the traffic, or for a smart manufacturing and logistics system to assign resources. These approaches to both simulating and modelling systems are already well represented by many applications and companies.

See the AgentLink roadmap (Luck et al, 2005) and IIS review (Bullock and Cliff, 2004) for overviews.

Micro mobility – personal and mesh transport

'"You know, had Moore's Law applied directly to the automobile industry, you would drive one car downtown, and they would be so cheap that you would pick up a new one to drive home. Your first tank of gas would be your last tank of gas." He said, "The only problem is they'd be so small you could never find them."'

Gordon Moore (of 'Moore's law') quoted by Gelsinger (2002)

A lot of the conflicts that exist around transport policy derive from the sharp distinctions that exist between personal and public modes. We naturally prefer the flexibility and freedom of personal transport we own and control that can take us between any two places whenever we want. These things also become important in how we express ourselves to others.

The computing industry is very familiar with how dynamics of ever more personalisation drive industry structure, since its history can be thought of as waves of computing that brought computing power away from the early mainframes into our office departments, then our homes and now into our pockets. Distributed power and personal control wins every time. These transitions in the industry happen every decade or so as the underlying technologies become around 10-20 times as powerful as they were at the last transition. The dynamics of change are much slower in transport, so we have not seen any major changes in the basic categories of transport for a long time.

However, as we look ahead with a 50-year horizon, it seems as though we are ripe for a transition, enabled by much more personal technologies with more powerful infrastructure. From a futures point of view, there are several signals of this.

A category of personal electric vehicles is making steady headway in the market, yet it doesn't even have a name. Many suburban high streets have shops selling electric vehicles for the mobility impaired. It is a common sight to see these weaving through the traffic. These have low design values, but car manufacturers are already beginning to show new concepts that exploit very sophisticated control technologies and bring the latest design thinking to start moving the technology into the mainstream. See the Toyota i-unit for example (Toyota) and the Segway (Segway). The latter was introduced with much fanfare and expectations that it would reshape urban transport. It hasn't, and on its own it won't, but it is an instance of a growing number of ultra-personal technologies that are gradually creating a new category that might have such a transformational effect. We might dub them 'pPods'[1] – the obvious allusion is intended to capture the notion that it is the movement of the technology into the personal expressive domain that will be part of its success and adoption by mainstream users.

[1] p for 'physical' and for the somewhat whimsical value of the name

We can view the same category from the mass transit side in examples such as the ULTra (urban light transport) system that is conceived as an automatically controlled, personal taxi system, running on its own guideway network (Lowson, 2002). Each passenger can be identified by their smart card, so the service can be personalised to respond to their special requirements. This general category of systems is known as personal rapid transit (PRT).

Lightweight materials, batteries, sophisticated controls, smart infrastructure and other rapidly developing technologies are all in place to allow these emerging models to go through rapid evolution.

It doesn't take much imagination to see the possibilities of re-engineering significant parts of our high-density urban environments to privilege combinations of pPods and PRTs in preference to cars. Existing pedestrian zones, historic town centres and major developments such as shopping malls and airports are the niches where such models are likely to start and expand.

Some researchers are thinking of the control systems for this class of transport in terms of swarms, by analogy with the ways that social insects organise themselves collectively through a mixture of global signals and local decision making. There are already low-technology versions of this (see IGT) and, as discussed in the agent technology section, there is a lot of potential in these approaches to achieve very responsive models of mass infrastructure.

Considering the movement of goods, we might imagine that there is scope for a sort of PRT for neighbourhood physical packet switching that would bring the equivalent of the container revolution to local distribution – a little like airport baggage handling thought of as an urban infrastructure. Considering that at the height of the dotcom boom the investors in WebVan put around $30 million into a first set of automated warehouses to pick groceries for delivery by conventional van delivery, the notion of an advanced shared infrastructure of this sort does not seem too fanciful in the 50-year horizon.

Virtual worlds, telepresence, and personal environments

It is less than a decade since the Web became a part of everyday life. That is a very short time in computing evolution. We are in the early days of building online environments and understanding how they will shape our activities. Rather than attempt to summarise such a vast socio-technical field, the following points are intended more as a point of view to guide the Horizon 3 thinking.

People and place First, we can assume that progress in all sorts of virtual environments and telepresence will be continuous and dramatic, creating the ability to link physical spaces across the globe to support rich and deep experiences for social and business purposes. At the same time, we should see this as going hand in hand with the shaping of physical space to support such interactions, and the continued human value of being together.

A profound effect of the online world is the way it expands our sense of the world we belong to, and in which we find our identity (Meyrowitz, 2004). People increasingly build the Web for themselves through new forms of social media – wikimedia, blogs etc – and environments in which they are embedded, and create new communities of interest unconstrained by place. We will certainly use all of these possibilities to make many more choices about where we need to be, and when, but it would be unwise to subscribe to a myth of physical transcendence as a basis for planning. This is discussed more below.

People and things Secondly, the online world is a great enabler of choice, with it getting easier every day to choose between suppliers, and to have whole bundles of services configured for our personal convenience. Behind the scenes, standards for web services enable applications to be woven together in real time among many different providers. Agent technologies bring additional layers of sophistication to such services and will combine with steady advances in human interface technologies.

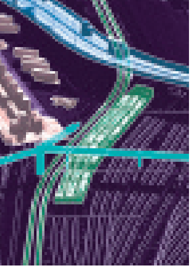
No dramatic breakthroughs are needed in speech technology and language understanding for us to give ever more effective instructions to the smart services and artefacts around us. These technologies fit into a growing discipline of interaction design that brings all the available modes together through human-centred design processes. These capabilities will far exceed anything we need in the third horizon to make and express choices about how we make the trips we want.

These powerful interface technologies will be able to draw on the full power of the information grids and utilities and will come together in what we might call 'life-serve environments' which offer intelligent support to mediate and support the choices we make. We are already becoming used to the power of intelligent search to bring us the information we want just when we need it – this power will grow substantially in range and sophistication.

Issues in emerging capabilities

The preceding accounts of technology developments have described new capabilities that we can expect to see in coming years, but without examining the problems that might come with them. These issues are treated at a high level in the project's scenarios and the section on Horizon 3, but there are three important areas of concern to highlight here that are particular to the information systems dimension of IIS.

These issues were examined in depth in the Foresight Cybertrust and Crime Prevention Project. The dynamics of those scenarios inform the possibilities of societal rejection of IIS explored in this project.



Digital footprints – surveillance and privacy

The more we instrument, monitor and control the physical world, the more we will find every action creating digital 'footprints' – a record of where we have been and what we have done that is a side-effect of doing it. It is very hard indeed to ensure absolute privacy while at the same time connecting things up. Once the information is available in principle, all sorts of reasons are found why it should be kept and made available, for commercial purposes such as service personalisation, and also for law keeping.

Who is in control?

There is a growing issue around the way that information systems will increasingly mediate and control our experiences of the everyday world. As our identity, credit rating, customer status and so on become available, and are integrated with ever more sources of information, we will all find ourselves at the mercy of a growing amount of software code that determines what we can do and the quality of service we are offered. Graham (2004a) has coined the term 'software sorted geographies' for the ways that software systems embody this differential access and he points to the need for political responses. This is also discussed in Lyons (2005).

Dependability

The technical community calls the world that we have described 'systems of systems' – artefacts that are always evolving, never finished and forever incorporating new elements from different providers. That is the world of cities, and it is the world of ICT. We are putting these together in ever more complex ways that are never fully designed or understood.

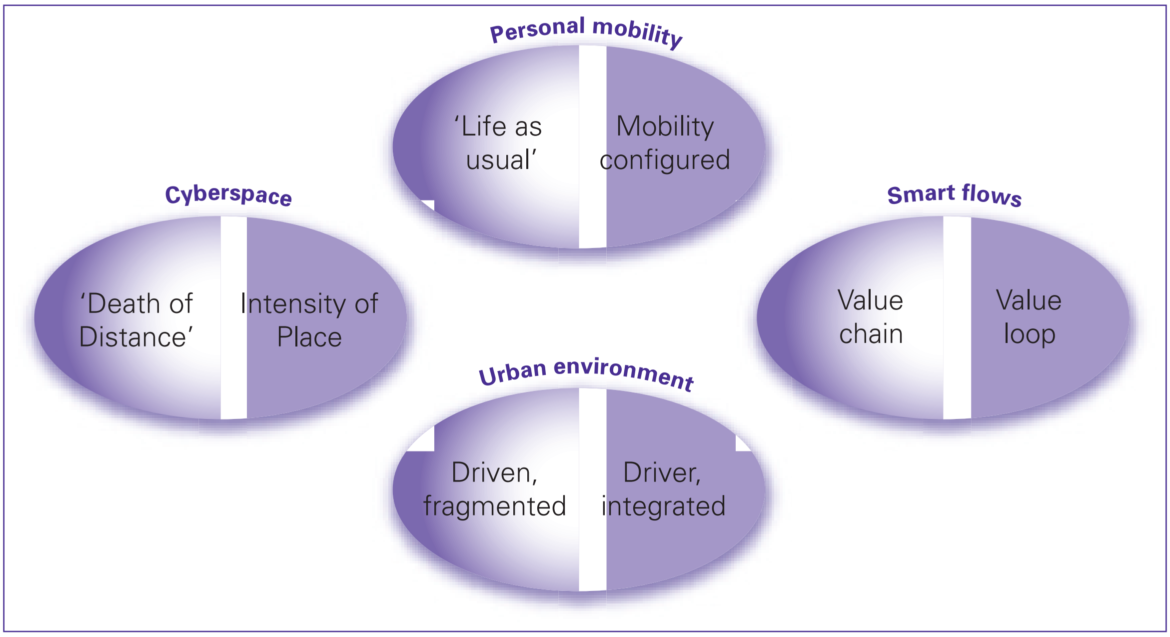
At the same time as we explore notions of agents and emergent behaviour for greater sophistication, we find that we cannot fully engineer the systems we already have to be fully dependable and free of unwanted emergent failure modes. While we can expect to make significant strides in both understanding and using mature engineering disciplines for IIS, we must expect that we will remain vulnerable to shocks and failures.

Part 3

Horizon 3: Envisioned future

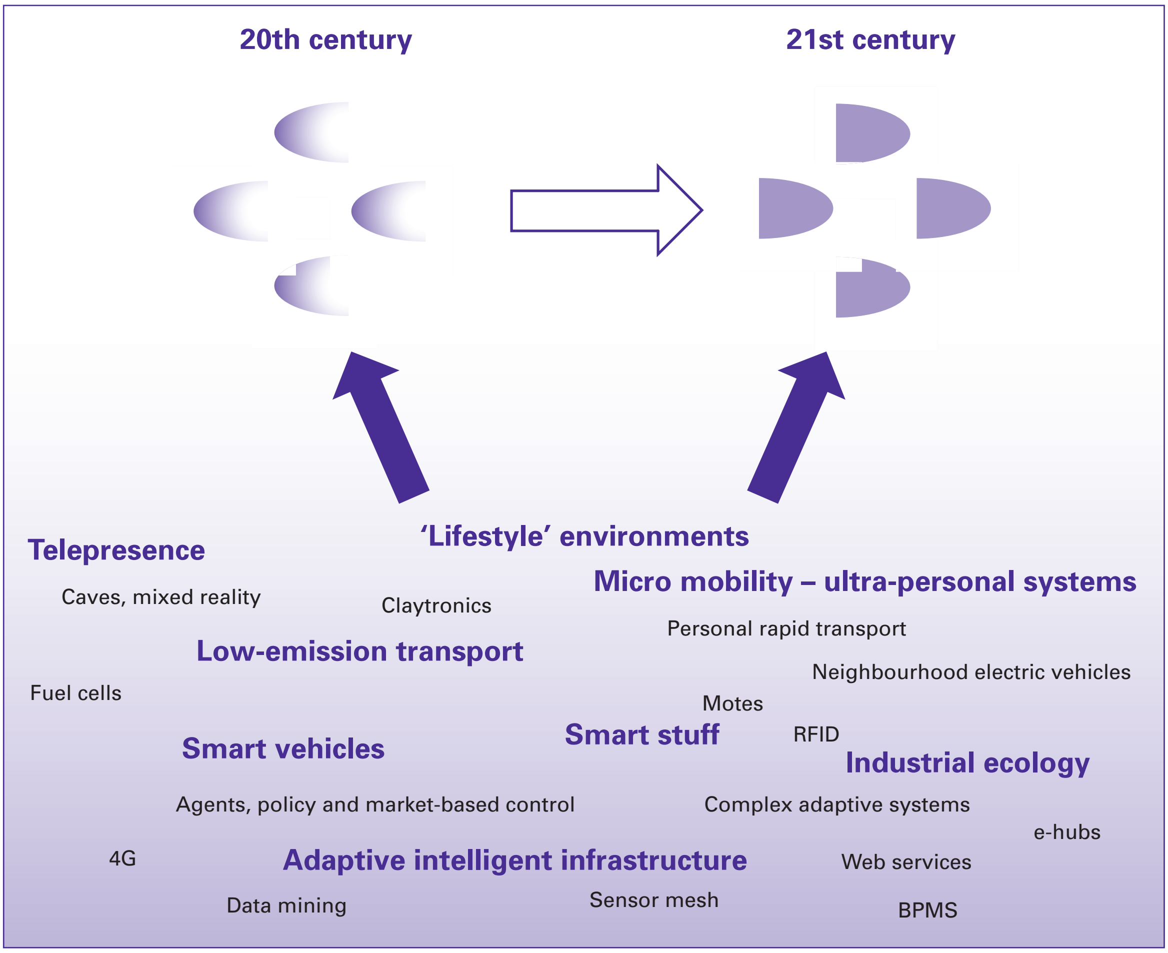
The main conclusion from the review of Horizon 2 capabilities is that it is not technology, or technological capabilities, that will determine the outcomes of the scenario, but the way in which we choose to use them. As we have discussed, when we move to Horizon 3, we shift to an envisioning process. Since it is how technologies will be used that needs to be in the foreground, we have identified four dominant ideas, and their possible complements, that focus on these overall patterns of use (Figure 4).

Figure 4: Four dominant and complementary ideas relevant to Horizon 3



The discussion is organised as a 'compare and contrast' exercise between two systems. The left half of each area represents the current mindset, the right a contrasting mindset. In doing so, we aim to create a different value context for the main capabilities that have been identified in the Horizon 2 analysis.

Figure 5: Technology capabilities and the shift to a 21st century lifestyle



Personal mobility

Model A – 'Life as usual'

'Life as usual' is intended to capture the mindset that has characterised travel for the past half-century – that anyone can travel anywhere they like on the globe for business or pleasure, whenever they like, and that they will typically use a personal vehicle, door to door, if feasible. Personal transport offers us unrivalled flexibility for point-to-point travel 24/7. The era of cheap flights has opened up the whole planet to business and leisure activities.

As Stephen Stradling (2006) says in his research review, we move around 'Because we can, because we have to, because we like to.' He summarises the research into the psychology of travel behaviour as two fundamental findings. First, the choice and use of how we travel plays an important expressive role for many people way beyond its utility. Second, people vary widely in the way they think about and make travel choices, and this varies between different groups of people, and individuals in different situations. Some people are looking to change their travel patterns but cannot see how others are strongly attached to the freedoms and personal meaning of their cars and strongly resist any controls. The research suggests that there could be considerable flexibility in travel patterns among many groups, and for many situations, while there will also be deeply embedded patterns that it will be hard to change.

Many aspects of the current mindset are self-reinforcing. As we make travel easier and cheaper, increase speed and capacity, integrate different modes, improve convenience and so on, we take these gains as enhanced opportunities for travel. As physical travel and global media make us familiar with more and more of the world, the whole world becomes part of our perceptual space, and a potential destination. Journeys that would in the past have been adventures become weekend breaks, and people sustain relationships with networks of friends, family and business everywhere. A recent advertisement seen on the London Underground perhaps sums it up: 'How can you have a favourite place when you haven't seen them all?'

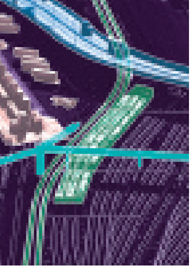
Patterns of daily travel are immensely complex, and not fully understood. We take here the high-level summary that, in general, the current mindset drives us to a more dispersed pattern of activity that then locks in higher overall demand for travel.

In addition to a general increase in travel, a second important effect of the current mindset is the way it influences the built environment, particularly with respect to the daily commute to work. An important behavioural insight (Schipper et al, 1992, referenced by Köhler, 2006) is that broadly speaking the time spent each day on regular travel activity has remained constant at an average of 55–65 minutes. This directly affects how individuals make choices around living and working. Faster travel increases the distance travelled, and expands the overall urban footprint. See therefore, for instance, the Axhausen (2006) research review of how the expansion of the road travel time region around Geneva has affected living patterns.

Cheap air travel is now following the same pattern, with some people choosing to live on the Continent and to commute daily or weekly to the UK.

IIS will naturally extend this mindset. For example, to the extent that they use smart systems to ease congestion and increase the effective capacity of the roads, they promote further use of existing road space.

'Predict and provide' was the natural policy stance underpinning these freedoms. The purpose of transport planning was to anticipate and serve the growing expectation of travel. This was the main policy framework for the latter part of the 20th century for all transport. In the UK, we have started to move away from this for road transport with the first steps towards using the potential of IIS to reduce usage through congestion charging. Air travel, however, remains largely governed by the older model.



Model B – Mobility configured

The current mindset drives a pattern of behaviour that cannot extend indefinitely. Even if we imagine that we can make a transition to clean, cheap, unlimited energy, that would only accelerate the other environmental impacts, especially congestion.

The future state is therefore one in which we will have to actively configure mobility to achieve balanced and sustainable patterns. We use the term ‘configure’ rather than ‘constrain’, because, although the goal is to create some limits to certain sorts of travel, the changes in patterns need not necessarily be viewed as negative constraints if they bring benefits. For example, many people would find it very desirable to have most of the resources of daily life within walking distance, and would then use other transport on a more occasional basis. If congestion charging simply rations road space, it is clearly a constraint; if it changes behaviour patterns, it is a reconfiguration. Ideally, we would like these reconfigurations to be seen as beneficial.

The following sections explore this idea of configuring mobility in three ways:

First, we look at the impact of activity in the virtual world on patterns of activity in urban space – the emerging notion of cybercities – and how these two spheres of activity can be mutually supportive, not disjointed nor antagonistic.

Second, we discuss the flow of materials and energy, and how we might shift our outlook during the coming century to notions of more viable cities based on ideas of industrial ecology – an emerging discipline which looks at industrial and ecological systems within a single conceptual framework.

Finally, we explore moving to urban design shaping patterns of mobility, rather than the other way around.

Cyberspace

Model A – ‘Death of distance’

‘In urban terms, once time has become instantaneous, space becomes unnecessary.’

Pawley in Graham (2004b)

The dominant myth of cyberspace is that it abolishes distance and makes location unimportant. We can sit on the beach and still do everything we could in the office, should we want to. Taken to its furthest extreme, the claim is that the ever growing capabilities of cyberspace allow us to enter a realm where we can relate with anyone, anytime, and that this will inevitably withdraw all rationale from our conventional city landscapes which are just a historical approach to solving problems that can now be better solved by telecommunications – clean digital bits will triumph over messy physical atoms.

However, there is much research that fundamentally challenges this view and suggests that we need to untangle genuine changes in our relationship to the use of space from a belief that the value of place will disappear.

First, it is demonstrably true that each new form we give to remote communications allows us to experience a richer set of relationships that are independent of where we happen to be at that moment. This means that we can bring together many more relationships beyond our immediate confines and can weave them around our daily activity. Meyrowitz (2004) coins the term 'glocality' to describe this sense of 'being inside and outside at the same time'.

It is also now common experience that this extended telepresence allows us to substitute many face-to-face meetings with some form of remote collaboration. We can take the extra flexibility of telepresence as additional freedoms in how we configure where we live and work, and how we conduct business, building in even more reliance on the gains in mobility.

We are just at the beginning of this revolution. The forms of extended presence 50 years hence will be so far beyond what we know now that it is futile to speculate on them, except perhaps through science fiction (*Star Trek* holodeck and so on).

Set against this are several key observations. First, the mundane but inescapable fact that we are always somewhere, and that most of the things we want to do have to happen somewhere, even when communicating through a virtual environment. Our most basic needs must be met in a particular place, the here and now. There is a physical setting to everything we do. But, beyond the mundane, there is the broader value of place.

If we think about it, we realise that we are using the freedoms created by telepresence and mobility to make choices about where we live, and how we work. It is precisely because we care about places and what they represent to us in terms of communities and activities that we value mobile communication so highly – it frees us to be in places we like.

Second, as many people have experienced, the notion of substitution is misleading. The more we communicate with people, the more we will find reasons to get together with them. While we can displace some reasons for travel, it is well established that increasing connectivity drives an increasing need for face-to-face communication. Relationships that are sustained by telecommunications usually create reasons to meet in person. Indeed, we use a huge amount of electronic communication to co-ordinate and plan travel and physical meetings.

It is now well understood that in many ways the use of telecommunications is to reinforce our relationships within their existing settings. Certainly, in the long-term flow of the relationship, many things that might have required a meeting might be accomplished remotely, but this is offset by the new opportunities that are created for shared activity in the real world.

Unexpected effects can occur, even when we appear to be reducing travel with telepresence. For example, a growing number of people go into the office for only three or four days a week, and work at home on the other days, but they choose to live further from work and have a higher weekly commuting mileage in consequence.

Third, the notion that we are transcending our physical selves does not stand up to observation and analysis. Our bodies will always be somewhere, we cannot actually be in two places at the same time, and co-presence brings with it the full depth of human culture (Meyrowitz, 2004). As Boden and Molotch (2004) put it, 'Co-presence is thick with information,' and 'Co-presence is so information rich that we feel a need to have it to know what is really going on.' Thus, coming together is one way to manage the very ambiguities and complexities that are caused by our increasing glocality. The booming conference business for those very same people who are at the cutting edge of the new technologies is indicative of this.

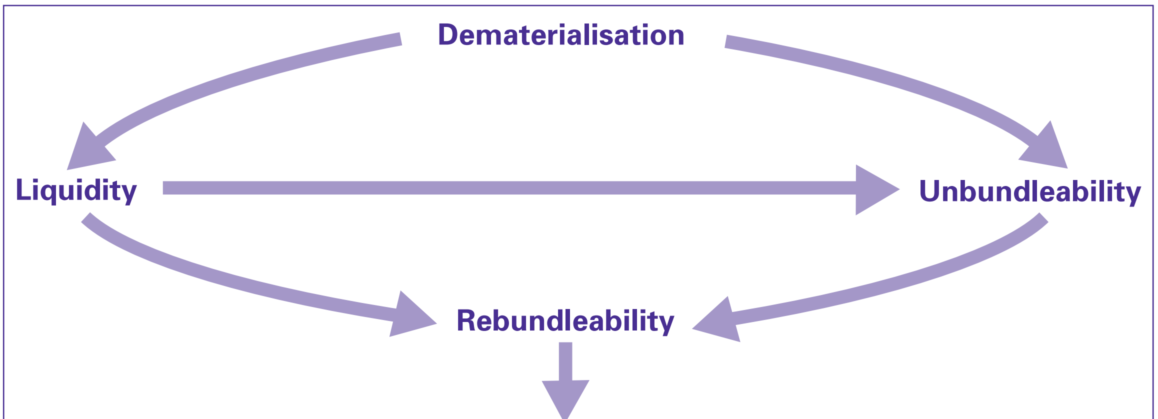
The dominance of the idea of the death of distance has obscured the positive relationships between urban economies and the information economy.

Model B – Intensity of place

There is now a growing body of work exploring the relationship between ICTs and the nature of urban life. An overview can be found in Graham (2004b). Starting from the observation that, rather than undermine metropolitan regions, electronic communications and urbanisation are developing hand in hand, Graham identifies three reasons for this mutual support:

1. ICTs play a central role in how urban centres exercise their global reach. The logic of globalisation has been analysed by Normann (2001) as a process of unbundling and rebundling, leading to increasing density of activities that are located in regions that can perform them best in the global context (see Figure 6). Urban centres are the nexus of a dense mix of high-value knowledge and services that drive these processes.

Figure 6: Reframing business



Normann R, Reframing Business,
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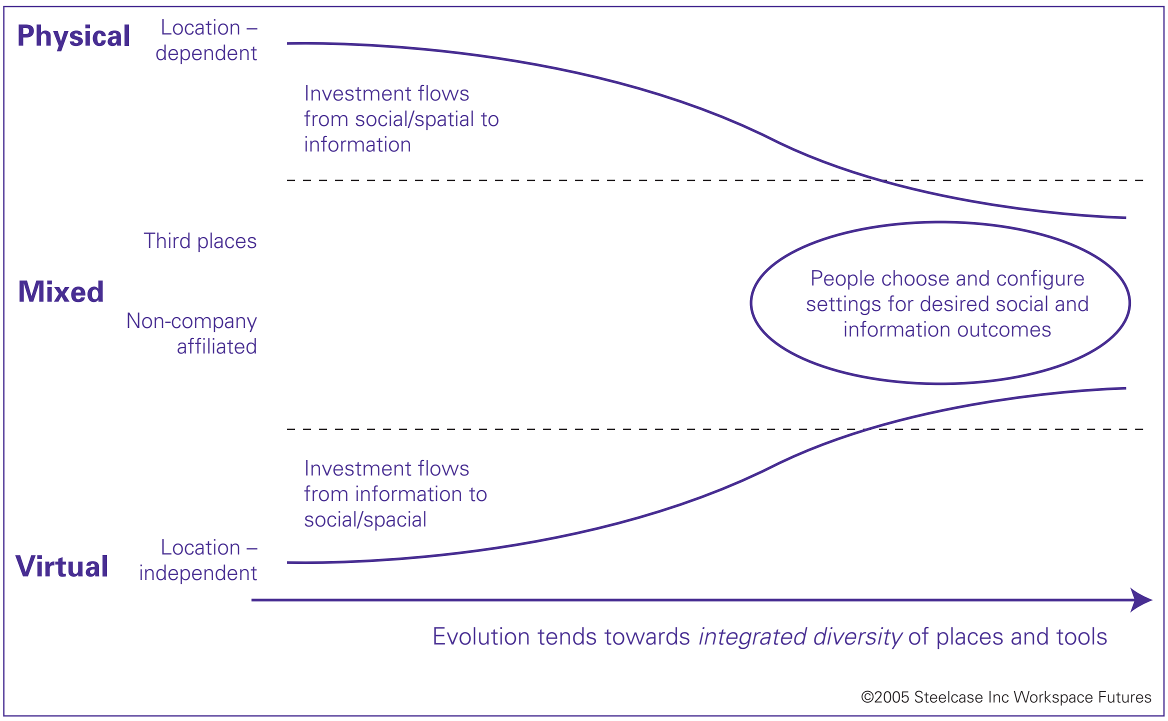
2. The intensity of these innovative complexes and exchanges demands the intensity of participation and social exchange that is best served by co-presence, for all the reasons outlined above. Thus, as Graham (Graham and Guy, 2002) notes, one of the paradoxes of the current age is that congestion is often a major problem for emerging complexes of multimedia innovation.

3. Major metropolitan centres bring together the resources that drive ICT investments. As economic exchanges are increasingly orchestrated and mediated by ICT, and the underlying infrastructure is embedded into the urban locations where that wealth is developed, so the relationship between cities and ICTs strengthens.

Having recognised this logic, we can have a much more proactive attitude towards the synergies, as well as the potential issues, in this co-evolution of urban and cyberspace into cybercities. It is time to move beyond the limited notion of 'e-corridors,' information districts and so on, and to recognise that ICT is integral to the use of urban space for all purposes.

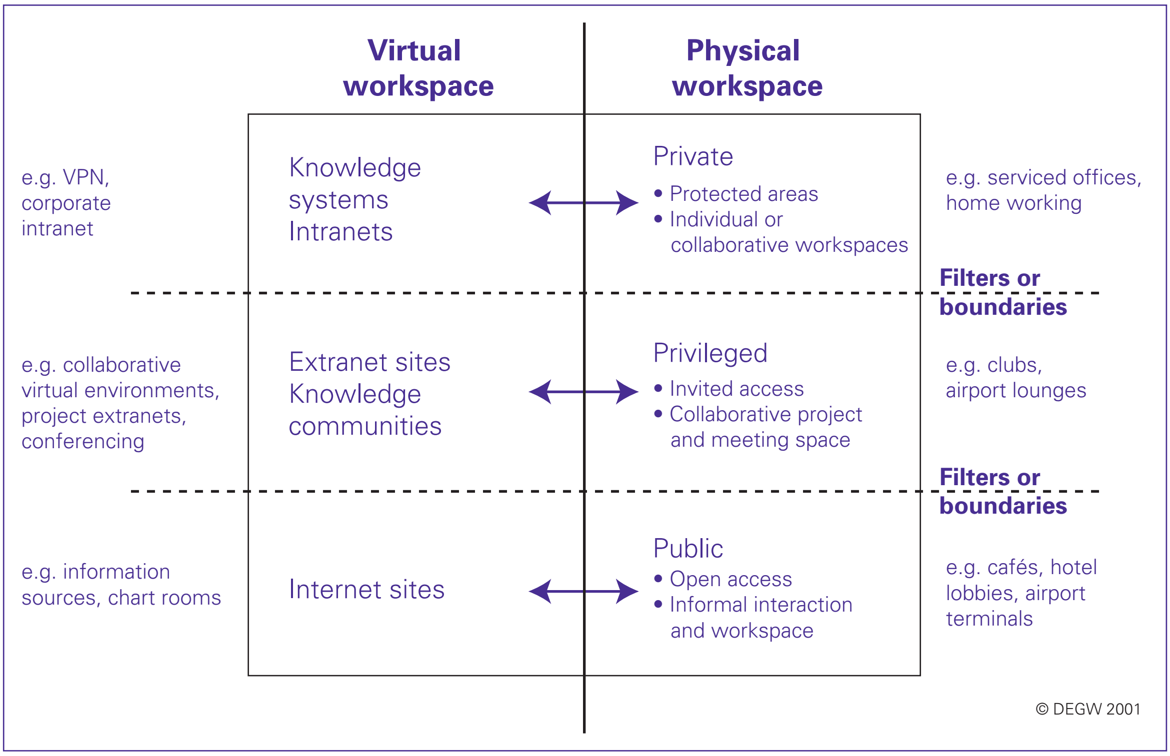
As an example of the new thinking, Figure 7 represents the results of a study by a major US company in the field of workplace design (Steelcase Inc). This reflects the view that companies that start as exclusively physical and those that start as exclusively virtual all appear to be moving in the same direction of mixed physical/virtual spaces, though they evolve there for different reasons. They find that, on the one hand, the freedom of virtual space allows us to choose and optimise physical locations for the particular form of work. On the other hand, as they evolve, virtual organisations want to strengthen their organisational culture with social and spatial dimensions, in physically diverse settings.

Figure 7: The evolution of workplace



The same ideas were explored in the Sustainable Accommodation in the New Economy (SANE) research project funded by the European Commission (Harrison, 2002), which developed the notion that 'the city is the office'. This is illustrated in Figure 7.

Figure 8: SANE research project space environment model



This model expresses the notion that the properties of virtual environments can be brought into supportive relationships with physical environments, and that the overall effect is to allow work to be distributed within the urban environment to the most appropriate location. In this way, the conventional rhetoric of the computer industry of 'work anywhere, anytime' is translated into working in the right place at the right time.

Smart flows

Model A – Value chain

'Supply chains everywhere – whether in profit or not-for-profit situations – are seeking to deliver the right products to the right place at the right time faster and at lower cost.'

Harrison and White (2006)

As for personal mobility, the movement of goods and materials is currently developed within our mindset – that we should be able to have anything, from anywhere at anytime. As the possibilities of global supply extend, our patterns of consumption develop and further reinforce the flows of goods. The job of the global supply chain is to support this in ways that are ever more efficient and responsive to the dynamics of demand and supply.

Again, paralleling the systems for moving people, there are many ways in which the emerging technologies of intelligent, integrated systems can significantly improve current systems. As a society, we will take these gains in reach, flexibility and general volume of movement, as described in the 2020 look ahead by Harrison and White (2006). Seen in this way, the technologies of supply chain management tie in with the underlying transport technologies in self-reinforcing patterns of use.

Without changing anything in Model A, there could be major adaptive responses to lower impact. For example, we could achieve this by changing the pattern of use of transport technologies, to lessen energy footprints by such measures as reducing airfreight and by improving energy efficiency.

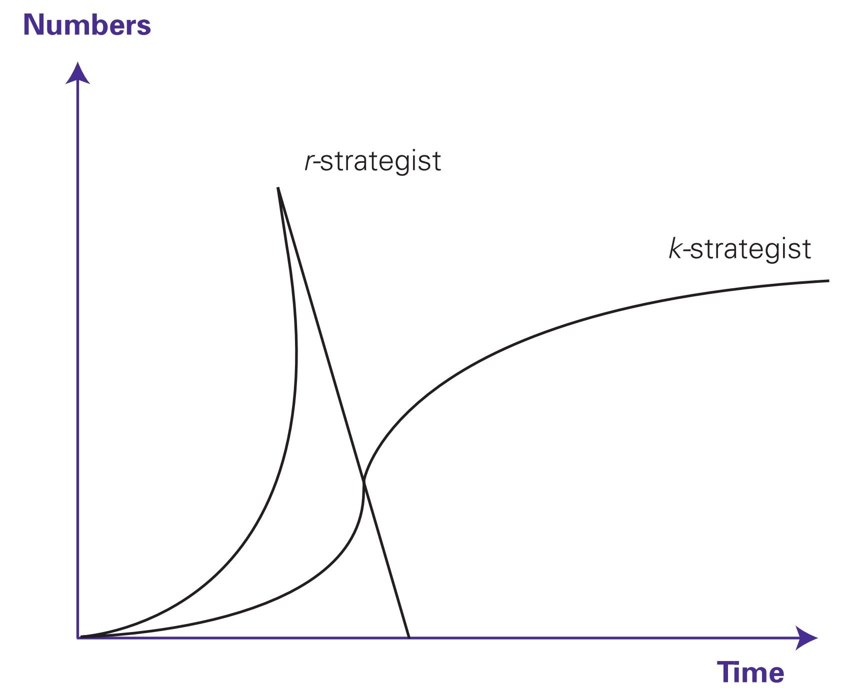
The problems with the model do not come from the movement of materials in themselves, but from the way that many of the environmental impacts are still external to the market. This means that at a planetary level we do not have a system designed for long-term sustainability. It is therefore vulnerable to instability, overshoot and collapse, as explored by the scenarios.

Movement and cycling of materials and energy is a source of life in natural systems. These don't have waste products as such, everything is input to something else, so our contrasting mindset looks at the transition to such closed loop systems.

Model B – Value loop

There is now a growing body of thinking under the general heading of 'industrial ecology (with its own journal, (*Industrial Ecology*), which is well represented in the overview by Tibbs (2000). This proposes that the only long-term solution to the wider impacts of our planetary flows of materials is that we make a transition from our open-loop, linear systems to systems that function in closed loops like natural ecosystems. We move from value chains to value loops. Tibbs captures this notion of transformation in a dramatically simple way using the concept of ecological succession in which a 'pioneer' ecosystem is replaced by a 'mature' ecosystem.

Figure 9: A comparison of k- and r-strategists population numbers over time



Source: Lawlor, 1984

In Figure 9, the r-strategists are plants that move in early to cleared land, reproduce and disperse seed rapidly, and then become locally extinct. Their population in a particular area grows quickly and then disappears as they move on to new areas. Many annual weeds are like this. By contrast, the k-strategists that follow after the r-strategists are around for a long time. They grow slowly and function in ways that are within the long-term carrying capacity of the area.

By analogy, as a species, we need to shift from our current r-form of the economy to a k-form. A similar notion from complex systems analysis is that of 'co-evolution'. The material flows and structure of industry will change in parallel with society and the environment, with feedbacks in both directions. This is a view of a continuously changing world, rather than a static 'mature' ecosystem. Another way of looking at it is that a mature system is also resilient – it can accommodate a high level of shocks from environmental change.

This is too big a topic to cover in a few paragraphs. The intent here is to call out a few key points:

- The essence of the idea of industrial ecology is that enterprises are connected in order to continuously circulate materials. This can happen on many different scales, from very small local loops, to planetary scale. This is a qualitatively different mindset from simply having manufacturers be responsible for recycling their products, since it looks at whole collections of organisations as complete systems or 'food webs', which make minimum use of virgin materials.
- Economic flows are decoupled from material flows. This transition does not have to be seen as a retreat from growth. The shift is that all the factors that affect long-term environmental stability function as internalities rather than externalities. This highlights that the transition cannot be achieved without interventions in how the economy and markets operate. This is now an active area of research served by its own journal (*Ecological Economics*) but without there yet being one overall conceptual framework.
- Returning to the role of this report as a technology forward look, we can see that, as discussed in Harrison and White's (2006) research review, the capabilities that underpin intelligent distribution and logistics will play a key role in the creation of industrial ecology. They create the very conditions for integrated flows to take place across webs of organisations, with notions such as 'e-hubs' providing the foci for the operation of market mechanisms, orchestrating the movement of materials and 'smart assets'.
- As with the preceding two topics, it is apparent that the new mindset in which we are configuring the flows of materials and energy into self-supporting structures will be intimately bound up with how we design and use urban space.

Urban environment

'Transport and information and communication technologies and the city are closely and inextricably linked. These elements must be designed to work together, in mutually reinforcing ways, so that the economic, environmental and social vitality of the city is maintained and enhanced. Transport must no longer dominate city design, but instead play an important, supporting role in improving the quality of life in the city.

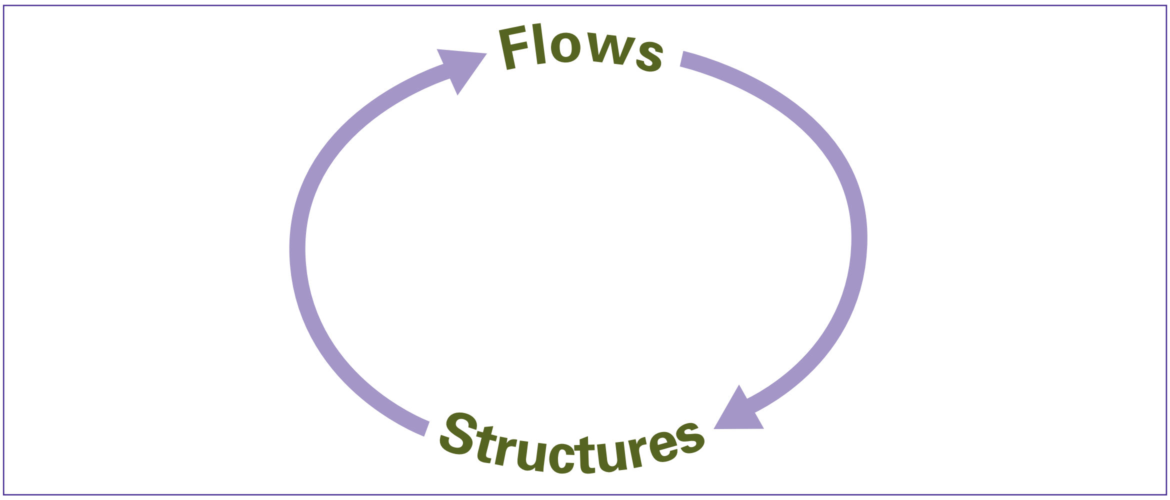
Cities will return to being multi-use and will re-integrate. The separation and fragmentation caused by incompatible land uses and the car will be reversed, as they again become centres of high-quality activity built around localised centres linked to the global networks.'

Banister and Hickman (2006)

The preceding sections of this forward look have each highlighted how the current mindset tends to treat the urban environment as something that comes behind, and in the service of, current processes. Rather than repeat the analysis, in this section we move directly to the alternative mindset, in which the urban environment becomes the point from which each of the approaches to all the other issues – personal mobility, cyberspace and material flow – is configured.

In each case, we have seen that space, and its intelligent configuration into place, is the hidden resource that we can use to re-conceive how our environment 'works' for us in ways that enhance sustainability and help us to tackle the increasing problems of keeping the current mindset. To do so, we step back from linear and 'silo' models of problem solving, and instead view our environment as a complete system of flows and structures in the manner of ecosystems (Figure 10).

Figure 10: Generalised view of an ecosystem



'Ecology is the scientific study of the processes influencing the distribution and abundance of organisms, the interactions among organisms, and the interactions between organisms and the transformation and flux of energy and matter.' (www.ecostudies.org).

In looking at a natural ecosystem, we can bring either flows or structures into the foreground. We can study the individual organisms, their structure and behaviour, and how they maintain themselves through their interactions. Or we can look at the flows of energy, materials, and information, and how they sustain, constrain, and ultimately configure the organisms that make up the resulting dominant populations. We need both perspectives to understand the system, and each supports the other. Similarly, as we study the flows of people and goods, we can bring either flows or structures into the foreground, but it is their mutual determination that matters most.

The core of our Horizon 3 envisioning is that we have the need and the opportunity to bring systemic coherence of flow and structure into the design of our built environment at every scale, from neighbourhoods to extended urban regions and beyond to global-scale networks.

However, in reaching towards a specific vision, we face a significant knowledge deficit. The IIS research reviews, and the related research on which this forward look has been based, reveal the immense complexity of the mutual interactions between the built environment, transport systems and culture. Even when we understand the correlations, there are still major uncertainties over causality. It is impossible to reach any uncontested conclusions. In addition, as already discussed, there is no clear conceptual and policy framework for sustainability in general, or for how to conceive of infrastructure in support of sustainability in particular.

Given this, we can, however, use a couple of thinking approaches to help us. What would make our societal systems more *resilient* and *adaptive* in the presence of the constraints and shocks we can anticipate? In doing this, we are looking at how the capabilities we have identified can be harnessed in fresh ways to enrich our urban systems, bringing them up to a higher level of adaptive competence for the long term. The test we apply here is: is the principle or statement put forward more likely to take us in the right direction than would the opposite statement?

Taking a rather high-level and sweeping view of the history of our urban environments, we can see it as three eras, two historical and a future one:

- the first historical era developed around the movement of people and goods with the power of people and animals. The structures reflected this, and gave us many of the historical cities that still remain embedded in the results of the second era. These cities were sustained by being embedded in a primarily agricultural economy.
- the second era developed around the use of unconstrained energy and materials, creating fast and efficient linkages of resources with markets, with flows totally dominating structures, creating urban sprawls, and now mounting congestion. Flows were essentially linear, with structures bearing no relation to overall cycles of use.
- the future, envisioned, era will connect structure fundamentally to cyclic, systemic flows at every level, in the service of intensity and quality of life.

Urban form and personal mobility – mobility configured

Urban environments can be designed to bring people and many of the things they want to do closer together. These are generally called compact and polycentric forms. At the lowest scale, they can be accessed by human power – walking and bicycles – and include access to public transport within walking range. Structures of this sort have a diameter of around half a mile.

Another significant level is around populations of about 50,000. These seem to be able to encompass a high diversity of everyday activities for a significant proportion of the population, where people can also undertake a large proportion of activities using 'slow modes'. Compact forms are well matched to public transport and can be the setting for advanced, highly personalised forms, such as neighbourhood electric vehicles, and personal rapid transit, and perhaps future(istic) notions of autonomous, on-demand, point-to-point solutions. As we move to the higher population levels, we need as far as possible to preserve the benefits of the lower-level structures.

There is no suggestion that one design form fits everything; rather, that an intense concern for diversity, intensity, and density of activity at every scale around notions of centres can be used to achieve a major shift towards manageable and sustainable patterns of mobility.

We already have many tools for actively configuring mobility around structure – parking and congestion charges, car-pool lanes, pedestrian zones, park-and-ride schemes and so on. These are all mixtures of the restrictive (parking charges) and permissive (pedestrian zones). The strong view of the opportunity is that we can make huge strides towards viable cities by redesigning them with permissive notions of activity that make full use of spatial system density. We can bring in 21st-century mobility solutions to support such structures, so that we experience many more of the positive, permissive aspects, rather then having to suffer the constraints extending our current mindset.

Urban form and cybercities – intensity of place

Telepresence is an abundant resource. We can embed ever more relationships into the fabric of our lives if we want to. We either conceive of this as the opportunity for individuals to be 'anywhere' or as the possibility of urban communities to be even more intensely 'here'.

As discussed above, the latest thinking in cybercity design recognises that 'virtual' work is always 'physical', and that the flexibility conferred by the growing power of telepresence can be developed hand in hand with the social nature of urban structure and used to configure the maximum use of local resources into global organisational patterns.

If we pursue this thinking, we can see it as a way to support the notions of compact urban design by enriching the diversity of activities located within each centre, while linking them to their distributed value networks.

Urban form and flow of materials, goods and energy – value loops

Glancing at any well-kept garden with its compost heap, insects, soil life, flowers and fruits, and comparing its system sophistication with the local recycling centre, will quickly convince us that we have barely started down the path of creating intensity of life through urban re-circulating systems of resources.

The potential of IIS is huge in creating such systems, since they equip us with a whole range of systemic capabilities:

- Any item, however small, can be connected to an unlimited information world to inform and influence its activities.
- Markets can operate at any level of granularity, across any number of organisations, and can be mapped onto location with any level of discrimination.
- Natural and artificial systems can be brought together into advanced environments where each supports the other (energy, waste, nutrients, heat and so on).
- Prices can be assigned to usage rather than possession of anything – contextual intelligence allows 'resource usage' taxing rather than 'value added' taxing.

More generally, contextual intelligence is unlimited in the sense that as a matter of policy and technical capability we can choose to link any particular transaction to any factor we like. In this way, we can 'wire up' the markets that support the systems we want. Any externalities can be made into internalities by linking them to the appropriate transactions. At the moment, we are taking the first steps with tools such as congestion charging and carbon trading. These are blunt instruments compared with our third-horizon capabilities to set policies for the control and trading of smart assets.

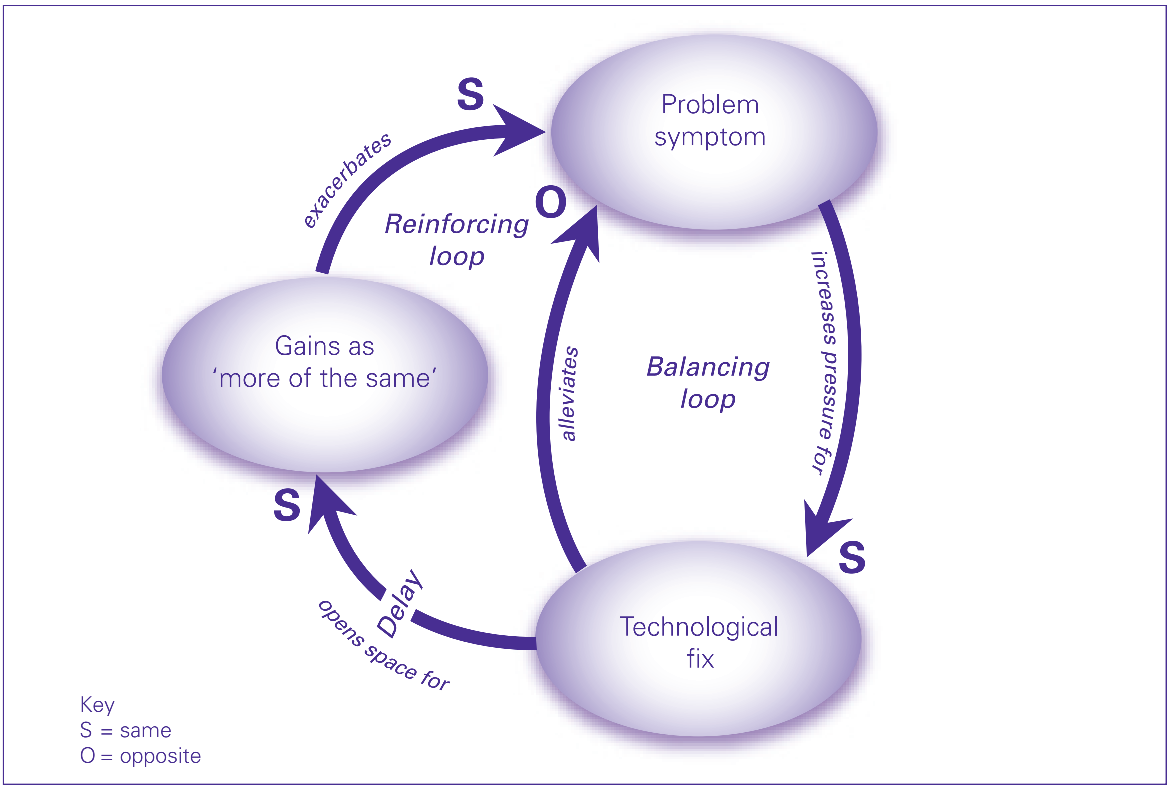
Modelling the scenario space

In this final section, we provide a simplified way of looking at the scenario space as a contrast between an extension of the existing model in contrast to a transition of the general type that has been considered above.

Infrastructure 'fixes that fail' – propping up the legacy systems

Applying intelligence leads to improvements that are lost again as people take the gains to perpetuate resource-intensive lifestyles (see Figure 11).

Figure 11: Fixes that fail – Propping up the legacy systems

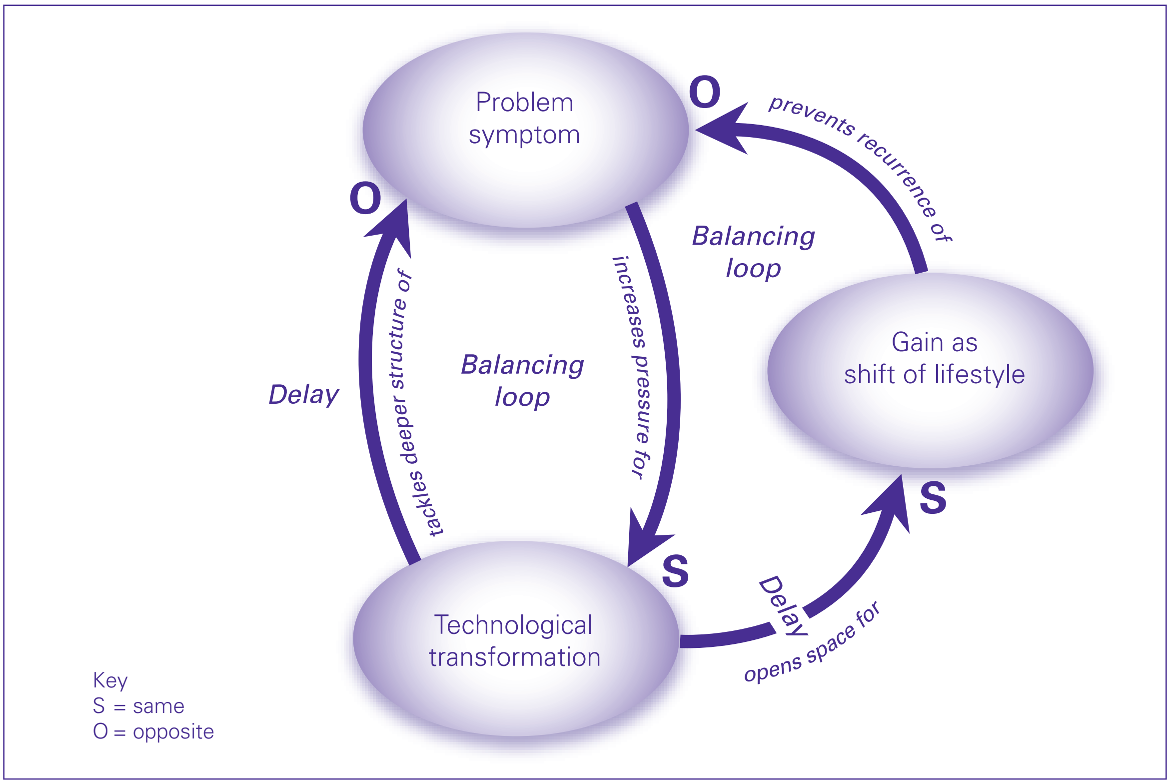


The application of 'intelligent technology' can be driven by the pressure to rectify a worsening problem. The policy adopted, for political and cost reasons, may often be a technology fix. The result of this fix is to relieve the symptom for a while – for example, engines that are more energy-efficient. However, there are often unintended consequences – such as people eventually taking the gains as bigger vehicles with bigger engines. Thus, the original problem returns, often worse and more entrenched than it was before. With this dynamic, we end up in the Good Intentions or Tribal Trading scenarios.

Infrastructure development – patient transformation

Applying intelligence is coupled with redesigning the work and built environments in a way that encourages people to take the gains as a shift in lifestyle (see Figure 12).

Figure 12: Infrastructure development – patient transformation



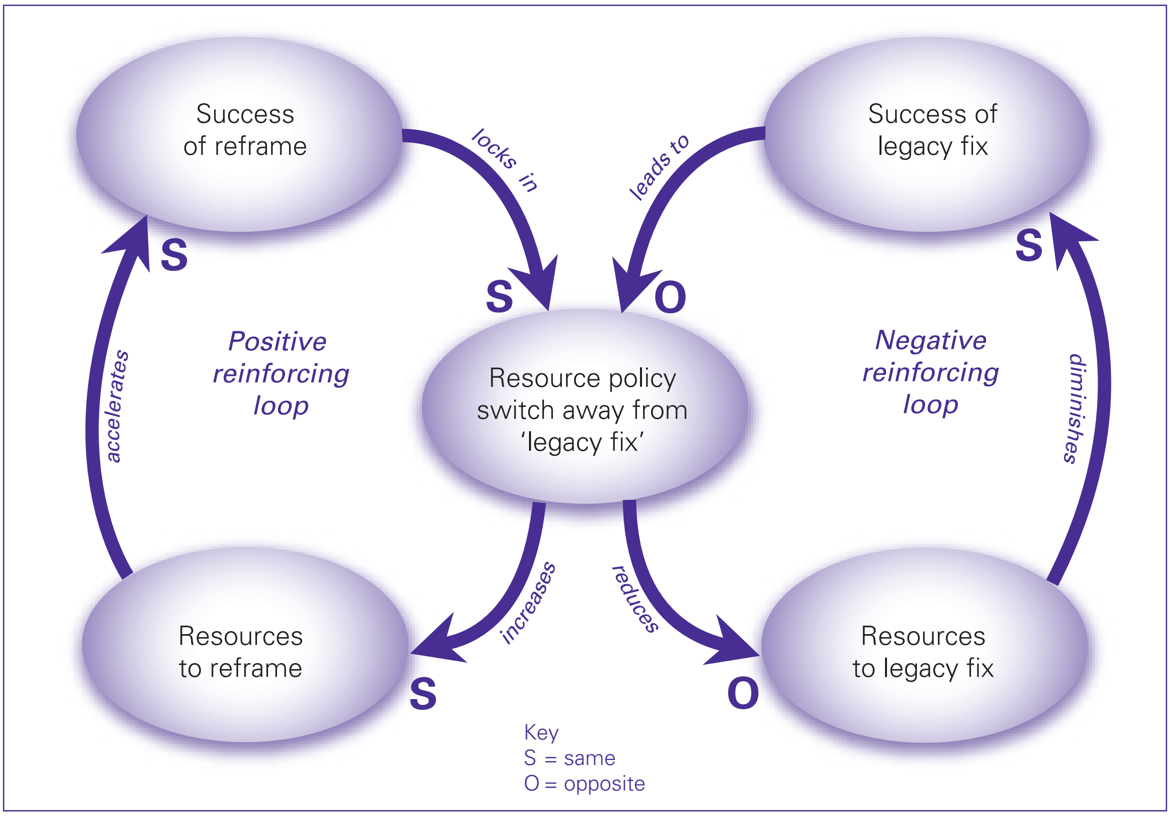
At first sight, this system archetype has the same form as the ‘fixes that fail’. However, the basic application of technology takes longer and is more robust and fundamental. In this case, it is not technological sticking plaster but well-designed cure. The second loop is very different in that the gains are taken towards sustainability and not towards exploiting the gains in the legacy assumption set. So there develops a dual tackling of the fundamental infrastructure problems, one from technology applications and the other from changes in values and lifestyle.

This does not necessarily have to mean reduction in the economy or standard of living if the approaches are consistent with the philosophy of ‘factor four’ which, it has been suggested, holds the key to sustainable development. It refers to an approach for achieving fourfold increase in ‘resource productivity’, brought about by simultaneously doubling wealth and halving resource consumption (Von Weizsacker et al, 1997).

Infrastructure transition – courageous policy shift to sustainable systems

Courageous policies and bold design examples increasingly divert resources to harness intelligent technologies towards resource-light lifestyles (see Figure 13).

Figure 13: Infrastructure transition – courageous policy shift to sustainable systems

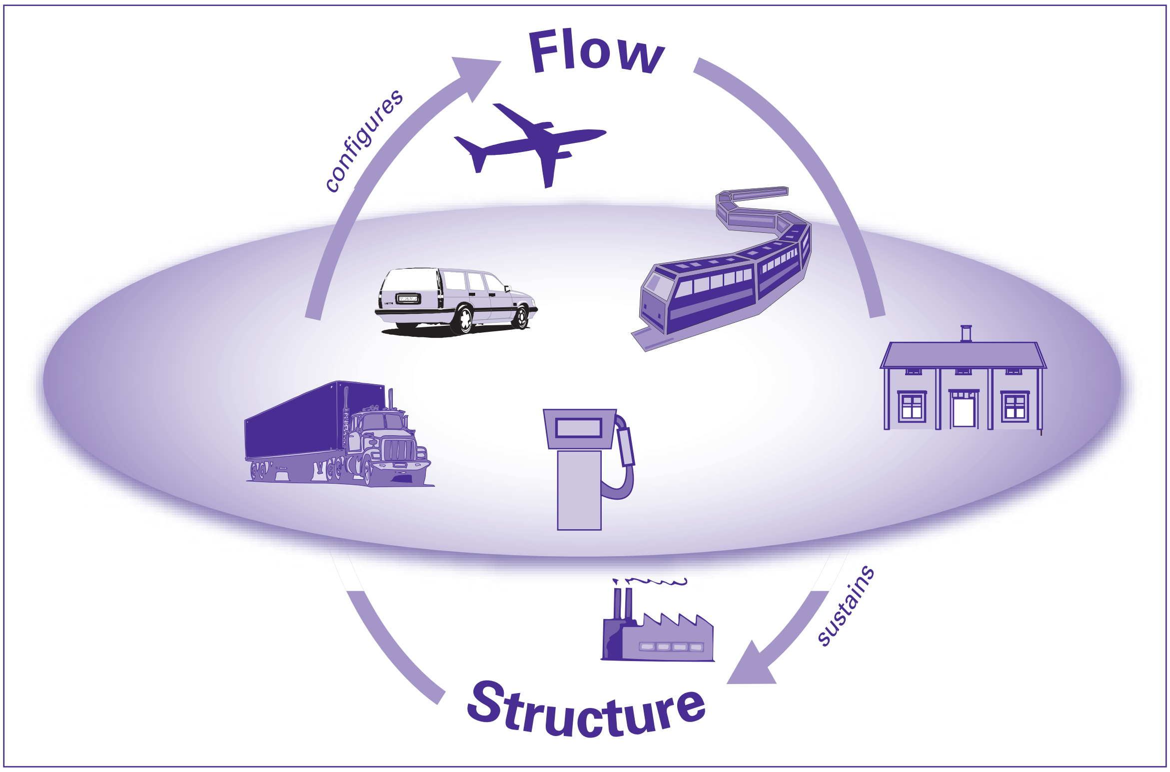


This system archetype of 'success to the successful' implies that at some point the failing fixes highlight that some patient and bold transformational investments are succeeding and so begin to attract more resources. As those successes become apparent, pressure to divert resources to the new approaches and technology applications gathers intensity to a tipping point, after which we find ourselves in the Perpetual Motion or Urban Colonies scenarios.

Footnote

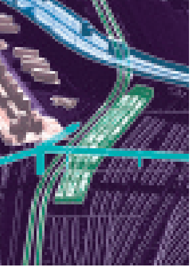
I^3 systems – *Integrated* intelligent infrastructure

Figure 14: Transport as a component of wider urban and global systems



The IIS project has focused primarily on transport. However, our Horizon 3 visioning makes it clear that, to achieve long-term solutions, we have to make the problem harder before we can make it simpler. We need to think about transport as a component of the more encompassing urban and global systems of which it is a part (see Figure 14).

The dominant theme of this paper is that by the intelligent design of our environment for sustainability, we can bring together many separate flows into systems that support the structure of those same environments.



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