

Intelligent Infrastructure Futures

Scenarios Toward 2055 –

Perspective and Process

This report was commissioned by the Foresight Programme of the Office of Science and Technology to support its Project on Intelligent Infrastructure Systems. The views are not the official point of view of any organisation or individual, are independent of Government and do not constitute government policy.

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Introduction

Intelligent Infrastructure Futures

The Foresight Project on Intelligent Infrastructure Systems (IIS) set out to examine the challenges and opportunities for the UK in bringing 'intelligence' to its infrastructure – the physical networks that deliver such services as transport, telecommunications, water and energy. In particular, the project explored how, over the next 50 years, we can apply science and technology to the design and implementation of intelligent infrastructure for robust, sustainable and safe transport, and its alternatives.

The technological opportunities and social factors are such that IIS can develop in many different ways, depending on the direction that society takes.

This report provides the background to the main scenarios report, *Intelligent Infrastructure Futures The Scenarios – Towards 2055*. The scenarios, along with the series of Research Reviews, provided a framework for the document *Intelligent Infrastructure Futures – Project Overview*.

The first part of this document contains a series of personal reflections by leading academic experts on how environment, society, crime and economics may develop in the alternate futures. These thoughts, which are the personal views of the individuals and do not reflect government policy, may help you to consider the implications of the scenarios for you and your organisation.

The second part presents a more detailed exploration of the methods used to develop both the scenarios and the systems mapping, or systems diagramming. These sections are intended more for the futures practitioner than the casual reader. There is also a more detailed description of how we identified the key drivers and trends that were used to explore alternate futures.

Intelligent Infrastructure Futures: Scenarios

The workshops of experts narrowed the discussion down to four scenarios that make it possible to investigate the ways in which the 60 key drivers of change might play out over the next 50 years. The future is unlikely to look like any of these individual scenarios and may well contain elements of all four. While the scenarios do not purport to predict the future, they do allow us to see how certain



combinations of events, discoveries and social changes might combine to create the future. As such, the scenarios allow us to see what we might need to prepare for and the opportunities that await us if we set the right course.

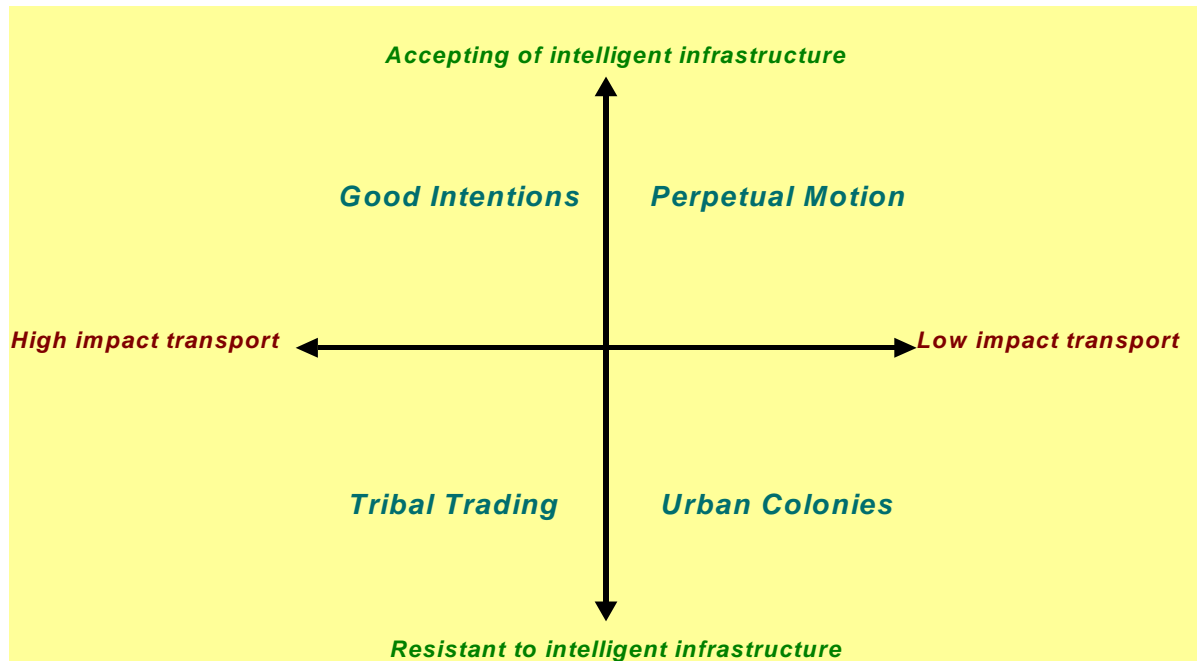


Figure 1 Four scenarios for intelligent infrastructure systems – the quadrants show the alternate states of the two 'axes of uncertainty' used in the futures exercise.

The defining uncertainties used in the futures exercise were: whether or not we will develop transport systems with a low-environmental impact; and whether or not people will accept intelligent infrastructure (see Figure 1).

The names given to these scenarios are intended as shorthand labels that capture the essential feature of each 'possible future'. It is worth restating here that these scenarios are just that, pictures of how the future could develop. The report has a full description of each scenario. We describe them briefly in the following section.

Perpetual Motion

Perpetual Motion describes a society driven by constant information, consumption and competition. In this world, instant communication and continuing globalisation has fuelled growth: demand for travel remains strong.

New, cleaner, fuel technologies are increasingly popular. Road use is causing less environmental damage, although the volume and speed of traffic remains high. Aviation still relies on carbon fuels – it remains

expensive and is increasingly replaced by 'telepresencing' for business and rapid trains for travel.

Urban Colonies

In Urban Colonies, investment in technology primarily focuses on minimising environmental impact. In this world, good environmental practice is at the heart of the UK's economic and social policies: sustainable buildings, distributed power generation and new urban planning policies have created compact, dense cities.

Transport is permitted only if green and clean – car use is still energy expensive and is restricted. Real-time information about transport is available in the cities. Public transport – electric and low energy - is efficient and widely used.

Tribal Trading

Tribal Trading describes a world that has been through a sharp and savage energy shock. The world has stabilized, but only after a global recession has left millions unemployed. The global economic system is severely damaged and infrastructure is falling into disrepair.

Long distance travel is a luxury that few can afford and for most people, the world has shrunk to their own community. Cities have declined and local food production and services have increased. Canals and sea-going vessels carry freight: the rail network is worthwhile only for high value long-distance cargoes and trips. There are still some cars, but local transport is typically by bike and by horse.

There are local conflicts over resources: lawlessness and mistrust are high. The state does what it can – but its power has eroded.

Good Intentions

Good Intentions describes a world in which the need to reduce carbon emissions constrains personal mobility. A tough national surveillance system ensures that people travel only if they have sufficient carbon 'points'. Intelligent cars monitor and report on the environmental cost of journeys. In-car systems adjust speed to minimize emissions. Traffic volumes have fallen and mass transportation is used more widely.



Businesses have adopted energy efficient practices: they use highly sophisticated wireless identification and tracking systems to optimize logistics and distribution. Some rural areas pool community carbon credits for local transport provision but many are struggling.

There are concerns that the world has done too little to repair the damage caused by decades of human activity. Airlines continue to exploit loopholes in the carbon enforcement framework. The market has failed to provide a realistic alternative energy source.

Intelligence in infrastructure systems

A key concept that the project embraced is that intelligence, in the context of thinking about intelligent infrastructure, can exist in four different ways. These all relate to the primary attribute of an intelligent system, that it uses all resources as effectively as possible to deliver maximum return for minimal investment of effort. The four levels of intelligence are:

- intelligent design of infrastructure
- obtaining intelligent information from infrastructure
- designing intelligence into infrastructure
- intelligent use of infrastructure.

The scenarios explore how *intelligent design of infrastructure* – for example of urban environments to encourage reduced travel – could improve the performance of the infrastructure and provide the most realistic way to deliver alternatives to movement, while providing individuals with choice.

The futures work also identified significant benefits from *obtaining intelligent information from infrastructure*, by which we mean collecting and processing information intelligently, so that travellers, operators and owners can make better use of that infrastructure.

By *designing intelligence into infrastructure* we mean building intelligent infrastructure that can respond autonomously and intelligently to external stimuli within a set of policy limits which may mean transport can then become an integral connected part of the wider infrastructure system.

Finally, there is *intelligent use of infrastructure*, which encompasses the idea that the action of users has a significant effect upon how effective those designs are in practice.

The summary report for the project, *Intelligent Infrastructure Futures: Project Overview*, discusses these four levels of intelligence in greater detail.



Part 1

Implications of the scenarios

The project set out to consider how we might apply science and technology to deliver intelligent infrastructure systems that are sustainable, safe and robust. In the following section a number of experts give their views on the sustainability of the scenarios. A widely used definition of sustainable development, attributed to Professor Sir Partha Dasgupta FRS of the University of Cambridge, is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. The three ‘pillars’ of sustainability are environment, society and economic wellbeing.

In all the scenarios we have assumed that climate change will be important. Dr Dan Osborn, Director of the Centre for Ecology and Hydrology (CEH) at Lancaster University, reflects on the general environmental trends and the context they provide for the scenarios.

This section also deals with two aspects of society. First, John Urry, Professor of Sociology and Director of the Centre for Mobilities Research at Lancaster University, considers the broader social factors reflected in the scenarios. Professor Paul Ekblom, of the Design Against Crime Research Centre at Central St Martins College of Art and Design, then looks at how crime could evolve in each scenario.

Finally, Dr Jonathan Köhler, of the Tyndall Centre for Climate Change Research, compares and contrasts the prospects for economic growth and development within each scenario.

The views stated are those of the authors and do not reflect government policy. They are intended to stimulate thought and discussion when read in conjunction with the scenarios in *Intelligent Infrastructure Futures: The Scenarios – Towards 2055*. You are also recommended to read the reflections on the scenarios written by Andrew Curry of Henley Centre, following each scenario in the above document, which explain the thinking behind their development.

Environmental implications

Dr Daniel Osborn

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Introduction

There is little doubt that people's interactions with their environment would be very different in each of the four scenarios described in the Foresight study. The scenarios themselves are of necessity too broad to allow accurate appraisal of the environmental interactions within each scenario. So, with colleagues, I considered what would be the most obvious impacts on the transport system as climate changes.

In this section, I sketch a few environmental factors that an intelligent transport infrastructure might need to cope with. If this all sounds a bit 'doom and gloom,' consider this: when I produced a draft of this assessment of environmental implications, it provoked a few quizzical looks and perhaps a bit of scepticism that some of these effects could be all that major. A few days later the UK had a spate of tornados: one, in Birmingham, left the transport infrastructure littered with debris and the wind drove posts of wood through vehicles' windscreens with considerable force. A few weeks later we had hurricanes Katrina and others to watch with awe and some trepidation. Not just the one or two events here – one after another, week after week.

For some balance, I also consider some issues concerned with the mitigation of climate change, and how this might also bring forward issues for consideration in the design of an intelligent infrastructure.

Climate change

Looking 50 years ahead, the most significant impacts on transport infrastructure are likely to arise from the effects of climate change and of policy decisions designed to cope with these. Changes and inadequacies in other infrastructures, uncertainties about fuels for transport and how the national energy mix might change could intensify effects for a range of reasons. Economic and societal well-being is commonly seen as intimately linked to steady growth in transport, making it difficult to see how we might reign in the impacts due to transport infrastructure. These links



are not well understood. We need research into their causes and drivers to inform sustainable management strategies.

On current trends, climate change is expected to increase *average* temperatures, by up to a maximum of 3°C by 2050 to 2080. There could also be more extremes of weather. Some urban temperatures, especially within transport systems, could exceed 40°C on hot summer days.

In practice, climate change is likely to mean:

- More flooding, not only from the sea and from rivers but also from underground sources such as overloaded sewers (see the Foresight Project on Floods and Coastal Development)
- More droughts, especially in the south and east of England, which already suffer water stresses
- Increases in rainfall in the north of the UK, especially, perhaps, in Scotland
- Storms will be more frequent and stronger
- More tornados and lightning strikes, which could temporarily disrupt communications within the intelligent parts of the infrastructure
- Increased risk of new pests and diseases establishing in the UK – these might be propagated via transport systems
- There may be a greater likelihood that combinations of extreme events will occur – for example, two or more flooding events or storms could occur in quick succession.

The impacts of climate change, and their severity, will depend upon the exact nature of the infrastructure. Engineers will need training in sustainable design and construction. For minimal disruption, infrastructure will need to be more robust and resilient in the face of greater climatic extremes. For example, the infrastructure will need to resist the effects of increased land instability when the ground is water-logged, and subsidence when it is dry during drought periods. One could lead to landslides that disrupt flow, the other to problems with bridges.

There will have to be the opportunity for transport to switch to routes that have not been affected by flooding, for example. The speed with which drivers need to be advised of problems suggests the need for more flexible and “real time” information systems. We may also need new ways of communicating to drivers, unaffected by light or visibility issues. These will have to avoid information overload in an emergency and also over-reaction to warnings – communication will need to be “smart” if not truly intelligent, for example, informing the driver *and* on-board computers. To maintain traffic flow, we may need to be able to use both motorway

carriageways which this would have implications for the design of junctions and central reservations.

The impact of climate change is likely to vary across the transport system. For example, the effects will be different for major routes, urban roads and country lanes. There will also be variations in different kinds of habitation areas. The issues can be far reaching in affected areas. For example, the risks of flooding from the sea, rivers and sewer overflows not only relate to physical issues but to pollution and mental health. The quality of life in some urban areas could be at risk. This might apply to inland as well as coastal and estuarine regions.

Changes in atmospheric chemistry could lead to more smog and fog. However, it is not clear what the impacts of a hydrogen economy would be on the chemistry and physics of the atmosphere. More research may be needed here, as atmospheric conditions have known impacts on human health.

Roads and rail

There will be a need to clear surface water more quickly from roads and from the rail network to avoid disruption and major accidents. This implies a need for drainage systems with higher capacity and more and larger balancing ponds. These systems may need intelligent monitoring and control so that other parts of the catchment do not flood. We will need to balance the opportunities to develop wetland habitats that can buffer sudden flows against disease risks. There could also be a role for road surfaces in this, or below surfaces, if they can be made more absorbent.

Major flooding events could be more frequent no matter what we do, so that dynamic route planning will be essential.

Intelligent systems will be needed to control traffic speeds in heavy rainfall, because storms and heavy rain may cause sudden reductions in visibility and vehicle instability.

There may be less provision for winter gritting because road conditions fall below-freezing less frequently.

Specifications for roads and bridges might have to change if land subsidence becomes more severe. Temperature effects alone could not only deform the physical infrastructure but might also affect intelligent systems.

Urban systems, including those below ground, would need to be more resilient to cope with flooding and increased temperatures. Ventilation systems will need



considerable improvement to control systems to conserve energy or recover power from the heat and its transfer.

Air travel and shipping

The most obvious affects here relate to the disruption likely to be caused by storms and their frequency. The responses within these two major systems will need to differ to suit the speed of travel in both systems.

Mitigating climate change

There are many options that might be considered for the next 50 years. I have listed just a small selection of measures relevant to transport. I also consider other sectors, such as manufacturing and the built environment, although actions to mitigate the effects of climate change in each of these areas will be equally if not more important than those for transport alone.

Taxing aircraft fuel could increase the need for fuel-efficient high-speed, or more comfortable, long-distance trains. Intelligent infrastructures might be needed to decrease the time between trains on such routes and to increase the routes' carrying capacity.

Taxing food miles, the distance that food travels to reach the consumer, would emphasise local supply chains. Increasing fuel costs may mean more goods being moved by water rather than road, leading to a demand for more coastal shipping and, even, new canal routes with, perhaps, automated barges

If the UK adopted the nuclear energy, as highlighted in *Perpetual Motion*, we may need to add to the power distribution infrastructure to distribute electricity to supply transport, as other fuel sources may be too expensive or unavailable. However, this form of energy distribution may make the infrastructure less resilient and robust.

If the UK is to meet national targets for CO₂ emissions, then we may need to accept centrally imposed measures to increase fuel economy, such as speed controls on major routes.

If there is reduced air travel to Europe, America and other international destinations, then it may be necessary to increase the capacity of, or to develop smarter means of controlling access to, local roads in holiday destinations in the UK to handle increased traffic.

A move away from car transport could mean that we will need safer and more secure cycle routes to reduce the “school run” and to encourage local shopping.



Social processes

John Urry

Professor of Sociology and Director of the Centre for Mobilities Research, Lancaster University

Perpetual Motion

This scenario is essentially a version of what has been termed 'business as usual' or 'hypermobility'. It sets out an exceptionally powerful model of what could take place over the next 50 years. There are many economic and social processes that are likely to push most societies and most corporations to seek to develop mobility patterns along the lines of this scenario. I would not call it perpetual motion.

The situation is more that of intermittent motion with an increasing proportion of the world's population either participating in it through their own movement or being affected by such movement through the voluntary or forced movement of others – such as kin, friends, workmates, members of diasporic communities and so on. People are often forced into a life of 'distant connections' through others moving. Hence the massive increases in long distance phone calls as well as the use of email (whose use seems to increase with distance), 'Skyping' and mobile telephony.

In the scenario, the move to ever more mobility is said to result from an individual desire for mobility. In reality, mostly people do not seek to be mobile for its own sake and especially not as an 'individual'. Rather, people seek to study abroad and improve their English, to migrate for a better job, to do business deals with other people, for family reunions at Christmas, to see long lost friends, to go on holiday together, to go a conference, to organise a political meeting, to form an international conspiracy and so on. And because people seek to do these things with other people who are geographically distant they need to travel.

So, living a 'networked life', with most members of one's network being far-flung, is something that is spreading worldwide and generates enormous amounts of travel. Moreover, travelling and having distant connections with those in other societies is often a form of status within contemporary life: this can be true of those living in societies that are both rich and poor.

In the case of the UK, there are so many historical and contemporary connections with the rest of the world, Empire/Commonwealth, the EU, financial services, the significance of London as a global city, sporting and cultural connections, overseas

students, international migration, Heathrow's role in international air-space and so on, that this stimulates vast amounts of work and leisure travel to maintain one's networks.

Moreover, one way to understand why increasingly available electronic communications – already a billion internet users – do not substitute for physical travel is because there is what has been called a 'compulsion to proximity', at least from time to time. This is a global phenomenon, so it would be extraordinarily difficult to somehow stop those living in the UK, who derive from many different societies, from engaging in such perpetual motion with significant others. Such reductions would anyway reduce economic and social well-being. Given that there is this compulsion to be 'co-present' with others, this will only be offset by real time telepresencing if we can simulate virtually most of the complex benefits of physically meeting others. So far, living a life 'on the screen' does not seem remotely as attractive as being with others in one's networks face-to-face from time to time. This is the basis of perpetual or 'intermittent' motion.

Urban Colonies

This scenario of 'compact cities' is very attractive. My comments relate to just two aspects: first, matters of detail and second what conditions might bring it about.

On the first, this scenario depends upon the spreading of various prototypes of such communities and supportive technologies. This spreading will involve government policies especially across the EU, the media and 'fashion'. On the last it will have to become unfashionable to live and bring up children in anything apart from such 'compact cities' – a little like the way that suburban living became fashionable in the middle years of the 20th century.

There will also have to be an enormous city building programme and the development of some distinct new materials and techniques to enable the construction of such compact cities. Indeed, the development of such compact places will probably require new kinds of legal entity, or private-public-community partnerships which can simultaneously invest and develop various post-car means of individualised movement.

New forms of such movement will need to be not privately owned. Indeed, ensuring a sufficient rate of recycling requires the general development of an 'access' economy in which the means of access are readily available but are not individually owned. Some current forms of travel relating to computer software, downloading music and so on indicate the putative development of such an access economy. It may also be that this scenario depends upon new kinds of 'friendship', on choosing



to know mostly people who live close by and can be walked to and being unperturbed by a lack of long distance travel and connection, except electronically. Status attributions will have to be re-localised.

Second, how would this scenario come about? It is difficult to see its emergence as being a linear development from existing patterns or something that governments on their own could simply 'introduce' – and certainly not without this being say an EU-wide development. There would need to be some kind of 'shock' to the system and this would almost certainly be a 'global' shock that provides a 'tipping point,' a little akin to the global shock of 9/11.

What would probably 'need' to happen to prevent continued climate change, and to move into a system of more decentralised urban colonies, would be a global shock that is understood worldwide as a total threat to the pattern of 'business as usual'. Examples could include some iconic extreme weather event or a war generated by massive reductions in oil supply or the suicide bombing of a means of transport that was qualitatively different from what had gone before. Such a catastrophic event could undermine the kinds of development adumbrated in the Perpetual Motion scenario.

Tribal Trading

This scenario sets out a rather moderate version of a conceivably darker and more dystopic nightmare that extends some current trends. In particular, we can imagine a neo-Mediaevalist scenario of the future, namely that the world would return to conditions more like those which preceded western capitalism and the development of a system of nation states.

With neo-Mediaevalism, there are no longer clear and well-enforced national borders. Rather, there are relatively separate and self-governing city-states, a re-localisation of the world. Surrounding such walled cities there is an enormously dangerous and chaotic environment which few people will enter without arms. Long-range travel is dangerous and only undertaken by those who are armed.

No longer do states possess the monopoly of legitimate violence. And there are some powerful empires, of McDonalds and Microsoft, although future empires are likely to be based upon the control of water and energy sources which are in increasingly short supply and guarded by armed gangs.

With such patterns it is likely that there will be massive inversions of various hierarchies, demonstrating the maxim that the first shall be last and the last shall be first. Global cities like London will have become ungovernable and unregulatable.

Many people will flee such places of danger and develop self-governing localities with localised energy sources. Emergent forms of global governance will evaporate.

Prescient visions of Tribal Trading can be seen in parts of the world today, parts characterised by 'wild zones,' where the rule of law has evaporated and gated communities seem to provide the main forms of security in a world that is 'nasty, brutish and short'. There is with Tribal Trading 'no such thing as society', more an array of conflicting groups based on armed might and seeking security (at a price) within different localities. Such wild zones are found in parts of the Middle East, the former Soviet Empire, parts of sub-Saharan Africa, some of the favelas in South America and in the poor sections of many cities in the USA and Europe.

Only the super-rich in this dystopia will be able to move: they will use helicopters, light aircraft and other personalised and secured forms of air movement. Mass travel and transport will decline. Travel will again be mainly the preserve of the rich and powerful, now though rather than using horses and horse-drawn carriages they will be able to fly over the trading and intermittently warring localities scattered below. Other rich groups will use space travel to escape the Earth and seek to establish secured communities on the Moon.

Good Intentions

This scenario might be better termed 'global sustainability'. It sets out some of the limitations upon the notion of the rights of the consumer and especially the idea of consumer sovereignty including the rights to mobility. The scenario highlights that there is no particular reason why the consumer should be 'king' – enabling the consumer to be king sets up such enormous positive feedback loops that take any such systems well away from 'equilibrium'.

The scenario brings out also the importance of international agreements and the concept of carbon entitlements and trading. Only these, it seems, can challenge individualised consumer sovereignty. Also, the notion of demonised frequent flyers is a provocative image mentioned in this scenario, bringing out how regulating social practices require transformations also in fashion and taste – best revealed currently in the UK in the demonisation of the drunk driver.

There are, however, further conditions that would need to be met in order for this scenario to be potentially realisable. First, it would be necessary to try to prompt corporations to develop virtual communications that would in some ways reproduce the fundamentally interactional and conversational nature of everyday life and really think through how intermittent travel could be substituted for, but not through merely living one's 'life on a screen'. Much travel is to do with the complex



pleasures of meeting others. Pleasures that will have to be reproduced or found in different ways once resource consumption is the basis of taxation, resources and wealth.

Second, it would be necessary to fund the development of hydrogen as a fuel not only technologically but also through new conceptions of appropriate vehicles, but not the resource guzzling four-person family car. Moreover, developing hydrogen fuelled vehicles is likely to originate from outside current leading corporations, as with the unexpected origins of mobile telephony in a Finnish toilet paper manufacturer called Nokia. Overall, the new travel technologies that this scenario depends upon generally do not arrive fully fledged but result from the unexpected and contingent: they are unlikely to emerge from existing travel operators or manufacturers.

This latter point suggests that an important UK government facility would be the worldwide monitoring of current initiatives, prototypes, social practices and business models wherever they are, that would enable moving beyond merely the good intentions of this scenario to figure out some plausible socio-technical systems that enable us to move beyond 'business as usual'.

Crime

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Introduction

No discussion of the future of society can ignore the likely effects of crime. While new technology can help to reduce the risks of crime, we need look no further than the Internet and the rise in identity theft to see that new technology also opens the door to new ways of committing criminal offences.

In this section, we provide some thoughts on crime and crime prevention implications of each scenario. The result is illustrative rather than systematic or rigorous. The aim is to open minds to new possibilities. This exercise drew on a wide knowledge of the crime field, supplemented by intuitive (rather than explicit) use of two frameworks.

One of these, “The Conjunction of Criminal Opportunity,”¹ is a map of 11 generic causes of crime that come together to make criminal events happen, and 11 corresponding intervention principles for prevention. For each cause, such as offenders’ resources for committing crime, we can ask whether the changes forecast in a given scenario are likely to affect it in ways that might significantly raise or lower the risk or seriousness of particular kinds of crime. They may do this by influencing individual causes, or by bringing those causes together in particular

1 Ekblom, P (2001) ‘The Conjunction of Criminal Opportunity: a Framework for Crime Reduction Toolkits’ - Crime Reduction website, www.crimereduction.gov.uk/learningzone/cco.htm

Ekblom, P (2002) ‘Future Imperfect: Preparing for the Crimes to Come.’ *Criminal Justice Matters* 46 Winter 2001/02:38-40. London: Centre for Crime and Justice Studies, Kings College.

Ekblom, P (2005) ‘How to Police the Future: Scanning for Scientific and Technological Innovations which Generate Potential Threats and Opportunities in Crime, Policing and Crime Reduction’, in M. Smith and N. Tilley (eds.), *Crime Science: New Approaches to Preventing and Detecting Crime*. Cullompton: Willan.



places and times, for example, bringing potential offenders and victims together through a transport network.

The same applies to envisaging how the changes forecast in scenarios might affect the motivation or ability to prevent the crime. The crimes considered can be highly specific or very broad categories, such as property versus violent crime, material crime versus e-crime.

The “Misdeeds and Security framework”² identifies the broad types of risk of featuring in crime, which material objects, places, systems and services, including the Intelligent Infrastructure itself, can face. These include misappropriation (theft), mistreatment (damage, injury), mishandling (fraud, forgery, counterfeiting), misuse (as tool or weapon for crime) or misbehaviour (as with an environment conducive to disorder and nuisance); and whether organised or not. For each of these risks, we can, in principle, identify some generic risk and protective factors. The most widely developed of these relate to ‘hot products’³ which covers the risk of theft of material objects, whether they are concealable, removable, accessible, valuable, enjoyable and disposable; and on the offender side, to developmental factors in early life, centred on personal, family, peer group and school.

Universals of human ecological circumstances and human nature captured in these frameworks include: conflicts, and their causes; the need for justice/fairness; the effects of disrupted expectations of rights, for example, to easy personal travel; and the inevitable effect of concentrations of wealth and perceptions of differential changes to people’s wealth.

Perpetual Motion

Road-rage incidents have been proportionally fewer as drivers have relinquished personal control of vehicles – with fewer frustrations on the road, less scope for bad driving and less likelihood of blaming the other driver. However, when things do go wrong they tend to go wrong badly and people are less used to having to cope with

2 Ekblom, P (2005) ‘How to Police the Future: Scanning for Scientific and Technological Innovations which Generate Potential Threats and Opportunities in Crime, Policing and Crime Reduction’, in M. Smith and N. Tilley (eds.), *Crime Science: New Approaches to Preventing and Detecting Crime*. Cullompton: Willan

3 Clarke, R. (1999). *Hot Products: Understanding, Anticipating and Reducing Demand for Stolen Goods*. Police Research Series Papers 112. London: Home Office.
www.homeoffice.gov.uk/rds/prgpdfs/fprs112.pdf

delay and disruption. Occasionally such disruptions are deliberate, created for purposes of vandalism, terrorism and even an infamous highway robbery of a gridlocked line of vehicles leaving Glyndebourne one evening.

Stress combined with working from home has generated the pressures and the occasions for an increase in domestic violence. And whereas in the past vengeful spouses and partners cut up their ex-partner's suits, shoes or cars, some have found that the worst kind of hassle to be visited upon someone is to destroy their ID devices and, if possible, the backups.

Household management computers have often been interrogated to reveal the movements of people under investigation by the police, but lawyers are wrangling over several cases where, if human, the computers would have been indicted for knowingly supplying false alibis.

Rampant consumerism has, as ever, been accompanied by rampant property crime.

The eagerness to encourage growth in the hydrogen fuel infrastructure led to a wave of fraudulent applications for subsidies, and not a few accidents with substandard installations, sometimes allowed through by corrupt safety inspectors.

Companies have developed added-value services that link personal ID devices to wallets and purses (for those who still have them), jewellery, pets and children, cars and bicycles. So a personal intranet links all mobile or portable property (loosely interpreted) to the owner. Robbers running down the street clutching, then throwing away, unplundered, handbags shouting at them with disembodied voices were an occasional amusing sight until the criminals abandoned the career as too risky.

Unsurprisingly, school bullies, stalkers and racists have misused telepresencing, as they did text messaging in earlier times. But more than one attacker or burglar has been spooked enough in poor lighting conditions by virtual 'guardian angels' to have been put off their stroke.

Quiet zones imposed unilaterally by local communities have undoubtedly demonstrated some of the benefits of social cohesion but have occasionally slipped into vigilantism and deliberate social exclusion.

Automated service delivery has continued the trend of removing human intermediaries who might deter or intervene in crime, as with the move from chemical to electronic photography, which freed child pornographers to take and circulate illegal pictures. However, this appears to be a transitional problem, as software is increasingly able to discriminate between legal and illegal behaviour and



intentions, and as companies that create inadvertent opportunities for crime are increasingly made responsible, 'polluter-pays' fashion, for clearing them up.

Urban Colonies

Reduced consumption of goods means the people are more likely to value those that they do possess, and perhaps more are likely to have them repaired (and designed for repair) rather than to throw them away. There has been a revival in the second-hand market, reviving, in turn, criminals' interest in burgling homes rather than stealing brand-new goods from shops and the supply chain. However, a parallel trend towards mass-customisation and personalisation of those new goods that are produced has made them less attractive on the stolen goods market – who, after all, would want to buy in a pub, a music player that had been configured to fit someone else's ear, or their idiosyncratic colour preference?

Hijacking of freight road trains occasionally occurred until security procedures and satellite tracking were tightened up. One incident was reminiscent of the Sherlock Holmes story 'The Lost Special,' in which an entire railway train was diverted into an abandoned coalmine by re-laying, and then taking up, disused rails.

Reduced international travel at least had the benefit of putting the brakes on people-trafficking, a trade into which organised criminals had moved at the end of the last century because the penalties were less than those for drug smuggling. Unfortunately, the financial and social capital accumulated by the offenders combined with some energetic and enterprising horizon-scanning of their own meant they were able to diversify into Internet-based crime such as illegal gambling, pornography and even blackmail of the illicit users of their services. However, economists employed by the more sophisticated enterprises pointed out that this 'quick buck' approach would neither contribute to a steady yield nor encourage new users to sign up. Many criminal enterprises networks therefore evolved from predation to parasitism.

The change to public transport caused enormous resentment among many who regarded the private car as their inalienable right, and during a long transition period this was expressed by vandalism, assaults on officials and various kinds of collective action only occasionally before seen in Britain – such as the fuel tanker drivers' strikes of the early 2000s – and progressively empowered, it seemed, by each new feature of the Internet.

The many practical disruptions of people's lives – locked into particular patterns of work, school run etc – led to much stress and not a little conflict. Fights over the routes and destination of the hybrid buses/taxis were not confined to Friday and

Saturday nights in entertainment centres. Eventually, new expectations over collective and individual rights, queuing principles and etiquette to smooth the way, did evolve.

As an instance of joined-up government, the Home Office quietly let private vehicle crime slip slowly down its list of priorities. In any case, demand for private vehicles to steal was diminishing and this was more a matter of letting nature take its course.

The welcome move towards sustainable design and service delivery quickly began to encompass crime and safety issues – after all there is little sustainability in a building where people won't live or work because of concerns about crime, or whose repair and maintenance costs are significantly augmented by constant damage from break-ins, graffiti and vandalism. The lead interest in schemes such as the police service's Secured By Design had been firmly in the social housing sector, but pressure from government, insurers and enlightened consumer groups and architects, combined with research reassuring developers that buyers would not be deterred by increased emphasis on security, eventually brought the private sector on side.

As ecological/systems models replaced neo-classical economics, new thinking began to be applied in the intersection of crime, the economy and sustainability, and new tools such as Crime Impact Assessment began to be developed.

Tribal Trading

Whereas crimes over fuel and electricity used to be targeted on the utilities that supplied them – abstraction, defrauding meters, non-payment of bills – the targets are now far more local and even sometimes personal. Fights and long-running feuds over hydro-power or even fresh water, gas from old landfill sites and quarries, for example, have become a regular feature of life as global ownership, trading and power supply has been replaced by local equivalents.

But these are just part of wider territorial conflicts. Local democratic government has been replaced, in some localities, by gangs and latter-day robber barons who have driven out, or filled the void in, the provision of civil law, criminal justice and democratic rule. Even after things settled down following the Great Disruption, gang rule has been difficult to uproot. As the experience with ex-terrorist influence in Northern Ireland showed some decades earlier, social groupings have become more geographically clustered, although nobody is explicitly using the term 'ethnic cleansing'.

Localisation has been accompanied by greater pressures for conformity, and to some extent the closure of the gap between an independent 'youth culture' (which



reached its peak in the early 21st century) and the rest of the population. In effect, the last generation of independent youth became the first generation in decades to exercise heavy control over their own offspring – who could no longer travel freely, safely and cheaply on their own, who could not afford their own expensive sub-cultural props and who no longer had support for their independence from a vanished commercial system.

The restriction of vehicular travel to the privileged and the relative desertion of roads has left the remaining, wealthy, drivers vulnerable and attractive to robbers, and at times provocative to the have-nots. With few vehicles in production, theft of parts and cannibalisation are rampant.

The Disruption played havoc with people's finances. Savings lost their value, pension schemes vanished and hasty attempts to convert to gold and other more trustworthy forms of value were welcomed by a wave of fraudsters. Home security, plenty of family members at home and firearms are the means by which people hang onto their wealth in many places. There is a good trade in vintage metal detectors for those who have forgotten where they buried their wealth – or those others who would find it first.

Some newer housing built after the Great Disruption resembles the fortified farmhouses still found in the country north of Carlisle, relics from the time of the border reivers. A call to the police is unlikely to bring a fast response, if any – and besides, parish justice is likely to be quicker and cheaper, though not fairer.

Attempts, post-Disruption, to re-establish free-market trading conditions have proved difficult. Few realised how much the free market depended on communication and trust, and on common standards – even agreed weights and measures. Much trading still depends on personal or hired muscle to enforce deals, both within and especially between communities.

Good Intentions

In an increasingly regulated world of diminishing personal choices on travel, work and leisure, driven by environmental and energy considerations, and yet inhabited by people who grew up expecting the opposite, we expected, and found, at least in the transition period, much cheating and infringement of regulations, and perhaps servicing of travel/energy cheats by unscrupulous entrepreneurs. This was a new niche for organised crime, having found the drugs trade too hot and the people trade shrinking with diminished travel. There were interesting parallels with the criminogenic Prohibition Era of 1920s USA, only this time not alcohol but vehicle fuel and travel were the desired but rationed fix.

People came to expect to watch hawk-like for cheats and what they saw as unfair distribution of scarce energy and travel resources. Perceived vulnerability of the system to cheating and unfairness threatened to seriously undermine the 'environmental contract' to diminish travel, between drivers and the state. Pressure for punitive treatment of cheats strained the resources of the police and Criminal Justice System. Vigilantism and other kinds of direct action started to befall those who still demonstrate conspicuous consumption, as began apparently harmlessly with the campaign to deflate the tyres of urban 4x4s in the early 2000s.

On the other hand, less travel did reduce the opportunity for some crimes, although most criminals continued as always to offend close to home and in familiar surroundings. It led to the restoration of less mobile, more conformist communities, where reputation replaced anonymity and the opportunity to be the stranger-criminal decreased. But a new wave of rural flight led to conflicts over scarce accommodation and employment.

Besides ideological opposition to flow management of road traffic, akin to attacks on safety cameras of the early 21st century, we saw vandalism for 'fun', extortion under threat of disruption on private toll roads particularly, and terrorist exploitation of maximum chaos for minimum effort. At least joy riders and calamitous car chases became a thing of the past, although the 'extreme sport' of racing unregulated veteran cars through regulated traffic streams occasionally caused chaos and injury. Regulated traffic, out of the hands of drivers, did, though, reduce road rage.



Economics

Dr Jonathan Köhler

Tyndall Centre for Climate Change Research

Introduction

This perspective outlines the overall social and economic situation that is described in each of the scenarios. These outlines are qualitatively assessed against a baseline. This baseline consists of an extrapolation of current economic trends. The historical growth rate of the industrialised countries has been around 2% per year since industrialisation. The main changes taking place in the global economy are:

- Globalisation – rapidly increasing international trade – although, for the UK, internal trade and freight transport is still around 80% of the whole – and an acceleration of the economic processes of knowledge and technology transfer, due to IT.
- The change in economic structure of the ‘advanced’ economies away from manufacturing and towards services – the UK now has only 20-30% of GDP from manufacturing.
- Ongoing transformation of society through technological change, in particular in IT. Not only can information intensity and extent be expected to increase and become cheaper, but social activity will shift further to being oriented around products and services based on IT.

We have applied these trends to the UK. Our assessments of the scenarios consider the position of the society and economy in the UK in the relevant global context. We will assess overall economic growth, consumption, changes in industry and services and the role of government expenditures.

Perpetual Motion

This is essentially the baseline, in terms of general economic activity and society. For the UK, this implies a relatively high average growth rate. Given the comments about limits of labour supply for less desirable jobs, automation of currently labour intensive services will be extensive. Leisure consumption will incorporate even higher levels of IT than current services. The switch to automated services and partly low carbon transport will have been a major factor in maintaining economic growth, measured in conventional terms as GNP. Corporations are now mainly global.

Government in the UK is still highly centralised at the national level, with increased levels of fiscal expenditure financed by the strong growth over the long term.

Comments about the urban environment and a retreat to the country suggest pockets of urban deprivation, so there will still be considerable public social expenditure. The comments about high stress levels also suggest considerable private expenditure on health. Since most people are wealthy and there is no suggestion that taxation would increase to high enough levels to provide the high levels of care demanded by a stressful society, health insurance to fund private health care will be much more common than in 2005.

High real resources prices, compared to 2005, will cause major technical advances in resource efficiency of manufacturing and services, in a similar way to the developments of the transport system that are detailed. This implies the development of a major new economic sector in resource management.

Urban Colonies

This scenario represents a fundamental shift in economic patterns. However, this does not mean that economic growth will suffer. On the contrary, the fundamental change in social priorities will require exceptionally high, continued levels of investment. Such high levels of investment characterised the economic boom after World War 2 and long wave of growth from 1950-1973. This implies that the Urban Colonies scenario is one of very high overall growth, higher than the historical rate as projected forward for the Perpetual Motion scenario.

Consumption patterns have changed very considerably in this scenario, such that consumption goods form a significantly smaller proportion of household consumption than in 2005. However, consumption of (decentralised) IT services is very high. Industrial production shows continuing growth in this scenario.

The building sector will benefit from the urban restructuring and the development of new transport infrastructures supporting low emissions transport. The transport vehicle sector will be able to take advantage of a rapid turnover of the vehicle stock to incorporate low carbon technologies. The resource management and recycling sector will become one of the major industrial activities, more so than in the perpetual motion scenario. Furthermore, health and leisure will continue to grow, again based on decentralised IT, but growth will also be fuelled by an increasing willingness for household to pay for such services, given continuing growth and a reduction in consumption of physical (material) goods. Government will also be centralised, probably funded by fairly high levels of taxation combined with strong



economic growth. However, regional city governments will have greater importance in provision of public services and fiscal policy.

We should also consider the geography of growth. Urban regions are the drivers of economic growth, as is the case in the UK in 2005. They will continue to be the main centres of population. Indeed, given high growth in cities and poor rural service provision combined with a high degree of migrant labour in agriculture, the countryside will depopulate.

Tribal Trading

This is a scenario of a major depression, caused by high energy prices and climate change impacts. National economies disintegrate.

Within the UK, there is a patchwork of new, regional and local political/social communities. The international financial system may well have collapsed also, to be replaced either by barter or local bilateral agreements. There will be the use of different, scarce commodities as currencies, of which oil will be one: silicon chips could be another.

Consumption patterns have fundamentally changed. There is a significant move towards a combined lifestyle of household or 'village' production with a 'workshop' style of industrial organisation. Material standards of living have fallen, compared to 2005 in the UK for most people. Governments will be strictly local, with local taxation and remaining public services provide also at a local level.

The need to defend local borders will mean that, as in many poor countries in 2005, defence and military expenditure is a large part of government activity – up to 70% of government activity by value in some cases. However, the remaining local communications systems still have high knowledge transfer/processing capability, so there will still be relatively rapid knowledge and technology diffusion and transfer.

The technologies and industrial activities will be different, because it will no longer be practicable to have complex logistics chains. There will be a very high emphasis on recycling of materials, which will replace industrial manufacturing of products starting with raw materials construction.

Good Intentions

In economic terms, this scenario contains significant elements of the baseline/perpetual motion scenario. There are two major changes:

- A switch of consumption away from road passenger transport – and probably a move to less energy/resource intensive forms of freight transport, such as inland waterways, coastal shipping, US style rail-freight operations
- A major change in the UK's fiscal system to higher resource and energy taxes and consequent higher prices for transport.

However, the overall economic processes of growth and globalisation remain as in the baseline scenario Perpetual Motion, that is around 2% GNP growth per year and the internationalisation of commercial and industrial activity. The switch from transport will change consumption patterns significantly, perhaps to IT based leisure and smart buildings with many virtual reality facilities. Industrial activity will not change so much, other than a shrinking of the automobile and aviation industries. This may be compensated for by increased attention to IT developments.

A lack of early action will mean that the increase in transport prices has not caused a shift in urban living/work patterns, although we can expect a reduction in long distance commuting. A further change will be the localisation of production, where transportation and/or energy/resource costs are a significant part of production costs. For energy costs, this is only true for a few industries – iron and steel, industrial chemicals, paper, cement and aluminium. However, there will be a dramatic impact on international tourism, which will decrease significantly from 2005 levels.

Service sectors will continue to play an important part in the UK economy, with the leisure sector changing to accommodate a return to within UK travel – possibly associated with a return to rail/ship based international travel to Europe. Governments will have a similar role to the baseline/perpetual motion scenario, with the same issues of financing social expenditures, but solved through increased revenues from resource taxes/ permit trading schemes and a favourable economic growth rate.



Part 2

Developing scenarios

Andrew Curry
Henley Centre

Introduction

The future is uncertain. While it may seem to be beyond our influence, in reality we can control many aspects of the future.⁴ Futures work is a way of investigating some of the uncertainties and of exploring areas where we can control the future. It is about rehearsal, creating and exploring multiple possible futures, with the purpose of taking responsibility for the future.

Good futures work increases the speed at which organisations, and their partners and stakeholders, can respond to changes. It prepares organisations for the future, and helps them to identify strategies that will be robust against a range of possibilities.

Scenarios are a useful tool in helping us to think about the future. Effective scenario exercises develop by asking a strategic question about the future. The question forms the basis for all elements of the project. For the Foresight Project on Intelligent Infrastructure Systems, the question was:

“How might future generations of technologies be applied in the UK over the next 50 years to deliver robust, sustainable, intelligent, responsive and adaptive transport infrastructure systems?”

The project consisted of four phases with workshops at various stages:

4 ‘Futures Fluency: Explorations in Leadership, Vision and Creativity’ by Wendy Schultz, which draws on ‘Reinventing Courts for the 21st Century: designing a Vision Process’ by W Schultz, with C Bezold and B Monahan (Williamsburg, Virginia: National Center for State Courts, 1993)

- Driver prioritisation and analysis
- Evaluating uncertainties
- Scenario matrix construction
- Construction of scenario narratives

The outcome of these four stages is a set of scenarios and narratives that policy makers, business and other organisations can use to explore how they would be affected by, and might act, in different futures.

Stage 1 – Driver prioritisation and analysis

Drivers of change are factors that shape the future. Some drivers are already highly visible, others less so. While we may be able to determine the effects of drivers of change on the present and the near future, it is less easy to determine their effects in 50 years time.

It is, therefore, important during this stage of the scenario process to identify a broad range of drivers and to consider which will be most important in the future, rather than to focus on drivers that are most important today. Typically at this stage, therefore, drivers are prioritised according to their future importance for policy.

Stage 2 – Evaluating uncertainties

Having prioritised the critical drivers, the next step is to consider how the important ones might play out in the future. Some drivers will have uncertain outcomes: others will be based on predetermined elements. Both types of outcome are important during this stage of the scenario process. For uncertain drivers, it is essential at this stage to identify the nature of the uncertainty and the range of possible outcomes. It is also important to explore the dynamic interplay between drivers over the 50-year time period.

The critical output from this stage of the futures exercise is a number of 'axes of uncertainty' which describe the range of uncertainties for the future, together with the range of possible outcomes. We use these uncertainties to define the scenario space and to shape the production of the narrative for each scenario. Predetermined elements define strategic issues which need to be addressed across all the scenarios.



Stage 3 – Scenario matrix construction

The scenario matrix is a 2x2 schematic that defines the main parameters of the scenarios. We construct the matrix by juxtaposing the two axes of uncertainty. These reflect the most important uncertainties, and offer the most insight, or provide the most intriguing glimpse of the future.

Matrix construction is an art rather than a science. The final 2x2 array is often decided through negotiation, intuition and extensive workshop testing.

We develop four scenarios of the future. The actual future is likely to resemble some mixture of all of them. The narratives are intended to highlight some of the critical themes that emerge from the workshops.

Stage 4 – Construction of scenario narratives

The narratives for each scenario are constructed within the logical framework that comes out of the scenario matrix. The narratives draw on all the material in stages 1 and 2 and on wider research, including the state-of-research reviews commissioned as part of the Intelligent Infrastructure Systems project. The narratives describe both 'end states' and timelines. End states describe what the world looks like in 2055, as well as at different points of view along that journey, in this case, 2025 and 2040. Timelines are descriptions of how the future has evolved from the present. Wherever possible, stakeholders participate in testing and exploring the emerging scenario narratives.

Stage 5 – Working with the completed scenarios

With the completed scenarios, policy makers, business and other organisations can explore how they would be affected by, and might act, in different futures. Users do not choose a 'preferred' scenario: they use them to evaluate different policy options, business opportunities and research directions.

The scenarios, appropriately used, can help to identify success criteria and determine the effect of different policy instruments. Generally, these policy measures differ in each scenario: the discussion can help participants to build a shared understanding of how the increasingly complex changes taking place in the world could affect their activities.

With the scenarios policy makers can explore the issues and choices they face today. All scenarios contain elements of the present extrapolated into a logical

future. Exploring them allows policy makers to see the consequences of making – or not making – decisions that they might face in the near future.

Systems diagramming and scenarios

Tony Hodgson

Decision Integrity Ltd

Scenarios allow detailed thinking about possible futures. A weakness of the scenario approach, however, can be that it can be difficult to pin down their implications for policy and strategy. When it comes to analysing how a particular policy initiative might play out in each scenario, it can be hard to frame the “what if?” question and to see how it could shape real decisions and ideas.

One way to clear away these difficulties, and to realise the full benefits of scenario thinking, is to consider the ‘deeper structure’ of each scenario (see Figure 2). This is a way of looking beneath the events and trends that may characterise a future, and of thinking about why these events and trends might happen.

Deeper investigation can reveal trends that make some events more intelligible and thus more easy to anticipate. However, where there is uncertainty and discontinuity, there is more than one possible outcome and so forecasting breaks down. We then need multiple scenarios to cover the range of possibilities.

A key factor of the structure of scenarios is that effects can also be causes. Using systems thinking, we can penetrate deeper into what underlies events and trends.

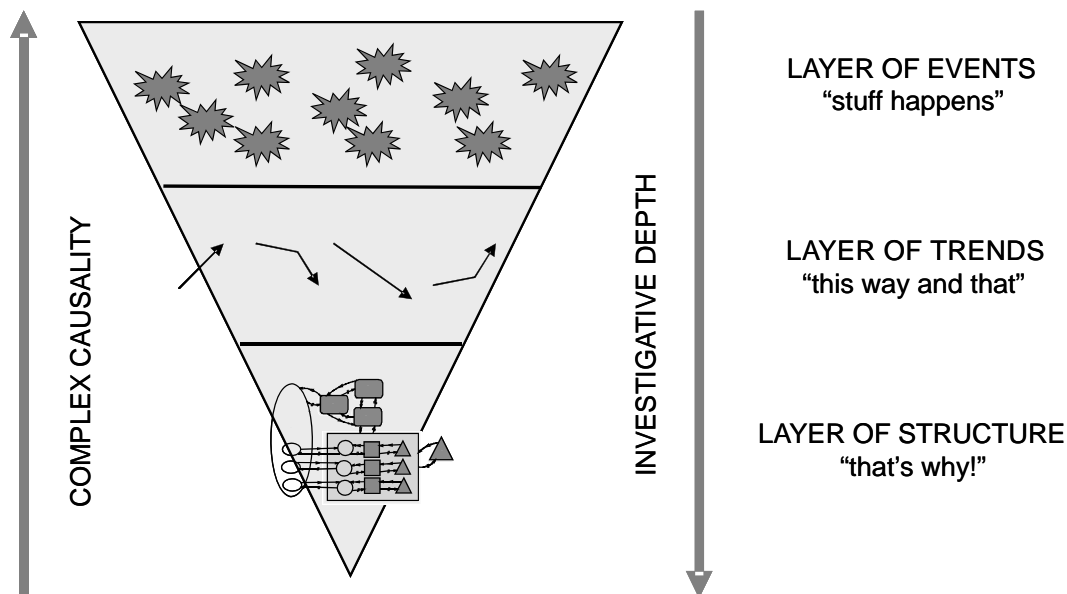


Figure 2 Proper analysis of scenarios benefits from looking beneath the events that may characterise a future.

By modelling some of the complex interlinked drivers, we can increase the sense-making value of the scenarios. Analysing the deeper structure can also reveal how “tipping points” might switch the direction of events towards one scenario rather than another.

Systems thinking helps to make complexity more intelligible. It is a way of making an appropriate simplification.

The system of drivers shows how the drivers identified by experts as relevant to intelligent infrastructure systems could be inter-related. As the scenario develops over time, the key causal relationships at the heart of the scenario also develop.

The "Interacting System of Key Drivers" (see Figure 3) is based on the analysis by the Henley Centre of the dominance/dependence relationships (see Figure 9). It takes that analysis further by looking at the drivers as a system of interacting forces which create feedback loops that mutually reinforce each other. Different loops in the diagram play out differently in the different scenarios.

To bring out the differences between the scenarios and yet relate them through a common variable, a diagram after the description of each scenario shows the main reinforcing and balancing feedback loops that affect the volume of transportation. The main futures report, *Intelligent Infrastructure Futures: The Scenarios Towards 2055*, contains diagrams of the inter-relationships, showing subsidiary feedback loops that significantly moderate the core causal relationships specific to each scenario. The story vignettes in each scenario map onto the dynamics of that scenario, illustrating how the structure affects the way people behave in typical circumstances.

Systems work also helped to develop the ‘Horizon Map’ (see Figure 4) that supports the work on the separate report *Technology Forward Look - Towards a Cyber-Urban Ecology*. This ‘rich picture’ summarises the thinking behind the forward look, with its analysis of three time horizons and the technologies that could influence the future in the longer term and the dominant ideas that are likely to shape the technology in the longer term.

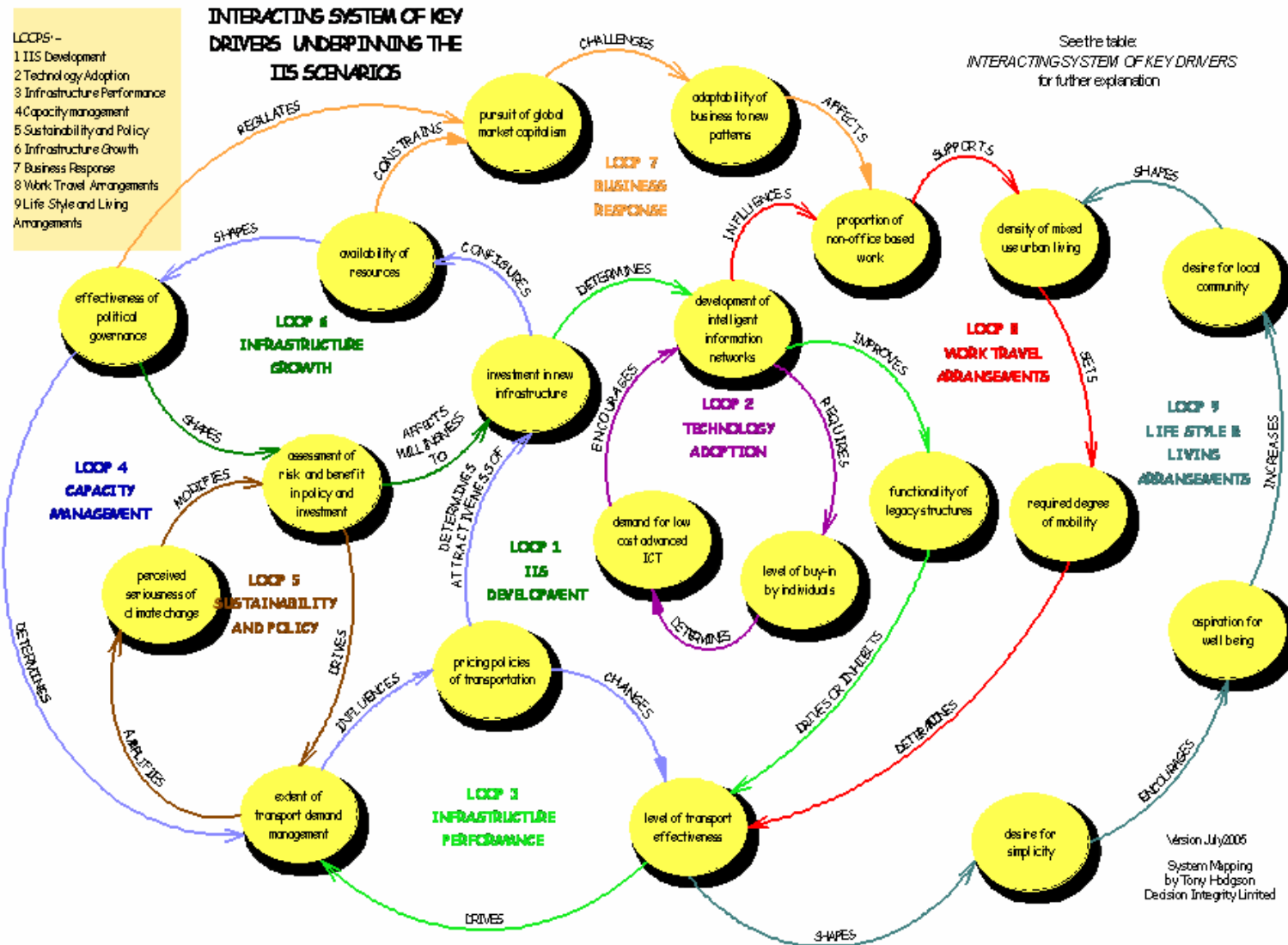


Figure 3 The 'system of drivers' shows how drivers relevant to intelligent infrastructure systems could be inter-related.

Foresight Intelligent Infrastructure Futures
 The Scenarios – Towards 2055
Perspective and Process

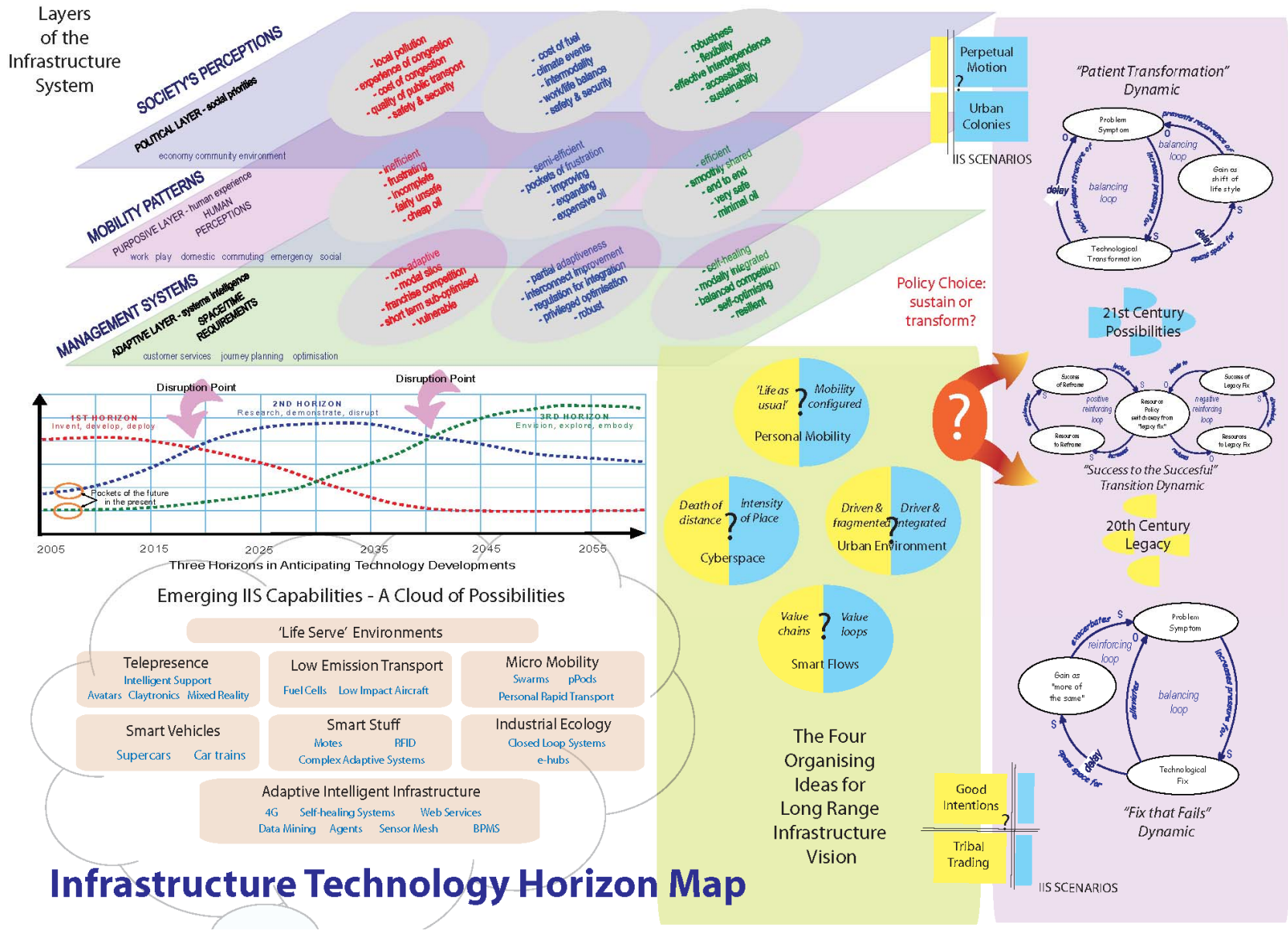


Figure 4 Technology map

Methodology

Andrew Curry
Henley Centre

Introduction

Henley Centre utilised a three-stage process for this project; driver assessment, scenario development and scenario testing (see Figure 5). This approach is based on current thinking about how organisations learn. Stakeholders are involved from the first stage of the process – reviewing the drivers – through to the development of the scenarios and their implications. The work on systems mapping, also known as systems diagramming, helped to inform the scenario development, and was, in turn, informed by the scenario process.

Stage 1 – Driver assessment

The scenario planning exercise began in February 2005 with research into the issues, drivers and other factors likely to shape the development of intelligent infrastructure. This included use of Henley Centre’s Knowledge Bank of consumer trends and behaviours, which draws on both qualitative and quantitative insight. In addition,

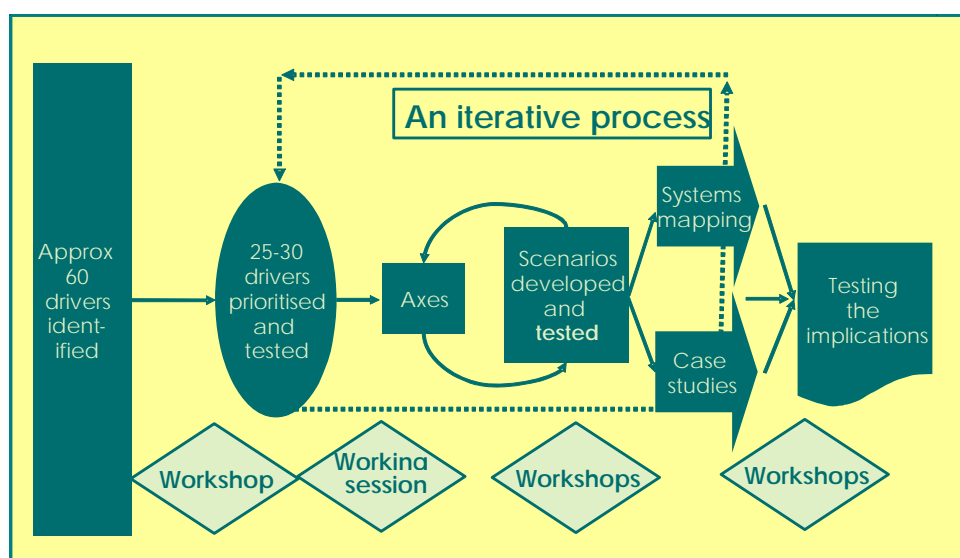


Figure 5 Driver assessment is a multi-stage process that involves stakeholders at all stages.

Source, Henley Centre

Henley Centre used Foresight’s review of relevant futures work.

Given the 50-year timescale of the scenarios, we also researched drivers and issues from a number of other sources, including:

- Foresight projects on Cognitive Systems and Cyber Trust & Crime Prevention
- The current Foresight Vehicle Link Technology Road Map

To test that the driver range was sufficiently broad for 50 year scenarios, we also checked the literature for other long-range scenarios, to test their views of long-term drivers of change. Finally, to ensure a comprehensive driver assessment, they were tested against a multi-level STEEPO matrix (see Figure 6).

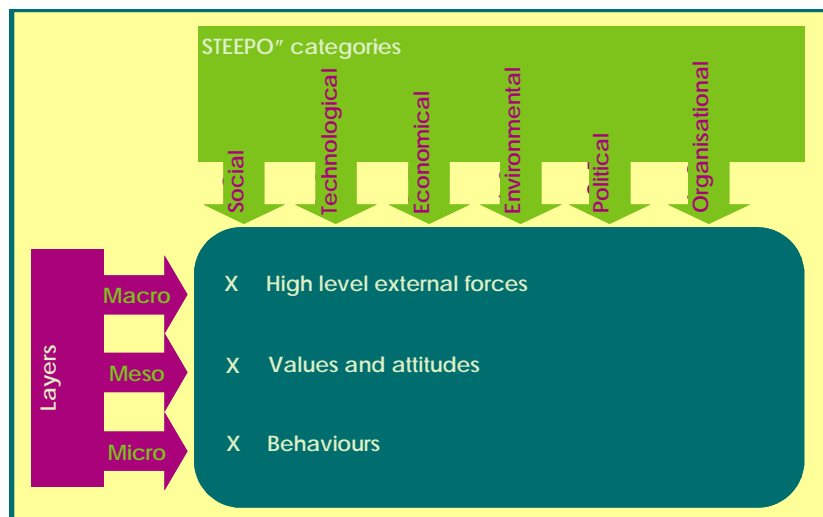


Figure 6 STEEPO matrix tests drivers to ensure that they are comprehensive

Source: Henley Centre

This research enabled us to assemble a pack of 62 initial key drivers and issues. These drivers were felt to have a potentially significant impact on intelligent infrastructure and its development over the next 50 years. A significant proportion of the drivers are specific to transport and infrastructure, although some capture wider trends, for example sustainability and the use of technology.



IIS drivers

Many factors will affect the future of transport and how we use intelligence to support movement. These factors, which can range from rising tensions between freedom of information and privacy to autonomous vehicles becoming safer and more efficient, are generally referred to as drivers for change. Preliminary workshops for the project identified some 60 key drivers that could influence the future direction of intelligent infrastructure:

- Growing demand for mobility - passengers and goods
- Growing skills shortage as infrastructure acquires the skills
- Increasing migration (and emigration)
- More frequent clashes of multicultural values - faith vs. secular, for example
- Growing awareness of the importance of 'employee liveability'
- Increasing importance of the knowledge economy
- Ageing, yet more active, population
- People face increasing time-intensity
- Growth in 'cyberfraud'
- Emergence of better physical and virtual management systems
- Satellite location devices
- Smart antennas
- Increasing use of 'telepresence'
- Technology
- Converging revolutions in biotech, nanotech, infotech and cognitive science
- Culture of control
- 'Real time' everywhere
- Growing debate on housing density in inner cities
- Growth of Asian economies
- Growing global energy deficit - increased demand and consumption
- Emergence of radical solutions to climate change
- Declining trust in institutions
- Growing crisis in higher education puts the science base under threat
- Decline in power of national governments
- Increasing world trade
- Emergence of networked organisations, clusters and supply chains
- New decision-making frameworks
Proliferation of choice
- The rise of pan-regional hubs
- The end of affluence
Increasing emphasis on sustainable design
- Rise of 'zero waste' movement
- Changing patterns of demand for housing in some areas
- E-commerce continues to grow
- Increasing focus on tourism and its contribution to climate change

- Decoupling of tourism and transport
- Rising tension between freedom of information and privacy
- Emergence of megacities
- Changing family and household structures
- The rise of 'slow'
- Growing utilisation of 'embedded' technology
- Continued growth of an 'always on' culture
- Semi-autonomous/autonomous vehicles becoming safer and more efficient
- Grids and networks create shared capacity
- 'Digital natives' - growing up accustomed to technology
- Reducing cost of ICT and enhanced data processing
- High-speed rail travel
- Growing gap between rich and poor
- Continued capital underinvestment
- Growing (impact of) climate change
- Increasingly localised/decentralised energy production
- Relatively low spend on energy research and development
- Increasing consumer desire for social and environmental responsibility and transparency
- Growth of the surveillance society
- Complex just-in-time models are vulnerable to external shock
- Demand management of transport provision
- Changing data storage: from desktop to network
- Movement away from office-based working
- Emerging debate around provision of 'citizen's income'
- Rising importance of local provision
- Taxation increasingly based on resource consumption rather than income
- Move towards full-cost accounting
- Emerging infrastructure, emerging cultural form

Driver prioritisation

A two-day workshop enabled the participants to test the drivers in a number of ways and to determine which drivers would have the most significant positive or negative affect on the development of IIS between now and 2055. Individuals were asked to evaluate each driver for its relevance.

As a way of stretching out thinking 50 years into the future, we utilised the 'Three horizons' model (see Figure 7).

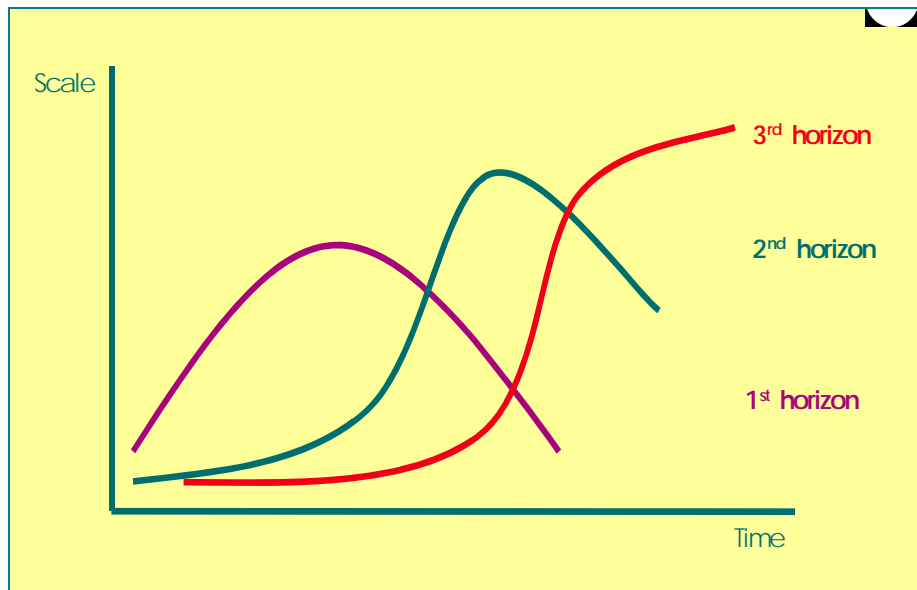


Figure 7 The Three-Horizons model

Source: Tony Hodgson, Decision Integrity

- Horizon 1 describes the situation whereby society continues along its current path; progress continues for a while and then declines as infrastructure and systems become old and outdated.
- Horizon 2 comes into play when a disruptive event or technological innovation takes place; for example, the introduction of hydrogen fuelled cars. There is an 'S-curve' of progress during development of the innovation, until progress overtakes that of Horizon 1.
- Horizon 3 is where there has been a significant overall attitudinal shift within society; this takes the longest to emerge but can significantly advance scale of progress in the long term.

As part of the driver prioritisation process, we asked participants to categorise drivers according to whether they would be most significant in driving change in Horizons 1, 2 or 3.

Whenever participants believed that there were missing drivers, or where they felt that drivers did not capture fully the issue, we included or improved these drivers as part of the process. Following the workshop, we added several drivers (see list of prioritised drivers below).

The workshop reached a significant degree of consensus about those drivers that would have the most significant impact on the development of intelligent infrastructure. This workshop process prioritised the list of drivers as those that would have the most significant influence on the future:

Horizon 1 – key drivers

- Increased mobility
- Growing perception of risk
- Scepticism about political process
- Climate change
- Return of local community
- Transport demand management
- Growth in world trade
- Pervasive low-cost ICT

Horizon 2 – key drivers

- Non-office based working
- Supply chain costs
- Digital natives
- Need for new infrastructure
- Legacy infrastructure
- Emphasis on quality of life (Wellbeing)

Horizon 3 – key drivers

- Effective political governance
- Intelligent Information network
- Resource limitations

In addition, we prioritised some additional drivers which, although the participants of the workshop did not consider them to be central to any single horizon, had received particular attention during discussion, and were therefore most likely to be key to the development of IIS:

- Density of urban living
- Comprehension of mathematical complexity
- Individual privacy
- Return of simplicity
- Pricing of transport
- The cost of oil (per barrel)
- Ageing population



- Adaptability of business
- Individualism
- Global market capitalism
- Impact of Asia
- Transport congestion

After prioritising the most significant drivers, we used 'Futures Wheels,' a proprietary technique developed by Henley Centre, to explore how the prioritised drivers may play out in each Horizon (see Figure 8). With Futures Wheels we can explore the future and understand how issues and uncertainties relate to each other,

leading to potentially unexpected and potentially new outcomes in the future. This technique helped us to understand how drivers of change might combine or collide, and what the consequences and uncertainties may be.

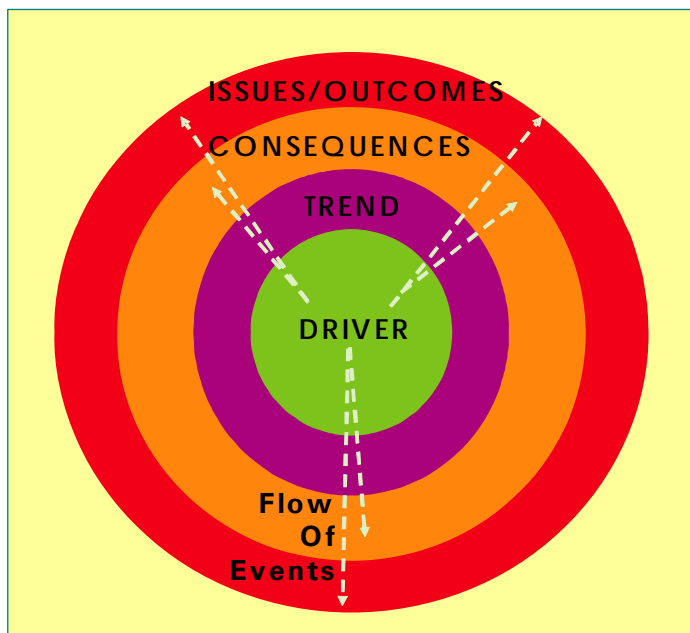


Figure 8
The Futures Wheel is a technique for exploring how drivers of change may play out in each Horizon

Source: Henley Centre

Stage 2 – Scenario development

Scenario axes

The project team assessed the priority drivers in terms of their relative impact on the other short-listed drivers. This analysis feeds into a 'Dominance and dependency matrix' (see Figure 9) which is the basis for the development of the scenario axes, and which identifies:

- Drivers that are dominant and therefore have a major impact in terms of affecting change;
- Drivers that are dependent and therefore are relatively uncertain in their impact, as they tend to follow change.

High Dominance	Growth in world trade	Pervasive low-cost ICT Effective political governance Global market capitalism	Increased mobility Climate change Return of local community Transport demand mgt Wellbeing Intelligent Info network Resource limitations Individualism
Medium Dominance	Digital natives	Perception of risk Legacy infrastructure Return of simplicity Adaptability of business	Non-office based working New infrastructure Density of urban living Pricing of transport Transport congestion
Low Dominance	Scepticism about political process Comprehension of complexity The cost of oil (/barrel) Ageing population Impact of Asia	Full cost supply chain Individual privacy	
	Low dependency	Medium dependency	High dependency

Figure 9 Dominance/dependency analysis

Source: Henley Centre

Using this method, we identified four types of drivers:

- Critical/uncertain drivers (highlighted in orange) have both high/medium dominance *and* dependency – they influence, and are influenced by, other drivers.
- ‘Context setters’ (blue) are drivers which emerge as high or medium dominance but low dependency – i.e. they influence other drivers but are not influenced by them. They create the contexts for all the scenarios.
- ‘Output’ drivers (green) are more dependent than dominant. These don’t influence other drivers to a significant scale, but often give guidance to critical policy issue.
- Drivers which were found to be neither significantly dominant or dependent (white) are less important in helping develop the scenarios. They often turn out to be ‘secondary’ descriptors of drivers which are already captured in the other sectors.

Developing the axes

The development of scenario axes is both science and art. We have found in the past that it is best to review a number of different combinations against the project question and the project’s purpose to identify those that create the richest set of scenario stories. We considered various iterations of axes. The final combination was viewed as the set which best reflected the key drivers, creating divergent but strategically useful and interesting scenarios.



The scenarios were set along two axes of uncertainty:

- Accepting of intelligent infrastructure ←————→ Resistant to intelligent infrastructure
- High impact transport ←————→ Low impact transport

The axes combine to create a scenario space with four scenarios that described in the first section of this report (see Figure 1).

The first axis relates to the acceptance of IIS and describes social attitudes. At one extreme on this axis, the digital-native generation, which has grown up using technology, is confident that it will continue to deliver and protect. Personal data and identity are protected; continuous investment in physical and IT infrastructure allows development of flexible and adaptive systems. Businesses take advantage of the intelligent infrastructure to form wide-reaching networks. At the other extreme, terrorism, viruses, identity theft and fear of disruption and instability mean that people are mistrustful of intelligent systems. Economic uncertainties add to their risk aversion. People rely on legacy infrastructure – or even bypass it where possible. Groups of businesses, and the affluent, use private networks and services.

The second axis describes the consequences of transport on the environment, economy and society. At one extreme, high carbon emissions, continuing dependence on oil, and a significant waste footprint all contribute to high environmental impact. Social impacts – noise levels, land take and lower social and community cohesion – are prevalent. At the other extreme on this axis, cleaner fuel technologies have reduced carbon emissions, the waste footprint has shrunk and resource constraints emphasise product longevity. The social and community impact of faster transport, however, remains ambiguous: segments of the community may still be excluded because of uneven access to transport.

At this stage of the process, a scenario development workshop considered what might happen in each 'scenario space'. Based on these two axes, participants discussed potential futures for each of the four possibilities, using combinations of the extremes of each axis. The workshops also explored the uncertainties around each scenario, and what events would need to happen in Horizons 1, 2 and 3 for this scenario to become a reality.

Using the output from this workshop as a starting point, Henley Centre worked with the wider futures group to develop the scenarios. It was at this stage that the scenarios were named, and draft narratives produced. It is worth pointing out that the names given to the scenarios are designed simply to help people to remember them. Use of shorthand names is essential if the scenarios are to become part of a

live strategic conversation between an organisation and its internal and external stakeholders.

In considering these alternative views of how the future might play out, we should emphasise that parts of each of these scenarios could play out at different times in different regions or among different groups. The 'real' future for IIS in 2055 probably lies in some combination of these wide-ranging possibilities. Nevertheless, in order to develop a robust future strategy, it is important to consider the implications of the full range of future possibilities that is encapsulated by the four divergent scenarios.

Stage 3 – Scenario testing

The scenarios that emerged from the scenario development stage were well developed and fairly rich in content. The next stage was to hold a two-day workshop to test the scenarios and build up a fuller set of contextual scenarios, and explore the surrounding issues. During this workshop, participants used role-play simulation exercises to explore, test and improve the draft scenarios.

Before the workshop, the Henley Centre's team wrote for each scenario:

- A 'scene setter,' detailing the situation in this scenario at around 2020 (end of Horizon 1) and explaining a hypothetical event that pushes the scenario into Horizon 2.
- A set of private briefs for six or seven fictional organisations that might be dominant players within this scenario. We aimed to include in each scenario a government body, a commercial organisation, a lobbying group, and a group of 'dissidents' of some kind. The briefs detailed each organisation's background, aims, objectives, current issues and pressures.

Participants worked in groups representing each of the hypothetical organisations. Each group worked from a scene setter and its own private brief. The groups then acted out situations and negotiations similar to those in which real organisations might find themselves in this scenario. Groups were allowed to make 'agreements' and 'press releases' if they desired. Towards the end of the exercise we announced a further event, which pushed the scenario into Horizon 3 (approx 2035).

The aim of this exercise was not to create any set outcomes but to utilise tacit knowledge to explore possible futures.