FACTORS SHAPING THE FUTURE OF THE TRANSPORT SYSTEM

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ABSTRACT

The transport system, in particular the urban transport system, can be considered as a complex large-scale socio-technical system which is locked in around a set of prevailing beliefs and technologies. It is optimised to facilitate maximum economic and physical throughput growth. There is a growing desire to reduce or eliminate the negative side effects of current transport systems, particularly the car. This desire is expressed in terms of proposed policies for urban design and sustainability, but it is not clear that these desired programs of change are enough on their own to shift the transport system from its current state of lock-in. A significant new paradigm of personal belief and social values, or a major technological development, would be needed to enable a shift in the transport socio-technical system. It can be anticipated that significant social change might involve the emergence of a less materialistic, and hence less materials-intensive way of living. This shift could perhaps be catalysed by major disruptions or crises, whether political, economic, ecological or climatic. Major technological development is unlikely to be based on incremental technological change but instead on advances fundamental enough to shift the existing system from its state of lock-in — probably involving both a new power source and a new propulsion principle. Based on past technology trajectories in transport and energy, a major new transport mode may well emerge, or be emerging, by 2010. The new mode would have to significantly surpass the performance of existing modes, as well as having lower environmental and social impact.

INTRODUCTION

Transport planning takes place in the context of a number of orthodox assumptions about expected future conditions. While it is of course entirely possible that all these assumptions will prove to be correct, there is a real danger that the future could hold significant surprises that might invalidate current planning activity. If this happens, either the transport infrastructure could prove to be inadequate or inappropriate, or investment made to prepare for needs that fail to materialise could be wasted.

Attempting to see the future is problematic by definition, but it is also a basic requirement for any planning task. This is why a variety of 'futures research' techniques have evolved to anticipate factors that could drive the future strategic environment outside its expected range.

This paper takes a 'scenario thinking' approach derived from scenario planning.[1] In simple terms scenario-based planning involves researching key strategic variables and factors that are changing or that could change. It then assembles the findings into qualitative pictures or stories that illustrate possible future outcomes.

Thus the scenaric possibilities explored here are intended to help frame thinking about the future of transport and to extend existing strategy and policy thinking. They explore the factors that may determine the conditions that transport decision-makers will have to face. Scenario thinking is a way of learning about and understanding the future implications of the present and hence of identifying advantageous policies and strategies. It involves creating and exploring hypotheses and thought experiments about the future.

LOOKING INTO THE FUTURE

The combination of the private motor vehicle and a well-developed road system is the dominant form of urban transport in cities around the world, and is the main focus of this paper. In many ways this generic urban transport system can considered as a large-scale socio-technical system that has achieved stable technological lock-in[2] lasting for roughly the last seven decades. Lock-in is the phenomenon by which dominant technologies become established in spite of the existence of technically superior alternatives. Examples are the way the 'QUERTY' typewriter keyboard remains dominant in spite of alternative keyboard layouts that are easier to learn and faster to use; or the dominance of the NTSC television standard in the United States, in spite of the existence of the technically superior system used in Europe. Lock-in is the result of the interplay of technological development and social context,[3] and although the term is usually applied to specific technologies, it can apply equally well to large-scale technological systems such as the 'car-road' system that dominates urban transport.

The extent of the car-road lock-in can be gauged from the importance of the car in the global economy. The world automobile industry is the largest manufacturing industry in the world, with 13 percent of gross global production. It is a major customer of the global metals industry, taking 10 percent of world steel production, 25 percent of world aluminium production and 66 percent of world lead production. In OECD countries, transport uses over 30 percent of final energy consumption, and motor vehicles use about 46 percent of world oil production, which has been growing on average at 1.6 percent a year for the last 30 years.

The car-road system is relatively far from saturation in most Australian cities when compared with the situation in, say, Bangkok. To the degree that the car-road system is reaching its limits internationally as a viable urban transport system, we might expect to see a decisive shift in the system occurring in countries where the system is both closest to saturation and where there is also a tradition of transport system innovation, as in parts of northern Europe. In the UK, for example, the prospect of indefinitely adding to the road system, only to return to congestion after a few more years, has led to an active search for new policy, although the political will to enact it has not yet been forthcoming.

Scenarios for the future of transport need to address the possibility of a fundamental shift, or discontinuity, in the car-road transport system precisely because it may now be reaching the limits of its social acceptability and technological currency. The shift would be to a new stable system — an integrated configuration of new technology, new policy, new social behaviour and a new economic context — that may well not be a ‘car-road’ system. If the shift is triggered by social change, it is to be expected that the new solution will change the balance between mobility and accessibility, by reducing the relative need for mobility, but this need not be the case if the shift is triggered by radically new technology. If combined with an intensification of environmental concerns such as global climate change or wildcards such as a global oil supply shortage, such a shift could occur in a comparatively short time — say, over as little as ten or fifteen years.

The ‘business as usual’ alternative is that the existing system could simply progress towards higher levels of saturation over the next ten to fifteen years, without significantly changing in character. This kind of saturation would be driven by economic growth, and this growth could either be ‘more of the same,’ or be dominated by growth of the information economy. Conceivably, in this kind of scenario the car-road system could be a stable state that may endure well into the next century. It may turn out in retrospect that the middle decades of the twentieth century represented a rapid society-wide transition to the use of private motor vehicles, away from previous modes such as public transport. If population growth slows, over the next ten years or so the number of cars owned by a given urban population might reach a plateau — alleviating long term increases in congestion — and if associated problems such as air pollution and carbon emissions turn out to be solved more easily than we might expect today (for instance by the ‘Hypercar’ concept), the resulting ‘mature’ car-road system could be the urban transport pattern for many decades to come.

While this sort of scenario might seem plausible when Australia is considered in isolation, other outcomes appear equally plausible when the world as a whole is considered. Given the pressure on urban transportation systems internationally, and the intensifying concern about issues such as global climate change, it is entirely possible that today’s car-road system as a whole may shift in a decisive way in the near future. The determinants of socio-technical lock-in are by definition societal and technological, so such a shift would be the result of significant new technological innovations — breakthroughs — or of fundamentally new policies or economics which alter the usage of existing technology. Either of these is more likely to originate in the United States, Europe, or Japan, rather than in Australia where the pressures are less.

BASIC FACTORS DETERMINING THE SYSTEM

The existing urban transport system can be considered as an expression of the push for economic growth, tempered by efforts to ensure social equity. Its stability as a system is largely dependent on the dynamic of exponential growth of mass throughputs in industry and human population. In this regard the car-road system resembles a chaotic attractor in dynamic systems theory. Before looking at the sources of change that could shift the system, it is useful first to look at the basic shaping factors.

Economic Growth

Economic growth is frequently promoted as the fundamental goal of industrial societies. This assertion is based on the set of managerial concepts and economic theories that together comprise economic rationalism — the belief that the greatest increase in prosperity, or economic welfare for the community at large, will come from applying economic principles consistently and comprehensively. According to conventional economic theory, the greatest growth in economic welfare will come from continued expansion of formal economic activity, which will itself be facilitated by such things as a global free trade regime and world-class competitiveness of local industry. Since the collapse of communism, this thinking has come to form the dominant political ideology of almost all national governments. Private enterprise and the free operation of the market is seen to be the most efficient and effective way to facilitate gains in the standard of living, and hence indirectly to achieve improvements in social welfare.

In transport policy terms, the goal of economic growth calls for provision of high quality infrastructure to support economic development and private business activity. In practice, this primarily means providing and maintaining a road network. There are a number of reasons why roads are the favoured focus of this public expenditure. They existed before any motorised mode of transport, and they are the basis of all mobility. Movement by road is the one transport mode for which the travel bed is universal: roads accommodate pedestrians, bicycles, trucks, buses and 250 km/h sports cars. Common or community expenditure on roads is very easily justified by this universality. However, specialised roads for high speed traffic (freeways and motorways) are not so universally useful, and their base of political support is correspondingly narrower. The dominant design of all roads to favour motor vehicles is very much an expression of the push for conventional economic growth.

Social Equity

Balancing the push for economic growth is the desire to ensure social equity, or at least to reduce extremes of social inequity.

Historical experience has shown that increased industrial production and free markets do not necessarily guarantee equitable distribution of the resulting benefits throughout society. There are always some people who are unable to participate effectively in the market, whether through disability, illness, or lack of appropriate skills. Industrial societies have learned that they need to ensure that the most disadvantaged people have at least the basic requirements for subsistence, medical care, and access to social participation. This provision is made by deliberate expenditure of government revenues on specific programs of intervention.

During the first half of the twentieth century considerable progress was made towards ensuring social equity in industrialised countries. This thinking emerged in its most developed form in the Western democracies after the Second World War, with the advent of the welfare state. Communist regimes made the most extreme efforts of this kind, by attempting to dedicate entire national economies to achieving social equity objectives. In Western democracies, the lack of individual freedom this imposed was ideologically unacceptable, and in any case experience showed that the communist approach failed. Nevertheless, social welfare spending as a corrective to free market economics is deeply ingrained in Western-style democracies.

However, because social welfare services are heavily subsidised or provided free of charge, there is no built-in economic constraint on demand. In consequence, welfare programs need to be carefully managed if costs are to be contained. This cost pressure, and the unfavourable comparison of the bureaucracies of welfare with the ‘efficiency’ of business, has led to efforts everywhere to deliver social equity objectives by means of market-based mechanisms, and by obliging welfare bureaucracies to behave as if they were businesses.

It has become evident that welfare availability can undermine personal self-reliance, as well as induce a wider group of people than those strictly in need to take advantage of what is offered. This not only raises costs, but also weakens mainstream economic activity. On top of this, the industrialised countries have found themselves under competitive pressure from industrialising countries with lower wage rates and lower levels of social expenditure. For all these reasons, the objective of ensuring social equity is under pressure in industrial economies, and provides a potential target for political opportunism.

In transport terms, providing social equity means equitable access to transport (including access for the disabled) at public expense. This has come to mean providing subsidised public transport to all parts of urban areas, at all times of day, and at a low cost to users. In practice this is done by means of train, tram and bus services.

Because welfare services are seen as only needing to provide a basic or even minimally acceptable level of service, and because the cost is seen as a drain on public resources, there is continual pressure to spend the minimum necessary. This sets up a vicious circle of reduced attractiveness and declining use, in effect increasing the subsidy per head. In addition, the greatest subsidy is going to those with the greatest ability to pay — for example to peak time travellers. Because of the objective of low price to the user, the real cost of public transport is now typically several times higher than the revenue recovered in fares.

Continued downward pressure on public expenditure is likely to further erode socially equitable access to transport services. It will mean more privatisation of public transport, with a resulting reduction in service quality on non-economic routes unless the design of regulations and incentives is able to address these issues. If social equity declines and is neglected for too long, it will become an additional source of potential discontinuity for the transport system.

PRESSURES FOR CHANGE IN THE SYSTEM

The interlocking efforts to achieve economic growth and social equity plus the present state of technological capability are the factors that largely shape the current urban transport system. Also acting on the system, however, are a number of pressures for change. Among the most coherent in terms of policy proposals are a desire to reduce dependence on the car — largely motivated by the negative side-effects of car use — and a desire to achieve sustainability across the entire economic system, including as a subset the urban system.

Urban Design to Reduce Transport Dependence

This source of potential change consists of a number of closely related proposals concerning the spatial design and population density of towns and cities, aimed in part at reducing the requirement for motorised transport. It is argued by a rising number of vocal and influential planners and architects that a combination of localised increases in population density (in terms of dwelling units per unit land area) and specific kinds of spatial design can significantly improve the quality of community and simultaneously reduce travel consumption. These proposals go by a variety of names: The New Urbanism, Transit Oriented Development (TOD), Pedestrian Friendly Development (PFD), and Traditional Neighbourhood Design (TND), among others. Historically, the roots of these ideas can be traced back to the Garden Cities movement of the early part of the century.

Taken as a whole, these proposals seek integrated solutions to issues such as the quality of community experience, traffic congestion, air pollution and so on. The emphasis is on access, rather than mobility. Access signifies the ability to get to a desired destination easily, and implies the proximity of desired destinations. Mobility signifies being able to go further faster. With appropriate mixed-use zoning and compact spatial design the need for mobility can be reduced and accessibility increased. Although density is increased locally, average density is not necessarily increased, as generous provision of public space is also a feature of these planning concepts.

In transport terms the aim of these proposals is to reduce car dependence and reduce the trip lengths taken by car — the need to use a car would simply be less. More trips would be made on foot or by bicycle, for example to go shopping. The locally-increased density makes it feasible to serve urban areas effectively with mass transit, light rail being the favoured mode. Housing is located within a 10 minute walk of the transit stop. Car access within this radius is reduced, enhancing the quality of social interaction in the common space. This is achieved by traffic calming, and the construction of *Woonerfs*, a Dutch invention meaning ‘living yard.’

Woonerfs create a single street space, without a division between footpath and road surface, which visually emphasises that all road users have equal rights. Cars have access but no priority over pedestrians. This is further reinforced by paving the surface not with asphalt but footpath-style, for example with brick paving.

In Australia, these proposals are probably most closely associated with Jeff Kenworthy and Peter Newman in Perth. The New Urbanism movement in the United States is another powerful expression of this thinking, with a detailed agenda and many enthusiastic proponents. As a program of proposals for urban design, the elements of this thinking are easily communicated, and are appealing to pressure groups looking for concrete proposals for action. Nevertheless, there is debate as to whether tolerance of density hinges on cultural factors, particularly on the need for privacy (itself a culturally-defined concept), and cannot merely be imposed. In this regard the writing of Hugh Stretton is sometimes considered to be counterposed to this paradigm, but in fact the New Urbanism movement itself comprises a diversity of views, particularly about whether to insist on maximising infill, or whether to focus on improving the quality of inevitable development on the edge. However, the slow rate of replacement of urban structure and housing stock means that, in the absence of other forces, existing urban systems will largely resist this potential source of change for several decades.

Sustainability

There is an emerging conviction that industrial societies in their present form are fundamentally unsustainable both socially and ecologically. The concept of sustainability is being advanced in response and is increasingly influencing the thinking and planning of businesses and governments around the world[4]. For example, the Australian government has a National Strategy for Ecologically Sustainable Development.[5]

Sustainability comprises a complex bundle of environmental concepts, economic ideas, concern about social issues, and new ways of applying technology. In the words of the United Nations 'Brundtland' Commission, 'sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.'

In economic terminology, this translates into economic development that does not deplete 'natural capital.' Natural capital refers to the vast network of living ecosystems that stretch across the planet, and are responsible for maintaining clean air and water, healthy soil, and stable climate. These things are essential for a functioning economy. Sustainability calls for the design of an economic system that lives within its means by not reducing the ability of the natural environment to provide the life support services on which we all depend.

A distinction has been made between what has been described as 'strong' and 'weak' sustainability. Strong sustainability requires the preservation (or increase) of net natural capital, while weak sustainability allows technological capital to be substituted for natural capital. When a test for weak sustainability was applied to the 20 countries for which the necessary data were available, only 11 passed. When a strong sustainability criterion was applied, all countries failed — although Holland came closest with a depreciation of natural capital equivalent to only one percent of GDP.[6] The long term goal would be that all countries should achieve strong sustainability.

The agenda of sustainability is an attempt to redesign the infrastructure of society to resolve some of its deepest-rooted problems from a systemic, integrated perspective. This focus is what has been referred to as the 'triple bottom line' of sustainability: 'socially responsible, environmentally sound, economically viable.'[7] Sustainability is in effect a call to reframe economics. The new discipline of ecological economics seeks expanded terms of reference to ensure that the economy delivers true economic welfare, not just growth in GDP.

From this perspective, existing industrial technology is fundamentally unsustainable and requires a new approach. Sustainable industry would mean replacing the existing 'take, make, waste' structure of industrial production with a 'waste equals food'[8] approach to manufacturing[9]. In turn this would require a thoroughgoing redesign of all the major infrastructure systems which support modern life. In principle, this can be done without sacrificing the basic comforts of modern life: the provision of 'hot showers and cold beer.'[10] But it would require fundamental rethinking and the willingness to accept many new innovations and modifications of ingrained habits.

In terms of transport, sustainability with today's technology — in particular, carbon-intensive energy supply — would require a large reduction in trips. Intermediate or enabling policies might include measures such as full-cost real-time transport pricing; 'pay at the pump' car insurance; telecommunications to substitute for travel; and curbs on the use of hydrocarbon fuels to reduce CO_2 emissions.

The introduction of environmental and social full-cost accounting would reveal to users the true costs of different modes of transport. The aim would be a reduction in car use over time through improvements in accessibility, and hence a reduction in environmental impact. Innovations might be introduced that relate costs directly to the amount of usage, such as ‘pay at the pump’ car insurance. The use of telecommunications to substitute ‘virtual presence’ for travel could be emphasised. And if fossil fuels remain the primary energy source, serious attempts to deal with the root causes of environmental pollution and global warming would almost certainly involve carbon-intensity reduction measures such as carbon taxes.

Transport policies such as these would be radical in the context of today’s economic system. While current policy efforts aimed at reducing the unsustainability of transport undoubtedly have value, the notion of a transport system that is somehow ‘sustainable’ independently of the rest of the economy is almost certainly illusory. Sustainability as defined and promoted by the United Nations needs to be understood in a society- or economy-wide context.

The philosophy of sustainability holds that no matter how advanced our technology, we will face environmental and social constraints; that technology is never more than a tool, and that its effects always depend on what we choose to do with it. In other words, technology per se does not solve problems — it is our intention and determination to solve them that is all-important. The power of technology is now becoming so great that it is increasingly difficult to escape this truth. Thus the challenge of sustainability is not merely to find ‘better’ or more powerful technology, but to find new ways of using both existing and future technology to yield better social and environmental outcomes.

THE POTENTIAL FOR CHANGE

Regardless of how cogent arguments for change such as increased urban density and sustainability are, they are unlikely to result in a major shift in the urban transport system unless one of the two major determinants of socio-technical lock-in — social values and technology — also change in their favour.

Social Change

The importance of social change can be expressed very simply: the design of systems won’t change unless most people embrace the values underlying the redesign.

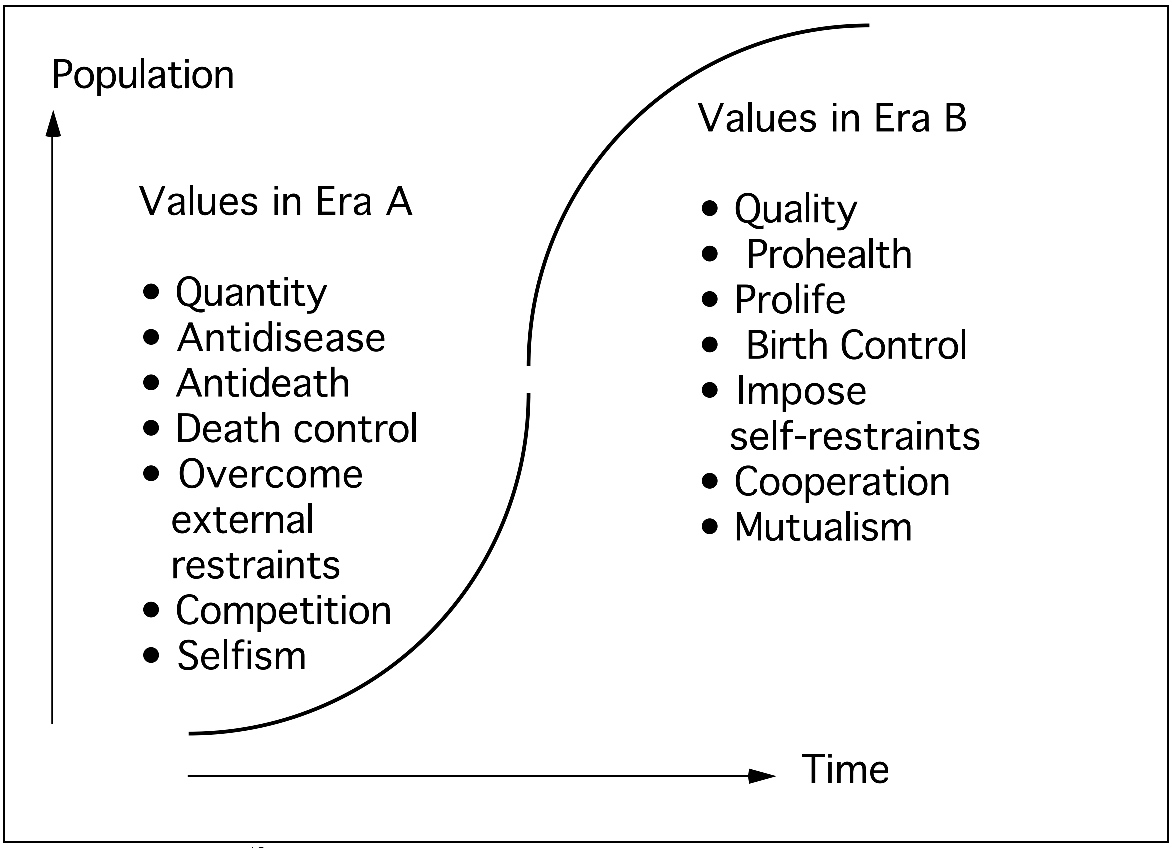
Around the world, there is increasingly a collision between the values of the industrial revolution — unrestrained use of technology to exploit natural resources for rapid growth in production — and the limited capacities and resources of the biosphere. This collision is giving rise to an entirely new set of beliefs and values. This is an extremely powerful source of change, since our beliefs determine what we value, which in turn shapes our motivations and intentions and the way we behave.

The underlying philosophy and beliefs of industrial society shape both the acceptable uses of technology and the economic theories that now prevail. Neither the current form of technology nor economics is absolute, in spite of the commonly held view that both represent objective solutions. In fact both represent an interaction between available knowledge and social attitudes. This makes both subject to change.

If environmental deterioration continues, or is perceived to continue, there will be steadily increasing pressure for a change of perspective about economic growth, and that change will be a crucial element in enabling, for example, a move to sustainability. As values change, technology and economics will be altered, in turn reshaping the context of social experience.

Another potential source of new values is the dynamic of global demographic change. Although global population is still growing extremely fast, and is expected to approximately double during the next 50 years, the underlying rate of growth is slowing. The current deceleration would cause the global population to level off by 2050, perhaps at around 10 billion people. There are questions about whether this level of additional growth can be achieved without serious environmental disruption, but supposing it can, the transition away from exponential growth alone implies a very significant change in all aspects of society.

Since the onset of the industrial revolution, we have become so used to exponential growth of population and physical throughputs that a deceleration — let alone a reversal as in the more extreme scenarios of economic or environmental crisis[11] — would represent a profound change for social institutions, business organisations, economic assumptions and social outlook. Jonas Salk, the discoverer of the polio vaccine, has suggested one interpretation of the way in which social values might be expected to change as global population growth decelerates (Figure 1).



Source: Jonas Salk[12]

FIGURE 1: A Fundamental Shift in Values?

At the threshold of the twenty-first century the potential for significant social change is certainly plausible. Social values can determine whether socio-technical and socio-economic systems either lock in or evolve, even in the absence of technological change. Thus the potential for change in social values is one of the key determining factors in assessing the likelihood of significant change in urban transport systems. The other is technological change.

Technological Change

Technological development is continuing to accelerate and constitutes a major source of potential change. New developments that could see widespread adoption include better vehicle exhaust treatment, alternative fuels, Zero Emission Vehicles (ZEVs) or Ultra Low Emission Vehicles (ULEVs), hydrogen-powered fuel cell vehicles, hybrid-electric driveline vehicles, better batteries, ultracapacitors, flywheels, ‘Hypercars’, and ‘smart-car, smart-highway’ systems. (These technologies are not described in detail in this paper.)

The emergence of such technologies is likely to be accelerated by concerns about urban air pollution and its health impacts, global CO_2 output and its environmental impacts, and urban traffic congestion. Concern about energy use will also be a factor, but because concerns about the availability of fossil fuel resources have not been uppermost recently, this concern is a proxy for the others, in that a reduction in fuel use would indirectly reduce air pollution and CO_2 release. Improved fuel economy is a convenient R&D target for car manufacturers, as it is achievable, within their control, leads to new products, and does not tend to reduce car use.

For technology to completely reshape the transport system, several innovations would have to come together as a coherent alternative system able to overcome the inherent constraints in the present system.

For example, existing public transport systems are capable of a lower spatial footprint than the car-based system, and reduce embodied mass and energy throughput requirements when fully utilised. Unfortunately, they cannot usually fulfil this potential when competing with the car-based system (the counter-example being the city of Curitiba in Brazil[13]). The problem is that traditional public transport systems achieve these attributes by scaling up vehicle size and serving concentrated points of origin and destination. The car-based system, on the other hand, achieves randomised trip origins and destinations by reducing vehicle size, at the cost of increasing mass and energy requirements, and increasing the spatial footprint of the road/parking system.

Over time, the easy availability of random access trips by car has encouraged a redistribution of residential and job locations in cities (known in America as the ‘edge city’ phenomenon) which prevents simple reversion back to the centre-periphery pattern of trips provided by traditional public transport.

From a technological point of view, an alternative system would have to provide close to random access with mass and energy requirements as low as (or lower than) fully utilised public transport systems. But the random access characteristic of the car-based system is achieved by the existing spatially-intensive road system, so the replacement system would have to permit a reduction of reliance on the existing road system. This could imply a narrow track-like system, but it would need to be as highly reticulated as the existing road system.

Randomised trip patterns imply personal vehicles, which implies high embodied mass requirements if private ownership is necessary. Reducing the mass requirement would mean continual use of vehicles (unlike private cars, which remain idle between trips). Keeping the vehicles moving would also reduce the spatial requirement for parking. Keeping vehicles small would allow privacy to be maintained, but lack of individualised ownership would conflict with the social status dimension of the car-based system.

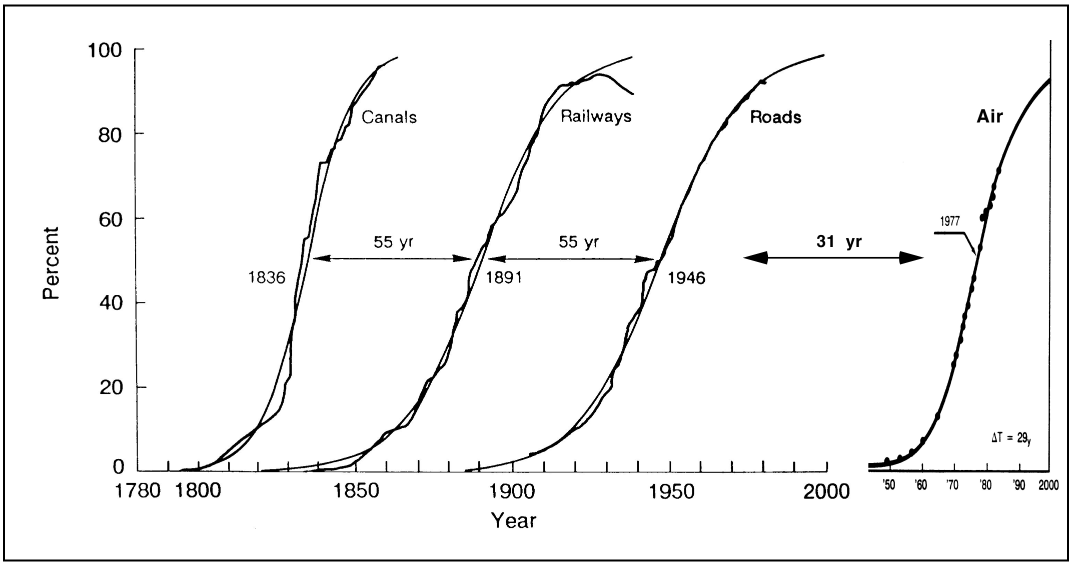
Few technological systems can meet these criteria. The bicycle, for example, provides small vehicle size, random access, and requires only narrow rights of way. Its use of metabolic energy actually enhances the health of the rider. Unfortunately it lacks speed, which is a prized attribute of the current system, and offers no weather protection. An alternative possibility is Personal Rapid Transit (PRT), which combines small (four person) vehicle size, continual use of vehicles, a light reticulated track system, and centralised power provision (which reduces pollution). Computer systems running advanced software promise to make this technology feasible, and test tracks are currently under construction in the United States. However, proposals of this kind are not new, and have consistently failed to dislodge the lock-in of the motor vehicle.

Thus, although there are many possible sources of incremental technological change in transport, it may require something deeper to shift existing systems based on technological lock-in. To discover possible sources of fundamental technological change it is necessary to look outside the field of transport. The prospect of a revolution in physics early in the twenty-first century is one of the most tantalising sources of potentially major change. Put simply, a new theoretical perspective is in prospect in which there is "no such thing as mass, only electric charge and energy, which together create the illusion of mass."[14] If true, this would mean that mass, inertia and gravity would not be basic physical properties as assumed by Newton and even Einstein, but would all arise from underlying electromagnetic processes, potentially opening the way for technologies that manipulate them in new ways. Since mass, inertia and gravity represent basic constraints for motion, it is easy to see that this could have profound implications for transport technology.

This prospect is of course highly speculative, but, as the next section shows, there is reason to think that it is at least plausible, which means it needs to have a place in any scenarios for the future of transport.

A NEW TRANSPORT MODE?

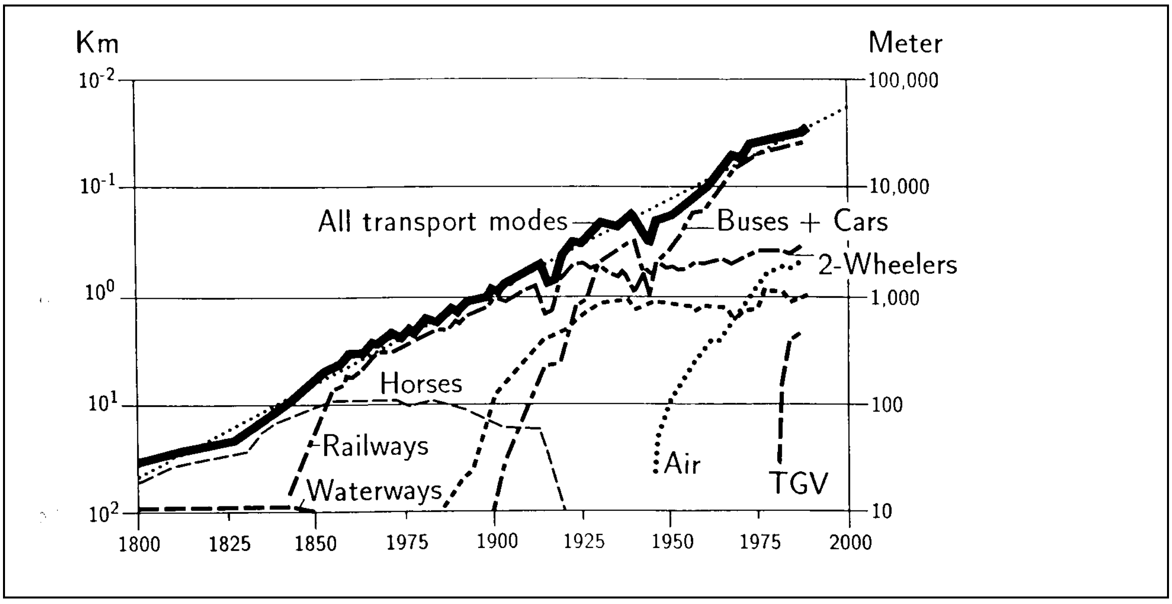
The history of transport in industrialised countries over the last 200 years has been one of repeated technological substitutions followed by lock-in and a period of dominance (Figure 2). Canals gave way to railways in the mid-nineteenth century. Petrol-driven road vehicles replaced the use of horses for road transport in the early 20th century. The rise of air travel followed the growth in motor vehicles and is now the fastest-growing transport mode. Major new transport infrastructures have been created at roughly 50 year intervals since the early 19th century (Figure 2).



Left: Growth of major transport infrastructures in the United States in terms of percentage of final saturation level.[15] Right: Growth of world air transport (passenger-km per year) shown with best-fit logistic growth curve for comparison.[16] (The horizontal scale of the right-hand figure has been adjusted to correspond with that of the left-hand figure.)

FIGURE 2: Successive Waves of Transport Infrastructure

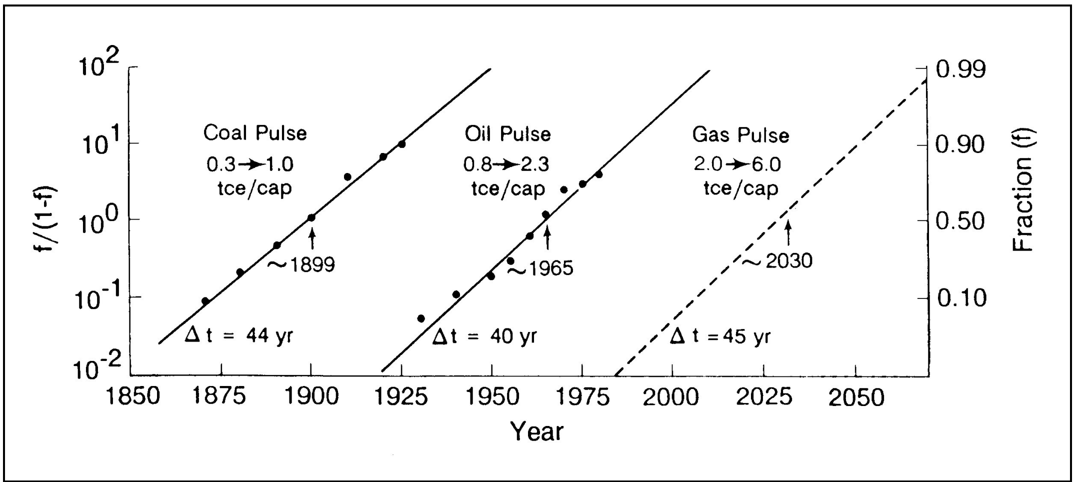
Successive transport technologies have gone through a phase of development and rapid growth, followed by saturation. A particular technology stops growing as it saturates its market and reaches limits of social acceptability and environmental impact, but perhaps more important, because its range and speed are no longer adequate. When a technology reaches this point, historical experience indicates that it is superseded by a faster or longer-range successor — although the old technology often continues and coexists with the new. This process of additive substitution has delivered consistently increasing mean speed for all modes combined (Figure 3).



Mean speed for all modes has increased 3% a year for the last 200 years in France. Source: A. Grubler[17]

FIGURE 3: Mean Speed for all Transport Modes is Increasing

The successive waves of transport technology have been supported by successive waves of energy technology (Figure 4). From the 1850s onwards wood was replaced by coal, which was then replaced by oil from the 1920s onwards. Each of these two major pulses of growth in world energy consumption lasted about 40 years. A similar pulse of growth in natural gas consumption now appears to be underway (nuclear fission power has never achieved this level of growth and is not shown in Figure 4).[18]



Successive waves of growth in world per capita energy consumption measured in tons of coal equivalent (tce).[19] The waves appear as straight lines rather than S-shaped curves because the vertical scale is logarithmic.

FIGURE 4: Successive Waves of Energy Growth

Based on the shape of their growth curves (also referred to as technology trajectories), both car and aircraft travel will be approaching saturation worldwide by about 2010.[20] This projection is consistent with the growth and saturation of past transport technologies, and it naturally raises a question about whether a new transport technology could soon emerge to supersede them. Given that energy and transport technologies run in parallel, if the past pattern is repeated, we might expect to see the emergence of a new combined transport and energy technology that would offer substantial improvements in range and speed — as well as social and environmental acceptability — over current technologies.

If this admittedly speculative extension of the historical pattern has predictive value, the new transport technology should begin to develop after roughly the same interval as previous technologies — about 50 years. Commercial air transport began to grow rapidly around 1950, so a new mode could appear shortly after the year 2000. Moreover, it should already be visible in the laboratory.

In fact, two major — but controversial — developments are claimed to exist at the laboratory stage, which in combination could give rise to a truly science-fictional mode of transport. Both are in principle consistent with the new theoretical perspective in physics mentioned above.

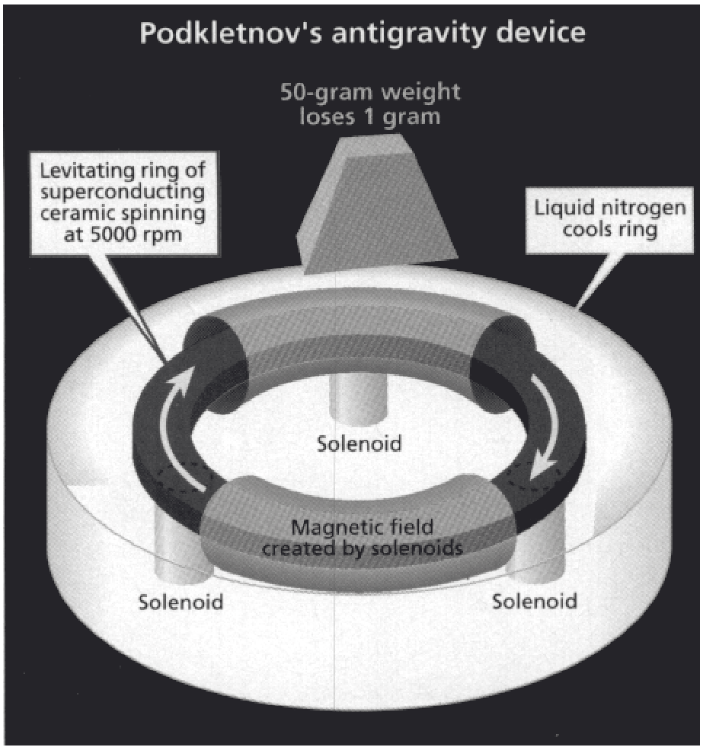
One of these is what the author Arthur C. Clarke recently referred to as the new energy revolution,[21] including cold fusion and zero point energy or quantum vacuum energy.

Although the science establishments in the United States and the United Kingdom have been slow to acknowledge so-called cold fusion, the US patent office has recently begun issuing cold fusion patents. Meanwhile, researchers in Japan, France, Italy and India have reported considerable success. Overall, the evidence is not yet clearcut, but it does point to a new source of energy, although this may not turn out to be fusion in the conventional sense. The first generation of cold fusion cells run on occasional inputs of light water and an activating current of electricity to produce a yield of heat energy in excess of the electric power put in.

Zero Point Energy (ZPE), although even more speculative, has been the subject of theoretical papers in prestigious scientific magazines.[22] ZPE is the energy of the virtual particle flux in the quantum vacuum.[23] Claims have been made that this energy flux could be directly tapped as a source of continuous free energy, possibly using compact power cells that convert the quantum fluctuation energy of the vacuum into electricity using a plasma-phase version of the Casimir Effect.[24]

The other major and controversial development claimed to exist at the laboratory stage is what the press colourfully describes as antigravity.

In September 1996, Eugene Podkletnov, a Russian scientist working at Tampere University in Finland, announced he had successfully demonstrated gravity shielding. He reported that the weight of any object placed over a magnetically suspended spinning ring of superconducting ceramic was reduced by two percent.[25]



Source: New Scientist[26]

FIGURE 5: Podkletnov's Gravity Shielding Device

A paper by Podkletnov describing his work was accepted for publication by the respected *Journal of Physics-D: Applied Physics* in 1996, but page proofs were leaked to the *Sunday Telegraph* newspaper in England, leading to sensationalised news coverage. Faced with intense media attention, Podkletnov withdrew the paper, apparently under pressure from potential funding sources not to reveal more pending patent applications. Podkletnov's findings are supported by theoretical work by Douglas Torr and Ning Li at the University of Alabama, and currently NASA is known to be funding gravity shielding research in an attempt to replicate Podkletnov's work.

Suppose this research bears fruit. Taken together, these two possible major discoveries could lead to an entirely new form of air travel. This would in many ways be a logical next step in transport technology, and one which has been repeatedly anticipated by science fiction. A levitation technology powered by an environmentally clean energy source could replace both existing aircraft as well as many existing surface vehicles. If small vehicles could be based on this technology, further expansion of the road network could be avoided — in fact it might be possible to dismantle many existing roads.

If this seems far-fetched, it is worth recalling that only 100 years ago, at the close of the 19th century, heavier-than-air powered flight was still considered to be in the realm of fantasy. As late as October 1903, Simon Newcomb, professor of mathematics and astronomy at Johns Hopkins University, published an article which showed scientifically that powered human flight was 'utterly impossible.' Just weeks later, in December 1903, the Wright brothers took off for the first time in their heavier-than-air flying machine.

For five years, the Wrights' claims were dismissed as a hoax by the *New York Herald*, the US Army, and most American scientists, despite scores of public demonstrations, affidavits and photographs. Even the local newspapers in the Wrights' own home town, Dayton, Ohio, refused to publish the story.

The experts were convinced that powered heavier-than-air flight was simply impossible. In 1906, *Scientific American* even ridiculed the Wrights' claims on the basis that the American press had failed to write anything about them. Finally, responding to the rumours, President Theodore Roosevelt ordered public trials at Fort Myers in 1908 and the Army, the scientific establishment and the press were forced to accept that the flying machine was a reality.[27]

THE OUTCOME FOR TRANSPORT

Whether or not radical new technologies emerge early in the 21st century, it does appear from the technological trajectories that the current transport system is approaching saturation. At the same time, the present global exponential growth phase is unlikely to last indefinitely, and existing transport technology has too many undesirable social and environmental features to be acceptable as a long term sustainable technology. So it is not hard to speculate that something new is coming. We could simply call it X.

At the very least we can say something general about the attributes X would need to have — for example it would need to have speed, range and cost characteristics better than current aircraft (a rule of thumb is that technologies have to have an order of magnitude better performance to be successful substitutes). That means it would be unlikely to be a surface mode. It would also need to have less environmental impact, which means it would be unlikely to be fossil-fuelled.

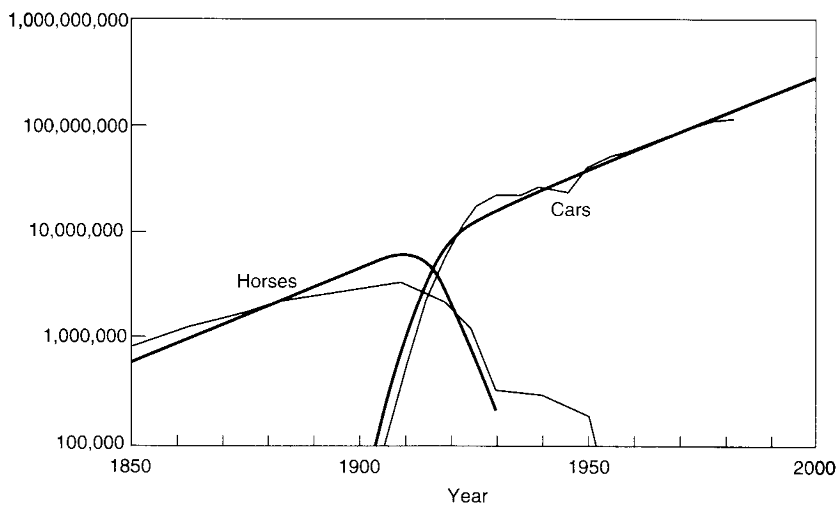
Attempting to foresee a fundamentally new technology is intrinsically difficult. At a minimum we can say that a new transport technology would have two generic aspects. One is an energy technology for propulsion, and based on historical precedent we could expect this to be something new. The other aspect is a means of supporting the vehicle and overcoming resistance to motion, and here some kind of levitation technology looks like a logical step forward.

Suppose X was in fact a levitation technology based on a ubiquitous source of clean energy. This would give it attributes that would make it highly suited to the development of a sustainable economy. It would fit the ideal profile for a sustainable transport technology: it would have close to zero environmental impact (in terms of fuel extraction impacts, vehicle emissions and land requirement); it would be based on an energy resource uniformly available worldwide thus avoiding social inequity; and it would be useable worldwide with little new support infrastructure.

Levitation would potentially also solve urban traffic congestion problems, as vehicle lanes could presumably be stacked vertically, although something equivalent to a combination of Intelligent Transport Systems (ITS) and high resolution air traffic control technology would be needed to ensure safety. The recent science fiction film *The Fifth Element* gives an idea of what a large city might look like with such a technology, albeit in a dystopian future.

Since supporting technologies for aviation already exist — radar, radio, avionics, air traffic control computers, airports, airframe manufacturing know-how, airline business systems — the new propulsion and energy technologies could be introduced comparatively rapidly. Commercial air transport diffused more rapidly than either rail or automobiles, and this hypothetical new development might be expected to spread at least as quickly.

The substitution of one transport mode for another can be surprisingly rapid. When cars were first introduced early in the 20th century, they took over from horses in less than fifteen years — by 1925 horses had all but disappeared from transport tasks in industrialised nations. The speed of this change demonstrates that we should be prepared for the possibility of a shift to a radical new transport technology in an equally short period of time.



Cars replaced horses (non-farm draft animals) in a 12 year period (Δt) in the US, and continued the same growth path (smooth lines are a curve fit to a logistic substitution model). Source: Nebojsa Nakicenovic[28]

FIGURE 6: The Replacement of Horses by Cars

Apart from the speculations presented here, there are no other obvious radical candidate technologies for X. We do know of many technologies for improving the characteristics of current vehicle technology — most of which are embodied in the 'Hypercar' concept proposed by inventor and policy entrepreneur Amory Lovins — but these may not provide the level of improvement required to maintain the established trend of speed and range increases during the last 200 years (Figure 3), let alone to trigger a state change in the transport socio-technical system. Yet if the society and economy of the future — sustainable or otherwise — is going to be technologically based and globally integrated, it would appear to be almost essential to have a new, environmentally clean, and fundamentally better transport technology.

SUMMARY AND CONCLUSION

The main points made in this paper can be summarised as follows:

• The transport system, in particular the urban transport system, can be considered as a complex large-scale socio-technical system which is locked in around a set of prevailing beliefs and technologies. It is optimised to facilitate maximum economic and physical throughput growth.

• There is a growing desire to reduce or eliminate the negative side effects of current transport systems, particularly the car. This desire is expressed in terms of proposed policies for urban design and sustainability, but it is not clear that these desired programs of change are enough on their own to shift the transport system from its current state of lock-in.

• A significant new paradigm of personal belief and social values, or a major technological development, would be needed to enable a shift in the transport socio-technical system. It can be anticipated that significant social change might involve the emergence of a less materialistic, and hence less materials-intensive way of living. This shift could perhaps be catalysed by major disruptions or crises, whether political, economic, ecological or climatic.

• Major technological development is unlikely to be based on incremental technological change but instead on advances fundamental enough to shift the existing system from its state of lock-in — probably involving both a new power source and a new propulsion principle. Based on past technology trajectories in transport and energy, a major new transport mode may well emerge, or be emerging, by 2010. The new mode would have to significantly surpass the performance of existing modes, as well as having lower environmental and social impact.

Two other points touched on in the paper are worth noting:

• Current worldwide exponential growth of population and industrial throughput are unlikely to continue indefinitely, and the deceleration phase may trigger a transformational socio-economic system 'bifurcation' within the next few decades. In more extreme scenarios this could involve an economic or environmental crisis or collapse, possibly precipitating a population crash.[29] Another way of putting this is that at a minimum, the business-as-usual world of exponentially-growing materials flows is likely to come to an end within the expected lifetime of any major new transport infrastructure built today.

• Sustainability of the transport system cannot be achieved independently of the socio-economic system as a whole, but the level of unsustainability[30] can be reduced and this is an important near-term goal for policy. True sustainability can become a goal for the transport system only after the whole socio-technical system moves towards sustainability.

All these points have implications for the assumptions that guide transport planning, which could and should begin to change to prepare for and adapt to the type of longer-run shifts anticipated in this paper. This will not necessarily mean doing different things in the short run — for the conventionally expected future — but rather avoiding particular actions or policy features that might hinder or make more costly a future transition to a new transport system or new transport technologies. In this way it should prove feasible to devise policies and strategies that work in both the familiar world of today and the possibly far more challenging world of tomorrow.

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