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Paradigm Shifts in Transport: Today's Heresy/Tomorrow's Wisdom

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Abstract:

We hypothesize that forecasts of travel demand into the near future (20 to 30 years) are flawed in that they fail to take account of significant trends that are becoming manifest in society. Many of these trends are NOT, as yet, obviously transport related but are contributing to a general, near term, paradigm shift that will see dramatic reductions in demands for mobility based travel to serve traditional needs. In the meantime, transport planners and policy-makers continue to propagate the technocrat philosophy: "if you can't compute it, it won't be" - the Romans might have said "Non demonstrare sum, ergo non erit". We, on the contrary, are more inclined loosely to follow the Descartian school, and say "Si cogito, fui pites" - "If I think, it can be". Within the next few decades we conjecture that reductions in demand for work, education, entertainment and shopping based trips will see the elimination of congestion, the disappearance of vehicular created air pollution, the general disappearance of most of the public and private transport industry and a dramatic shift in our value systems. The paper offers evidence to support the conjectures and attempts to forecast the significant changes that the changes to technology and value systems will bring about in the transport arena. The question of the role of government and transport planners will also be discussed.

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Introduction

Vision is the art of seeing things invisible.
- Jonathan Swift.

Forecasts of travel demand into the near future (twenty to thirty years) are flawed in that they fail to take account of significant trends that are becoming manifest in society. These trends are NOT, as yet, obviously transport-related but are contributing to a general, near term, paradigm shift that will see dramatic reductions in demands for mobility based travel to serve traditional needs.

In the meantime, transport planners and policy-makers continue to propagate the technocrat philosophy: "if you can't compute it, it won't be" - the Romans might have said "Non demonstrare sum, ergo non erit". We, on the contrary, are more inclined loosely to follow the Descartian school, and say "Si cogito, fui potes" - "If I think, it can be".

Within the next few decades we conjecture that reductions in demand for work, education, entertainment and shopping based trips will see the elimination of congestion, the disappearance of vehicular created air pollution, the general disappearance of most of the public and private transport industry and a dramatic shift in our value systems.[1]

The paper offers evidence to support the conjectures and attempts to forecast the significant changes that the changes to technology and value systems will bring about in the transport arena. The question of the role of government and transport planners will also be discussed.

Current Trends and their Relationship to Current Travel Patterns

There is no hope, but I may be wrong.
- Bumper Sticker

Demographies of the Future

Families in the developed nations will be smaller, more electronically aware, more scared of the external environment, more self-sufficient and more environmentally aware.

We are also seeing an increase in the proportion of aged in our societies - these people tend to take shorter trips and these trips are generally outside of peak periods. We can then expect a relative decline in peak and an increase in off-peak travel.

Hamish McRae (1994) when talking about changes in demographies had the following points to make that are relevant to this discussion:

- Retirement ages have to rise
- Female participation ratio in the workforce will climb
- Part-time working (including homeworking) will continue to rise
- Voluntary labour will be used to a greater extent and
- Greater efforts will be made to see the unemployed are in work.

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1 We conjecture that changes in value systems are not morally based but are rather economic/self interest based. When a particular type of behaviour becomes too expensive (there are many types of expense - death, dollars, health, educational level of the community, crime, violence, etc.) for a society to bear then that behaviour becomes unacceptable to that society and the value set of the society changes to reduce or eliminate the expense.
Our existing transport systems are reaching the limits of the price that our societies are willing to bear and we believe this heralds a paradigm shift.

Each of these factors will have a significant effect on travel patterns. Each, to some degree, will reduce the demand for peak period travel and will contribute to reductions in congestion. Each of these demographic groups will increase pressures for flexible hours and/or more home based work.

Cocooning, Cashing Out

The desire to avoid conflict and danger is causing more and more families to avoid the spaces outside their own homes and causes them to attempt, as much as is practical, to cocoon in their homes - and not only *in* their homes, for we are increasingly seeing the development of walled and gated communities, the re-creation of the medieval castle.

Also the increasing tendency for people to leave the traditional work-place at an earlier and earlier age is also fueling dramatic changes to the travel patterns we are seeing evolve in some developed countries already. the new age is one in which, "instead of being 60, settled and superannuated, the executive job market is moving to 50, fit and fired. And the trend is towards 45, fit and fired" ('Executives get early use-by date', *West Australian*, December 4, 1996).

At the same time, the 'baby-boomers' are living longer than their forebears. There is no reason to expect that the prematurely-obsolescent baby boomer will behave in any way like the 55-year old worker waiting for retirement.

The Electric Cottage

The introduction of electronic systems are allowing homes to become completely self-sufficient offices, shops (for ordering), schools and entertainment centres and are also improving the levels of service the home can offer in the more traditional areas such as health, and safety.

There has been much discussion over the last twenty years as to the changes that these systems will bring to demand for travel. There is a feeling that telecommunications will not create the changes first attributed to them. To date the figures banded about have not come to pass. In part this can be explained by a number of facts:

- the technology was expensive,
- the technology could not satisfy all needs of an office environment,
- the social pressures to avoid travel didn't exist,
- a critical mass of applications and organisations weren't available electronically,
- managerial systems were not prepared to accept remote work,
- there were fewer jobs that could benefit from teleaccess and
- there were fewer organisations and cultures that could benefit from teleaccess.

Many of these impediments have disappeared and more are disappearing or reducing in relevance every day.

The Telecommunications Revolution

The sophisticated equipment that is required to maintain a verbal and visual dialogue with anyone, anywhere and anywhen is now so cheap and cost effective that it is more and more being found in the private home. Prohibitive costs ensured, until only recently that these levels of service delivery were only available to wealthy companies and were shared by a wide array of personnel. This cost ensured that such facilities were held centrally and if you required their use you had to be in "the office". Now you can be sunning yourself on Kuta beach and still be able to employ all these electronic services with ease. No longer do you need to be where the hardware is located - it moves with you.

Whilst the new technology potentially makes the majority of workers 'footloose', our views of 'organisations' has to change if this is to be translated into a day-to-day reality. So far, "only 85 of the 126,000-strong [federal] public service have taken the option of working away from the office", despite this being provided in a hard-won award three years ago. This is attributed to 'fear of missing out on office politics (*Home work unpopular*, West Australian, January 13, 1997). Nevertheless, an estimated 500 000 Australians work from home.

Virtual Reality

"The real act of discovery consists not in
finding new lands but in seeing with new eyes."
- Marcel Proust

More and more production systems are being managed, not by switches that need to be flicked manually, but rather by switches that are switched electronically. The question now arises - if the switch can be switched by an electrical signal then does the signal have to originate in a location close to the hardware? The answer is NO. It is possible for an operations 'room' to be located anywhere in the world. We can just as easily manage a nuclear power plant from Iceland as from the operations room of the plant in South Australia. This is true of all manufacturing, production and monitoring systems that are managed electronically.

There is an extension to VR that we think should be mentioned and that is stereolithography. This is a process in which data can be transformed into a physical object. Scans of a 3-D object are taken and stored on a computer. These data, that define the 3-D attributes of the object can then be transmitted to a manufacturing plant. At the plant, in a totally automatic process, can, from a bath of liquid plastic, create a duplicate of the 3-D artifact. The obvious extension of this currently applied technology is that as the production systems become smaller and more compact, as the types of plastics that can be used become more varied[2] that it would be possible for sites such as drilling rigs to start the manufacture of their own day-to-day drilling necessities, fabrication shops would manufacture their own car panels and bumper bars, retail outlets would produce furniture in their back rooms available for very rapid delivery to customers in the showroom

The next step would be for the technology to end up in the home where you could create your own household non-consumables at the touch of a button. The only deliveries made to the home may then be consumables and a tonne of plastics for the households stereolithography production centre once a year

Now tell us that travel patterns won't change!

And we still haven't discussed the possibilities and potentialities of nanotechnology and the changes it may bring about Nanotechnology, if it fulfills only 10% of the rhetoric, could so dramatically alter the very fabric of our existence that the agricultural, industrial and information revolutions will appear trivial in comparison

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2 Currently we have plastics that can take on a wide array of colours, strengths, durabilities and forms We also have plastics that can be a strong as steel, can conduct electricity, can filter light or prevent it passing through, can insulate or be good conductors of heat and can change these properties with the applications of light, electricity or heat.
In fact it may not be too far fetched to believe that it may be possible to have a house and all its non-consumable contents made out of plastics even today.

The Virtual Organisation

According to Tom Peters (1992), the 'organisation' of the future will be characterized by 'disorganization', with constantly changing groups of people and skills coming together for a particular project and then breaking up. Individuals will flit from project to project and organisation to organisation and will be likely to be part of more than one project team at any time.

In these circumstances, the centralized, uni-location 'organisation' will be the exception. People who work in these virtual organisations will either have constantly changing travel patterns or will work outside the 'organisation as institution' - something which is already happening with the push to 'contracting out', for example, in government.

A Better Path

We are asleep with compasses in our hands
- W.S. Merwin, American Poet.

Technology has historically and will continues in the future to define our urban environment. Better transport systems made larger cities more 'profitable'. The advent of the private motor vehicle made the corner store less 'profitable' than the supermarket. The corner stores mostly disappeared, supermarkets replaced them and we traveled more in our cars to get to those supermarkets.

The technology of the private car created freeways, parking bays, congested cities, dead and mangled bodies, health systems that struggle under the load created by motor vehicle accidents, contribute significantly to air and noise pollution and the significant geographic separations between home and work with all the attendant social and community dislocations associated with those separations.

However there are new technologies that are becoming as ubiquitous as the private car and that offer even higher 'profits' for those that change to using these technologies. The nature of these systems to be more 'profitable' will ensure that they will, ultimately dominate the existing technologies - survival of the fittest works not just in biological systems but also in technological, economic, engineering and transport systems as well.

These technologies are electronic in nature - the personal computer, mobile faxes and phones, Internet, groupware, globalisation, intelligent agents, electronic entertainment, virtual travel, educational applications on screen, etc and they are changing everything we do and how we do it. They are also creating new tasks and eliminating the need to undertake old ones.

Technologies are causing a fundamental paradigm shift in all the world cultures. The question for us is - how will these shifts affect transport?

The Energy Question

In 1987 proven oil reserves were 32.5 years' consumption. With no cutbacks in consumption and no new discoveries the world would run out of oil in 2010/11 but this won't happen.

Global production of oil will peak around 2000 (Fleay, 1995), but long before the last drop of oil is pumped out of the ground the price will rise, conservation programs will be put in place, new discoveries will be made[3] or viable substitutes developed.

[3] New discoveries will however be relatively small because the world has been explored well enough for us to know that there exist no undiscovered massive fields like those in Alaska, the Middle East or Russia

It is not clear, however, that the oil-using industries have anticipated scarcity soon enough to avoid dislocations. Transport that depends upon fossil fuels or its substitutes will be far more expensive than it is today and as a consequence choice-based low valued travel will be reduced well before 2010/11 and in it's place electronic 'transport' alternatives will be employed[4] We conjecture that electronic alternatives to mobility may very rapidly come to dominate choice-based non-mobility necessary transport.

Forecasts of energy use in the USA, typically derived from models not dissimilar to transport demand models, have progressively been reduced. In fact, actual energy consumption in the USA in 1995 was and only two-thirds of Government forecasts made in 1976 and lower than the 'utopian ideal' proposed by 'soft energy' proponents (Lovins, 1996).

Is there any reason why should we expect transport to be any different from energy, since neither is desired for itself but for what it enables us to do?

Re-engineering

We believe that there needs to be a significant change in travel behaviours within our lifetimes. Urban planners, environmentalists, transport planners and the public at large seem again and again to say that this change needs to be fundamental in nature and that "fiddling about at the edges" won't fix the current or foreseeable problems. What we are all saying, in so many words, is that the transport systems need to be re-engineered.

If we agree with this statement then we must also support the basic tenets of re-engineering which state, rather forcefully, that to achieve significant breakthroughs in levels of service and/or efficiency in the delivery of a product or service there needs to be "**fundamental rethinking** and **radical redesign** of .... processes to bring about **dramatic improvements** in performance."

Government inability to contribute

"No corporation gets hit by the future between the eyes, they always get it in the temple."
- Dick Davis - Consultant.

"Except Government - they simply lose a bit more credibility."
- addendum by the authors

Governments and their associated bureaucratic systems have historically proved to be well off the pace when it comes to offering any type of leadership in the preparatory phases of significant change. Governments react to rather than drive change, we don't expect the systems developed by government agencies, governments or political parties to deliver useful or sensible policies or initiatives in periods of rapid change. In the past they have themselves remained so patently unchanged and unaffected by the changes going on around them that they offer little hope of leadership in the turbulent times that are coming. Governments, of all political persuasions, are structured to manage steady state systems - in their early manifestations they may forment revolution to gain power but they always seek steady stable systems to govern once they have power. Governments cannot manage chaos and they are becoming less and less powerful and able to control complex systems

[4] 'Electronic' will become a new mode in our current array of possibilities (car, bus, train, cycling, walking, taxi plane and electronic) and will probably end up as the most used mode; in fact if the telephone was to be considered as a mode of transport today then it would cause all other modes to shrink into relative insignificance

in any case as they devolve authority and responsiblity to charities, contractors and volunteer groups.

Experts?

The understandings and points of view of the experts in most fields are so entrenched that they cannot possibly drive a future they cannot see. As in nearly all disciplines we will probably find that it will be a non-transport person/s who forces us to change and to see the way things are going. Many of our ilk will be dragged screaming and kicking into the new world but it will happen - it is inescapable that the new technologies, the new social value sets, the new demands of the environment and of the next generation will alter the way we live, work, entertain and educate ourselves. The only question is the form and function that this continually evolving system will take in the near future. We proffer one possible future there are many others but each will have elements in common.

These common elements are those listed above, technology, social values, environmental demands and the growing up of a new generation. We are able to forecast significant parts of these futures. Some of the trends are there and they are inescapable, some are not yet observable in any meaningful manner. However, all the systems we can expect to see emerging in the next twenty to thirty years will be developed from existing technologies. These we know and understand and we can describe how they are evolving and also some of their possible consequences.

Some of the Changes the Paradigm Shift will bring about

Changes in Job Types - Infrastructure to Information

When our economies were dominated by production of physical goods there was a need to travel to observe, manipulate, purchase, deliver or alter these goods. There was no escaping the significant levels of demand for travel. This demand for travel continued to grow as our populations grew and as our demands for new and more physical products grew. Today the environment that determines the products and services we create has significantly changed that travel demand paradigm.

More and more our economy is dependent not upon physical goods but more and more on information and services. Goods that require to be physically transported are becoming less and less of the total transport task. Information can flow over wires and hence our concept of movement needs to move away from mobility in a physical sense and embrace movement in an electronic one as well. The electronic movement of the products of human labour will continue to grow and take a larger share of the total delivery task.

We generally believe there will be an ongoing increase in the levels of travel because we are not aware of any significant paradigm shift in the very near future. We believe there will be such a shift within the next two to three decades. This shift will see a dramatic alteration in the methods employed to observe, purchase and deliver goods and also their destinations.

The first three functions will be undertaken, for most goods, electronically and we also believe that mobility-based home deliveries for physical goods will skyrocket.[5]

[5] Many electronic (eg computer software) or service based products (eg booking airline flights) are already delivered directly to the home.
There is already evidence of a change in delivery practises for physical goods. Door-to-door parcel delivery services are one of the fastest growing industries in the world. Vertical integration opportunites between retailers on the Internet and door-to-door parcel delivery are too obvious to pass up as an investment. In fact there is already evidence of these types of moves

Overcoming of False Beliefs

Drexler (1992) and his co-authors postulate a list of false beliefs that have constrained development in a number of areas. We believe that the transport debate has been as hampered by these issues as have many of the other areas of human endeavour. These beliefs are:

- Industrial development is the only alternative to poverty
- Many people must work in factories (offices? question by authors)
- Greater wealth means greater resource consumption
- Logging, mining and fossil fuel burning must continue
- Manufacturing means pollution
- Third World development would doom the environment

These all depend on a more basic assumption:

- **Industry as we know it cannot be replaced.**

Some further common assumptions:

- The twenty-first century will basically bring more of the same
- Today's economic trends will define tomorrow's problems
- Spaceflight will never be affordable for most people
- Forests will never grow beyond Earth
- More advanced medicine won't be able to keep people healthy
- Solar energy will never become very inexpensive
- Toxic wastes will never be gathered and eliminated
- Developed land will never be returned to wilderness
- There will never be weapons worse than nuclear weapons
- Pollution and resource depletion will eventually bring war or collapse

These too, depend on a more basic assumption:

- **Technology as we know it will never be replaced.**

Most of the real world indicators of industrial and corporate change would indicate that these stated basic assumptions no longer hold true. The shifts in power in our communities and public and private organisations being brought about by the rapid advances in technology show that industry as we know it is being replaced. The jury is still out on the question of a totally new form of technology. But at least the jury is deliberating the question

When a technology/behaviour/system starts dominating a market it causes other alternatives to disappear even if the alternative selected is inferior. The advent of the petrol car caused technological lock-in. We stopped looking for alternatives once we had the petrol/diesel driven car. The steam car may have been superior to the petrol driven vehicle but we got locked into petrol driven. The car brought about a paradigm shift that locked all else out. A paradigm shift not only displaces existing systems but also locks us into the new paradigm

We believe that the existing set of beliefs on how the world works is ready to be displaced by a new set of beliefs, a new way of doing things - a new paradigm. And we'll get locked into this new paradigm just as we've been locked into all the others. The problem we confront is not will it happen but rather when and how can we ensure that the new paradigm is a good as it can be? Once it catches hold we're stuck with it possibly for a long time along with all its good and bad points

Some social commentary

Norman Myers (1990) paints a rather alarming picture of a possible future that we should not dismiss out of hand. As the global effects of the old-style destructive and selfish private car culture crashes headlong into the newer collective, caring and sustainable eco-culture that our children are growing up with we can expect significant clashes to occur. Can we expect

> "outbursts of angry citizens against 'energy laggards'? For example, attacks on single-occupant cars and grosser gas guzzlers, on blatantly energy-inefficient buildings, or even fossil-fuel power plants. Will we see 'energy wardens' authorised to issue on-the-spot fines to energy abusers? Will there be public pressure for governments to impose punitive carbon taxes on a host of energy-wasteful activities, both commercial and domestic?"

We believe we can expect some of these behaviours to be manifest as time passes[6].

Future Travel Patterns Arising from the Trends

All forms of teleaccess (telework, teleshopping, telelaw, telebanking, telecrime, telemedicine, teleinvesting, etc.) will bring about changes in travel patterns, collective delivery systems, the drive to cocoon, the capacity to be almost totally entertained and educated in your home, the social pressures not to drive a private vehicle that pollutes (air emissions, sound and safety[7]) and the need to deliver better, faster and lower priced products (goods and services) will see more of these alternatives being employed in the future.

With changes in social values and behaviours we can expect to see reductions in trips (Engwicht, 1996) and these will be mostly for work and shopping. These trip reductions will not be minor. We believe that within the next few decades trip reductions in the developed nations will be such that the air pollution and congestion seen in places like LA, Tokyo and London will be but memories of things past.

Some of the possibilities:

Work trips reduced by upwards of 60%: approx 60% of workers are considered information workers all capable of telework. Further increases in the proportion of information workers could see this figure grow.

Education trip reductions of 75% - 90%: only hands-on laboratories will require physical attendance[8]

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6 We have had significant confrontations in the last few decades because of cultural clashes and looking back on some of the reasons for those clashes we can laugh and now understand how silly they all really were. Remember the 60's and 70's and long hair on men? Remember the fights between the fathers and sons? It was all because of a paradigm shift - a redefinition of what it meant to be masculine. Short back and sides simply couldn't handle the change in perceptions a new generation had. A relatively trivial reason for all the angst. The paradigm shifts we are coming into are far more important than that - far more. We can expect a significant degree of social dislocation and friction.

7 Safety, in a transport environment, is simply another form of pollution (a negative externality). Some argue that traffic itself is pollution (Engwicht, 1996).

8 We've had people say that this isn't possible since many families require school as forms of child-care because both parents work. However, when people work from home, the argument becomes moot. Some families will still not have parents at home and will require a form of child-care but the numbers will be nothing like they are now.
There is also the question of social interaction but this could be achieved by the development of localised play groups of kids living in the same street or close by.

Shopping trips reduced by 90% - 99%: only trips to purchase item such as fitted garments and others that absolutely require a physical presence will need to be undertaken.

Entertainment trips will increase for destinations such as beach, picnics, etc other types (movies, video store, games parlour, social clubs, etc) will probably drop.

Aggregate Effects of Trends and Travel Pattern Changes

No matter how much you study the future, it will always surprise you; but you needn't be dumbfounded!
- Kenneth Boulding

Within two to three decades we will wonder why we, in Perth, constructed a Northern City Bypass, extensive freeways and also why we bothered to extend the rail system; in other words why we spent hundreds of millions on infrastructure that could not be cashed in, sold off or used for alternative purposes when no longer needed to fulfill their primary function [9] The streets we already have will be more than sufficient to satisfy any potential population growth we could ever envision. New roads will be required but only in new developments but we need no new capacity to manage peak periods; since traffic and travel patterns as we have today will simply not exist [10]

Changing work and education trip patterns

The idea of a 9:00 - 5:00 workday will disappear since corporations will be required to work 24 hours a day 365 days a year to survive in a global economy. With the elimination of the 9:00 - 5:00 five day week the morning and afternoon peaks will disappear and with the disappearance of the peaks so disappears the need for broad, long and expensive freeways and much of the current infrastructure devoted to physical mobility.

The private car will NOT disappear it will simply be used in a very different manner. Travel to friends, parks, the beach, occasional shopping, face-to-face meetings, holiday travel, etc. will still occur. But we don't need massive city parking stations, large shopping centre carparks, freeways, bypasses, large and expensive public transport systems, schools and universities with significantly sized catchment areas, extensive policing of road users or hospitals larger than they need to be just to deal with road trauma.

It is possible today for any of us to, over the Internet, enroll in a degree at Harvard, Cambridge or Oxford without leaving home. We now seriously ask the question: 'If you can get a degree from any of these institutions why would you bother enrolling at your local university?'

One of the authors was told by a close friend that works with a WA university that there had been very high level discussions between a number of the universities in WA as to

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9 There are many such examples in history. Castles became useless once the cannon was developed - a paradigm shift that totally changed the value of infrastructure. A castle of significant defensive value became virtually valueless, as such, overnight. However, castles continued to be constructed for many years after the advent of the cannon.
Why?
Two reasons:
1. Many refused to see or failed to understand the paradigm shift. We still suffer the same myopia. Investing in infrastructure that will be valueless long before we have extracted the investment costs.
2. The castle was a great status symbol and still had value as a place to live even if it couldn't be defended (our roads and rail systems have no such secondary value).

10 Our traffic models of course do not show any of this since they are dependent on historic travel patterns - totally meaningless when the fundamentals change.

which campus would survive the coming changes since there was a belief that WA would possibly only require a single physical campus by the turn of the century.

It's not just universities that are vulnerable to these changes - schools (primary and secondary) are also vulnerable. When a single teacher can record a lesson that can be beamed to 50 million students as easily as 10 then there is the potential to decimate the worlds education industry. When 90% of students don't travel to school, along with all the other possible changes, we would contend that traffic patterns will be unrecognisable.

Economic and workforce changes

We will also see significant restructure in the workforce as these changes start to take effect. The motor industry is a significant part of our economy. When our society consumes one tenth of the amount of oil we currently do, when we no longer need all the panel beaters, car yards, garages, RAC's and NRMA's, bus drivers, auto mechanics, transport planners, road builders and all the personnel that support these industries - what then? Also we need to realise that these changes will not just occur in WA but around the world. The total global effects are incalculable but will be significant, long-term and possibly socially devastating.

These same questions were last raised by our society just a decade ago with the advent of the desktop computer and the technologies that flowed from these (e.g. industrial robots, barcode readers). We failed to plan for these changes in any meaningful and coherent manner. We believe the same will be true for any significant changes in travel patterns brought about by changes in behaviours and social values.

History has shown that the time it takes for a new social paradigm to be accepted and understood by a society is far greater that the time required for the paradigm to affect that society. By the time society and especially government recognises the change and prepares to act in a coherent manner it's too late - early adopters and change agents have created the atmosphere that will drive the shape, beliefs, understandings and values that the new shifts will bring.

A real horror is the fact that often the 'experts' in the field most affected by the paradigm shift are unaware, resistant, deprecating or outright saboteurs of these new systems even when the benefits of the system are obvious to all but the 'experts'.

Future trends

To develop trends of future private vehicle usage from current and past vehicle usage trends is farcical (see figure 2). Travel is a derived demand - find out what causes it, forecast changes in these behavioural drivers and then forecast travel demand. That's how it should be done but that's not how we do it.

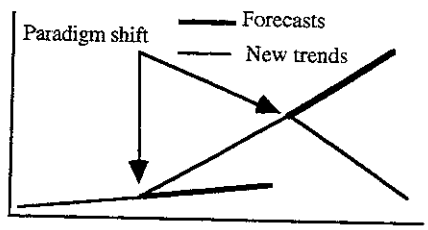

Figure 2. Paradigm shifts

That's why we believe many experts still believe that demand for physical travel, as opposed to virtual travel, will continue to increase. We forecast increases in population

and without thought forecast increased physical travel as an almost linear function of population. This approach is trivial, morally corrupt, leads to expensive and incorrect decisions and is methodologically wrong.

Some simple supporting evidence.

The National Travel Survey 1993/95 in the UK had the following statements to make regarding trips undertaken:

Pg 5; "fewer ... journeys than ... recorded in 1989/91"

Pg 21; "London residents traveled ... 22 per cent below the Great Britain average and 36 per cent less than other residents of the South East"

Pg 31; "the average number of commuting journeys ... fell by 14 per cent from 1975/76 to 1993/95"
"51 per cent of all commuting journeys began between 7am and 9am or between 4pm and 6pm on a weekday. This is lower than earlier years and possibly reflects the spread of flexible working hour arrangements throughout Great Britain."
"fewer journeys are made by workers - down from an average for full-time workers of 442 to 389 in 1993/95."

In fact over the period 1975/76 to 1993/95 total worker trips (full and part-time) dropped from 776 per annum to 657 per annum a drop of 15 per cent.

Traffic and Transport as Complex Adaptive Systems

Many in transport would agree that traffic systems are Complex Adaptive Systems - it would be unlikely to encounter a question as to the truth of this statement - it is generally accepted as such.

Where we, as a profession, come unstuck, or so we believe, is in the execution of our models of traffic and transport systems. Our models are fundamentally linear in nature.[11] We run and continue to develop linear models because we believe we haven't the capacity to develop 'real' models. So we continue to make wrong decisions because many of us have been led to believe that this is the best we can do. We disagree!

We feel that the science of traffic engineering is much like the science of economics - caught up in a form of self-consciousness and embarrassment for being somewhat less than 'real science' or 'real engineering'. We try to cover-up our fear by being as rigorous as possible. We build mathematically correct models (albeit ones which invariably include 'fudge factors', whose importance is rarely recognised, and which are usually rationalised as 'representing the inherent, but unquantifiable characteristics of one mode or another') that describe systems in equilibrium; a place we know traffic never gets, and model little of the reality we can walk out of the door and see (much like the weather forecaster that tells you it's all clear when you are standing out in the rain). We know our forecasts are wrong[12], yet we continue to defend the indefensible - just like economists who, when the real economy doesn't match the forecasts, blame the economy for not 'doing the right thing' rather than blaming their unrepresentative models (Ker, 1990).

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11 Complex systems are non-linear in nature and cannot be adequaely modelled by linear approximations. Adaptive complex systems, of which traffic is an example, are even more difficult to model adequately and yet we all agree that this is the reality we are confronting

12 It is not uncommon for traffic planning decisions to be based on models which have a predicted/observed error of ±25% at a *screenline* level and ±50% for an individual road!

We leave many variables out of our models because we cannot obtain meaningful data, because we cannot forecast their future values with sufficient accuracy (sometimes we can't forecast them at all and sometimes they go into models even so). We justify these omissions/additions by attempting to convince ourselves that these factors are not important, won't affect the end results significantly, or that their effects are swamped or dampened by others.

We also increasingly ask models to provide 'answers' to question for which they were never designed.[13]

The upshot of all of this is (or should be) an awareness that our models and related analytical tools ignore the fact that the future will not simply be an extrapolation of the past/present and, incredibly, are unable to include anything meaningful about human nature, which is dynamic not static, ever-changing not a constant.

If we cannot model effectively then why do we not take another route? Attempt to understand traffic as a complex self-adaptive system. The advantage of this possibility is that it may be possible to 'understand' traffic by the development of a few simple rules.

Here we would like to move the discussion to cellular-automata. In 1984 Stephen Wolfram (Waldrop [1992], pg. 225) determined that cellular-automata had a rich mathematical structure but have significant similarities to non-linear dynamic systems (like traffic systems). Wolfram also contended that there were four universality classes that all cellular-automata rules fell into. These classes were:

> Class I: contains what could be called doomsday rules. No matter what pattern of living or dead cells you started out with, everything would just die within one or two generations. In the language of dynamic systems the rules seemed to have a single 'point attractor'. That is, the rules seemed to mimic a mathematical surface that was shaped like a gravity well, the system would roll down the sides of the well and sit at the bottom, in a dead state.
>
> Class II: these rules were a little more lively, but not by much. With these rules the initial set up of living and dead cells would quickly coalesce into a set of static blobs, perhaps with a few other blobs that would periodically oscillate. These automata give the impression of stagnation and death. Here there existed a set of periodic attractors. A set of bumps in the mathematical surface within which the system could move indefinitely.
>
> Class III: these went to the opposite extreme, they were too lively. They produced so much action that the cells boiled with activity. Nothing was stable or predictable: structures would break up and reform almost immediately. Here were the 'strange attractors' so familiar in chaos. Here was a system that had been shot onto the mathematically surface with so much energy that they would never settle down.
>
> Class IV: here were the rare systems, the impossible to pigeon-hole rules that didn't produce frozen blobs, but that also failed to generate total chaos. What they did produce were coherent structures that grew, split, and recombined into new complex and 'living' organisms. They never settled down. They were not predictable, but not chaotic either, they were complex self-adaptive systems just like the Game-of-Life; the most famous computer based example of the implementation of a set of class IV rules.

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[13] The authors are indebted for this observation to a former colleague, the late John Foster, a meticulous and intellectually-honest transport modeller, who always felt very uncomfortable when asked to apply models in this way.

Given the evidence; when flowing well, traffic fits perfectly into the class IV rule set because of the evidence that the patterns of traffic flows, movements, etc., are not 'dead' or on the edge of 'death' and are certainly not chaotic. Traffic is rather orderly, directed and meaningful and becomes chaotic or dead only at specific times. There is certainly no 'death', no chaos, but rather complex behaviours that continuously undergo change and adaptation. The movement is directed towards a goal (much like a glider in the Game of Life). There exists a set of rules, that we may be able to discover, that will allow us to 'understand' the behaviour more clearly.

The change from class IV to classes I, II or III, which traffic goes through at times, can be likened to phase changes. Water changes from ice (class I or II) to water (class IV) and then to steam (class III). In the study of water we understand what brings about the phase transition - we don't in traffic but we should.

Studies in phase transition in chaos have shown that as we approach the onset of chaos there is an increase in computation. This is understandable if we realise that one route on the road to chaos is via an increase in complexity. The opposite is also true. If we reduce computation we reduce complexity and we approach class I and II behaviours.

Is the secret of remaining within a class IV rule set the maintenance of the correct level of computation? Could we employ the idea of computation to measure the effectiveness, efficiency and usefulness of our road networks?

At first this question may appear trivial in the extreme. However, a closer look could prove to be of value. What, in a traffic sense, could be represented by computation? We believe we can talk about the need for the controller of a traffic entity (a vehicle, a pedestrian, etc.) to concentrate on the job could be considered as a possible measure of computation. In a case of grid-lock there is no need for a driver to think about the job of driving the car – minimal movement: minimal computation (class I and II), as we increase the efficient use of the network we increase congestion, speed, decrease inter-vehicular distances, accelerate faster and stop faster, each of these acts requires increased concentration and effort (increased computation). Chaos in traffic would be a state where the ability of drivers to maintain required levels of concentration failed (as exampled by a crash) [14]

What needs to happen is to start to seek out the class IV rules that govern traffic systems and we haven't undertaken that search in any meaningful or directed manner as yet. What we, in the profession, have done is to dissect traffic into roundabouts, traffic lights, platooning, acceleration curves, etc., etc., ad-nauseam.

We don't get an understanding of LIFE by understanding, in microscopic or atomic detail, a living cell in all its separable parts. LIFE involves synergy that is far more than the simple addition of all knowledge of biological systems that we currently possess. So to with traffic. An understanding of traffic is far more than the addition of our knowledge of roundabouts, traffic lights, platooning, acceleration curves, etc., etc., ad-nauseam.

Maybe one of the major stumbling blocks is that many, or maybe most, of those in the area do believe that understanding can be gained by the simple addition of micro-based knowledge. That by learning more and more at the micro-level we will, in time, come to understand the whole. That is a belief system, and like religion cannot be logically argued - for or against. However; new branches of knowledge would suggest that we will never understand traffic, or any complex self-adaptive system, by a dissection of all the parts.

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[14] We would conjecture that an accident event (class III) in traffic immediately leads to localised death of the system (immediate phase change from class III to class I or II). Complexity increases until we make the phase transition from complex self-adaptive to chaos. However, it is impossible for a traffic system to remain in a chaotic state. Traffic, locally, comes to a relative or complete halt (class I and II rule sets dominate) immediately after the class III phase transition occurs and the accident occurs.

New work being carried out at the Santa Fe Institute (Waldrop, 1992) has tightened up a theory that the 'optimal' position for growth and adaptation, for all systems, lies at the edge of chaos. This central idea has been shown to be true in simulations of complex systems. The reason we must simulate these systems is that there exists no central quantitatively proven theory of complexity

We ask you to develop a hypothesis in your mind. Posit a simple single link road network, with one origin and one destination, with one thousand vehicles traveling from the origin to the destination, and all required to arrive before some stated point in time (morning rush hour), all traveling at the same speed in a simplified model. Now lets start to increase the complexity of the system. The numbers of links between the origin and destination increases, more nodes, the capacities of the links differ, vehicles travel at different speeds and so forth. The complexity of the system has increased, but so too has the efficiency of the system (from a real world perspective). Complexity has increased and so has efficiency and effectiveness. The necessary levels of computation have also increased. Decisions need to be made that were not needed in the simpler scenario. Now we need to determine the route as well as the time to leave the origin to arrive at the destination at the required time. In the simple scenario we only needed to work out the origin departure time

If you look at many other systems, both natural and man-made, you will discover that these 'rules' generally hold true - increased complexity implies increased efficiency and effectiveness. The manufacture of consumer goods, delivery of products to market, political systems (our two-party system has become bogged down in a two way fight with little imagination or creativity on either side. Japan and Italy have been able to effect dramatic change, maybe partially because of the levels of complexity inherent in their political systems), educational (better directed educational opportunities, more subjects, greater demands, etc., all act to improve the quality of the system) and legal (the legal system is NOT in any real terms complex - enough said) systems; they improve their ability to satisfy their primary function as the systems become more complex and computationally intense.

However; there is a level of complexity that traffic systems cannot go beyond to remain efficient. Attempt to move beyond this point and there is a phase change to chaos, immediately followed by death. Systems, to maximise performance, move towards *c* (where complexity is maximised) and also attempt to change the shape of the surface near *d* to make it difficult to slip from the edge of chaos[15] into death *e* (see figure 3 from Woodcock and Davis [1980]).

One of the reasons, we believe that catastrophe theory has fallen into disfavour with the 'quantitative'[16] crowd is that it is not possible to use the theory to forecast exactly when an event will occur. It is however; very useful in helping us to understand the process and to maybe working out how to get out of the chaotic or dead zone once we get there. However; here again those of us caught up in the 'quantitative' approach are not particularly enamored by cerebral understanding without any quantitative support; we feel that that is unscientific and therefore unsupportive and therefore of no value. This view is,

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15 We are willing to posit that robust complex systems have a different shaped surface at the edge of the catastrophic cusp. The surface, would probably, curve sharply upwards at the edge of the cusp (point *d*), making it far more difficult to fall over the edge into death. This would allow those systems to be more effective than most by making it possible for them to increase levels of computation well above others before going through the phase transition from class IV to class III and then immediately to class I or II

16 Here we could just as easily have inserted 'Newtonian' or 'Reductionist' along with all the negative attributes associated with those terms today. As has been said 'we are today only just starting to recover from Newton.'

we believe, utter BS. Astronomy is undeniably science and yet an astronomer cannot forecast a Super Nova, they seek to understand the processes and not at a pure quantitative level. There are many sciences of like type. In transport we may benefit from the same perspective.

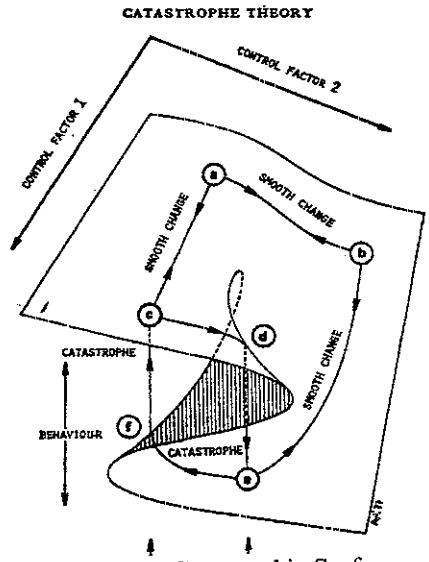

Figure 3. A Catastrophic Surface

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