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THE FUTURE OF TRANSPORT TECHNOLOGY

THE NEXT 100 YEARS

FROM HORSELESS TO DRIVERLESS CARRIAGES

26 March 2014

Background

Before we start the journey into a possible, even likely future, let me give you some context in terms of my background and approach.

- I am a practicing Electrical Engineer with 30 years experience in the research, development, manufacturing and deployment of products and solutions into the meat processing, car navigation, telematics, automotive, GNSS tolling and marine navigation industries. More than 500 products.
- One of the major enabling technologies in many of these products was GPS. In 25 years it has gone from being a military only technology to being in every new smartphone, tablet and car.
- How technology is adopted and moves from concept to niche application to mass adoption has always interested me.
- I am not a transport engineer, but may have learnt enough to be dangerous.

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Approach

- Current State
  - o Social, economic and environmental forces
  - o Simplified transport system
- Enabling technologies
- Barriers and enablers to adoption
- Benefits, paradigm changes and new business models
- Will it happen? Historic cross check
- When?

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Current State

Considering our difficult geography, large land mass, small population and limited tax base, New Zealand's transport infrastructure is generally well developed.

The are a number of social, economic and environmental factors that will make significant change in the next 100 years inevitable.

Demographics

- Limited population growth compared to transport infrastructure requirements (Statistics NZ) 2012 4.4m : 2061 6m projecting
- Ageing population (Statistics NZ)
  - % of aged 65+ 2011: 14%, 2061: 26%
  - By 2061, it is expected that between 10 and 18 percent of the labour force will be aged 65+
  - By 2061, life expectancy is expected to be greater than 85
- Continued urbanisation (MOT)
  - 60% of the population growth over the next 20 years will be in Auckland
  - 53% of population within the Auckland, Hamilton, Tauranga triangle by 2031

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Current State

Safety and the Human Toll

- Significant progress has been made reducing the road toll. (MOT 1990: 729, 2010: 375)
- The total social cost of road accidents is estimated to be $3.7 billion per annum.
- National Highway Traffic Safety Administration (NHTSA) attributed 93% of the 6 million crashes in 2010 to human error.
- A recent Roy Morgan survey showed 91.4% of all over 65s (170,000) still drive 5,000 to 10,000km per year.
- The crash rate per km starts to rise at age 75 and increases sharply after age 80.

Freight Task

- The freight task is expected to double in the next 30 years.
- Trucks will become longer and heavier in order to improve productivity, minimise congestion and transport related emissions.

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Current State

Growing cost of mobility in urban areas

- It is considered a fundamental right to be able to go where we want whenever we want.
- We rely heavily on our transportation infrastructure, particularly roads in urban areas.
- According to the 2013 Tom Tom congestion report, New Zealanders now spend a staggering 101 hours annually in peak-hour traffic, with Auckland having the biggest increase in congestion across Australia and New Zealand.

Observations

- Our ageing population will face a growing mobility challenge as age-related impairment prevents them from driving.
- The diversity of New Zealand transport infrastructure will increase with minimal loading on rural roads, heavy transport corridors and intensive urban transport networks especially in Auckland.
- With limited funds we will continue to struggle to develop and maintain our transport infrastructure.

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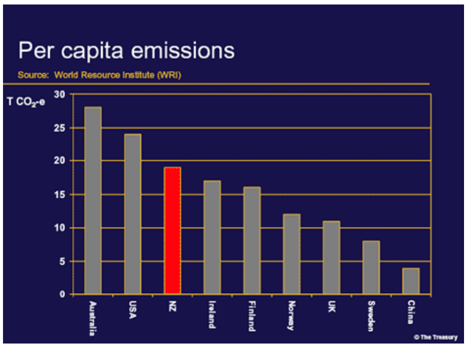
Current State

Reducing land transport emissions

- NZ government target (like many OECD countries) is to reduce greenhouse gas emission from 1990 levels by 50% by 2050.
- Our greenhouse gas emissions are growing rapidly. In 2006 we produced 26% more than in 1990.
- Land transport is responsible for 44% of NZ greenhouse gas emissions. The majority caused by road vehicles.
- New Zealanders per head of population emit nearly twice as much greenhouse gases as the British and almost five times as much as the Chinese.



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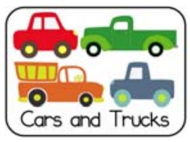
Simplified Transport System Review

Let's take a look at the components that make up a simplified transport system. Consider the constraints and limitations and see how we can improve the current state.

Roads

Intelligent Transport System



Vehicles

Drivers

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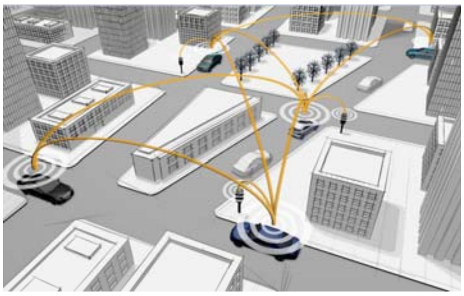
Enabling Technologies

Connected Vehicles

- "Connected Vehicles" use Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) technologies to communicate with other surrounding vehicles and traffic signals.
- Connected Vehicles will be able to communicate with each other, exchanging data on speed, orientation, and perhaps even driver awareness and intent. This will increase safety for nearby vehicles.



- The system is also designed to communicate with the roadway infrastructure. It allows for complete, real-time traffic information for the entire network, as well as better queue management, finding better routes by processing real time data and feedback to vehicles.

V2X (V2V+V2I) ultimately closes the feedback loops on what is now an open-loop transportation system.

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Enabling Technologies

Connected Vehicles

- As Connected Vehicles become more common, significant efficiencies could be gained with dedicated High-occupancy Connected Vehicle lanes. Because the vehicles are linked together with a resulting decrease in reaction times, the headway between vehicles could be reduced so that there is less empty space on the road. Available capacity for traffic would therefore be increased. More capacity per lane would in turn mean fewer lanes in general.

SARTRE project (Safe Road Trains for the Environment)

- V2X will enable precise traffic-signal coordination by tracking vehicle platoons. Will benefit from accurate timing by drawing on real-time traffic data on volume, density and turning movements.

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Enabling Technologies

Advance Driver Assist Systems (ADAS)

- The automotive manufacturers have been including driver assist features for a number of years; ABS braking, cruise control, stability control and reversing assist.
- New features we will start seeing in new vehicles include:
  - Adaptive cruise control
  - Traffic Jam Assist
  - Pre-crash system
  - Automatic parking
  - Lane keeping
- This has become an important area where manufacturers can create market differentiation. This has turned into an arms race with the ultimate prize being self-driving vehicles.

ADAS forms the subsystems that self driving vehicles will leverage in the future

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Enabling Technologies

Self Driving Vehicles (SDVs)

- These vehicles are equipped with cameras, radar, GPS and lidar sensors. These scan and 'read' the road ahead by picking out lane markings, as well as other traffic.
- Advanced control systems interpret sensory information and identify appropriate navigation paths, obstacles and relevant signage.
- Some use sensory inputs to update their maps, allowing vehicles to keep track of their position even when conditions change.

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Enabling Technologies

Self Driving Vehicles (SDVs)

The NHTSA is very proactive in realising SDVs. It understands the significant improvement in safety outcomes this technology can provide. It has established an official classification system:

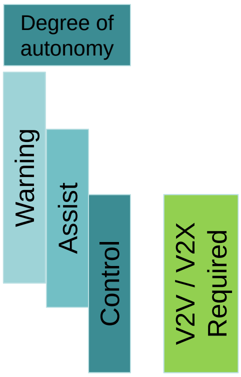
Level 0: The driver completely controls the vehicle at all times.

Level 1: Individual vehicle controls are automated, such as electronic stability control or automatic braking.

Level 2: At least two controls can be automated in unison, such as adaptive cruise control in combination with lane keeping.

Level 3: The driver can fully cede control of all safety-critical functions in certain conditions. The car senses when conditions require the driver to retake control and provides a "sufficiently comfortable transition time" for the driver to do so.

Level 4: The vehicle performs all safety-critical functions for the entire trip, with the driver not expected to control the vehicle at any time. This can include unoccupied cars.



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Enabling Technologies

Self Driving Vehicles (SDV)

- Integration between the V2X and ADAS is a fundamental requirement of a fully automated transportation system.
- The information passed between vehicles also greatly simplifies the technical problem of self driving a vehicle using ADAS sensors only mounted on the vehicle.
- The additional V2X information also provides additional cross checks and redundancy.

From KPMG report on Self-driving cars: The next revolution

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Enabling Technologies

Super Intelligent Transportation System (ITS)

Super-intelligence is the result of IT integration of all the components of a system; intelligent vehicles; intelligent infrastructure; intelligent control system; intelligent commuters and intelligent cargo.

These transport management systems could optimise the traffic flow across the entire network, responding to congestion in real time.

The system could change traffic rules according to a specific situation such as accidents and bad weather. Speed limits and traffic light phasing could be varied to control traffic flows and maximise network through put.

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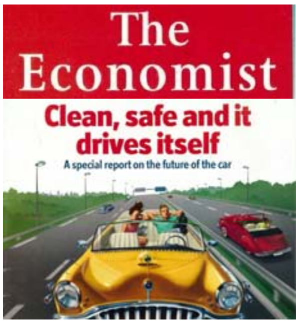
Enabling Technologies

Super Intelligent Transportation System (ITS)

When this happens:

"Vehicles will stop being an isolated means of transportation and being at the centre of the transportation experience into being a single small element in a vast traffic coordination and optimization system.

Vehicles will merely be the endpoints of such a massive traffic system, and hence be moving from the centre of transportation to the edge of a powerful computing and data intensive real time transportation system."



The Economist, "Clean, Safe and it drives itself", 20-26 April 2013

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Barriers and Enablers to Adoption

Consumer Acceptance, Safety and Trust

- Resistance from consumers to forfeit control of their cars until they are convinced the safety critical technologies are 100% safe and reliable.
- That said it will be an incremental change as more and more driver information, warning and assist features are released into new cars over the coming decades.
- Education of drivers to learn the semi-autonomous and fully-autofocus features and where and when they can use them will be important.
- As baby boomers mature past driving age they will be more receptive to SDVs in order to retain independence and mobility.
- Younger generations are likely to be more receptive and to become early adopters. They may perceive vehicles as commodities to get from A to B, allowing them to remain digitally connected and relaxed.
- Reliance on SDVs will produce less experienced drivers, when manual driving is needed. It is expected that drivers will need to manually drive vehicles in low populated areas. Unfortunately many of New Zealand's most dangerous roads will still be in such areas.

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Barriers to Adoption

Technology

The underlying technologies required for SDVs are developing incredibly quickly. Billions of dollars are being invested every year.

- Without V2X connectivity the self-driving vehicle will be totally reliant on its ADAS sensors. This is a very difficult problem to solve 100% of the time. Intense conditions such as busy city driving and extreme weather remain very problematic.
- SDVs relying on lane markings may not be able to identify faded, missing, or incorrect markings. The clarity of lane markings is affected by snow, and by older, visible lane markings - hindering the ability of SDVs to stay in lane.
- Until V2X connectivity is implemented at black spots and in intense conditions there will not be a suitable safety net with redundancy to offer complete road network wide self-driving vehicles capability.
- A vehicle's computer could potentially be compromised by a cyber attack, as could a communication system between cars.

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Barriers to Adoption

Economics

- Early adopters of self-driving cars will be paying a significant premium.
- The self-driving experience is unlikely to be road network wide.
- V2X functionality will need to be justified in terms of public good, so it will not be implemented until there is a reasonable adoption or commercial transport business case. Spending public money on transport infrastructure so the rich can drive around in self-driving cars will not be well received.
- Car manufacturers are bullish about SDVs; in time they will only incur a $2,000 premium over standard models.
- Car manufacturers are also talking about self-driving upgrades costing $3,000 to upgrade a standard vehicle to a fully featured SDV. This could potentially be subsidised by low insurance premiums.

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Barriers to Adoption

Regulation and Laws

There are many legal and ethical questions that need to be addressed such as:

- What happens when things go wrong? Who pays?
- To what standard should driverless vehicles be held? Must they perform as well as a perfect human driver for any conceivable manoeuvre? Or must they perform merely as well as an average human in a statistical sense? In any case, how should that performance be measured?
- These vehicles will collect and communicate a lot of data about when and where people are going. Loss of privacy is a real concern.
- How do we develop the control systems that make the “right” life and death decisions?
  - Weighing up whether to swerve to avoid a pedestrian or object at the risk of causing more injury to passengers?
  - When it is safe to operate in autopilot mode and when to hand control back to the driver?

The role of the regulator is critical in terms of implementing enabling laws and regulatory frameworks. This needs to be done in close collaboration with vehicle manufacturers and ITS providers and should follow global best practice.

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Benefits, Paradigm Changes and New Business models

An increase in the use of Connected Vehicles with ADAS or SDVs will make the following benefits and opportunities possible:

Economic and Productivity Gains

- The benefits of productivity and safety improvements, time savings and lower fuel consumption and emissions could have a total economic impact in the order of hundreds of millions of dollars.

Crashless Vehicles

- McKinsey Global Institute calculates the second-largest saving of SDVs (behind reduced congestion and travel times) is the reduction in vehicle accidents and related deaths – by estimating SDVs can reduce road accidents by 5% to 20% overall. The assumption is that SDVs will not be subject to the same type of accidents caused by human error.
- By 2020, Volvo envisages having cars in which passengers would be immune from injuries.

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Benefits, Paradigm Changes and New Business models

Improve quality of life

- Relief of vehicle occupants from driving and navigation chores.
- Removal of constraints caused by occupants' state: in an SDV, occupants who are under age, over age, blind, distracted, intoxicated, or otherwise impaired are no longer a risk.
- Alleviation parking shortages: cars could drop off passengers, park far away, and return to pick up passengers.
- Removal of superfluous passengers: an SDV can drive independently to where it is needed, to pick up passengers or to be serviced.
- Interiors can be customised as mobile offices, sleep pods or entertainment areas.

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Benefits, Paradigm Changes and New Business models

Improved Energy Efficiency and Reduced CO_2 Emissions

- SDVs should be able to achieve 15% to 20% fuel savings by eliminating wasted fuel due to rapid acceleration, speeding and erratic speed control.
- ADAS will allow vehicles to travel closer together in a road train or platoon formation. This significantly reduces air resistance and improves fuel efficiency by up to 15%.
- Self driving trucks in a platoon formation could achieve further fuel savings by optimising the speed to achieve maximum fuel efficiency.
- SDVs could be significantly lighter and more energy efficient than today's vehicles as they no longer need all the heavy safety features such as reinforced steel bodies, crumple zones and air bags.
- Reduced traffic congestion will also translate into further significant fuel savings.

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Benefits, Paradigm Changes and New Business models

New Vehicle Ownership and usage models

- SDVs will challenge the current vehicle ownership model and will blur the line between taxis and public transport.
- In the US even during peak traffic, fewer than 15% of the vehicles are in use. The other 85% are not being used. The average private vehicle is used less than 2 hours per day.
- If SDVs can drive themselves and can be booked when needed, there is no need to own the vehicle. Ownership is replaced with a service on demand.
- At the same time vehicle sharing could have a significant impact on vehicle manufacturers as we require fewer vehicles.

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Benefits, Paradigm Changes and New Business models

Reducing the need for new roading infrastructure

- Convergence between V2X and SDVs will transform the road and highway systems that were designed to support human drivers.
- Today's infrastructure demands features such as wide lanes and shoulders, guardrails, traffic signs and rumble strips due to the imprecise and often unpredictable movement patterns of human drivers.
- Research indicates that platooning of vehicles could increase capacity by up to 500%.
- SDVs become data probes for the central automated transportation system feeding back real time weather and road conditions. This would greatly assist with asset management and reduce maintenance costs.
- Simulation of intelligent control intersections designed for SDVs could perform 200-300 times better than current traffic signals.

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Will it Happen? Historic Cross Check

- Have such radical changes occurred in the past?
- Is there a historic cross check?

YES!!!

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Will it Happen? Historic Cross Check

It is 1890. New York City is an economic power house after a century of growth. Like major cities of the time, its land transport is dominated by horses.

- Population and population density (US Census)
  - 1800: 60,000 : 2,955/square mile
  - 1900: 1,850,000 : 90,366/square mile
- New city dwellers generated increasing demand for goods and services that in turn increased demand on horses for both freight and urban transport.
- By 1853 New York omnibus public transport carried 120,000 passengers per day.
- By 1890, an average New Yorker was using a horse car 297 times a year.

New York City - 1888

- The population of horses in 1880 for New York and Brooklyn was 150,000-170,000, or 4,000 horses per square mile. This translated into a million kilograms of manure and 150,000 litres of urine being deposited on streets and in stables each day.

Will it Happen? Historic Cross Check

- NYC like many other cities at the time, had an enormous problem with horse waste, flies, congestion, carcasses and traffic accidents.
- In 1894, *The Times* estimated that by 1950 every street in London would be buried in nine feet of horse manure.
- Urban planners from around the world gathered in NYC in 1898 to resolve this problem. The conference was brought to an early end with no progress. The situation was dire.

Society eventually started to make remedial progress:

1890-1905

- New York's street sweeping service was established.
- Electric streetcars replaced the horse drawn omnibus as the primary mode of public transport.
- Smoother asphalt streets.
- William Phelps Eno invented the rules of the road to reduce the number of horse related traffic accidents.

Will it Happen? Historic Cross Check

Herald the motor vehicle

- In 1900, there were 4,192 cars sold in the US.
- By 1912, this number increased to 356,000. In the same year NYC traffic counts showed more cars than horses.
- Horsepower was not replaced at once, but function by function. Freight haulage was one of the last. Trucks finally replaced the horse and cart in the 1920s.

1900 Keystone Three-Seater Autocycle
Keystone Motor Co., Philadelphia, PA
1899-1900

History would suggest that society will accept the technological changes in order to address the current problems of transportation and the environment.

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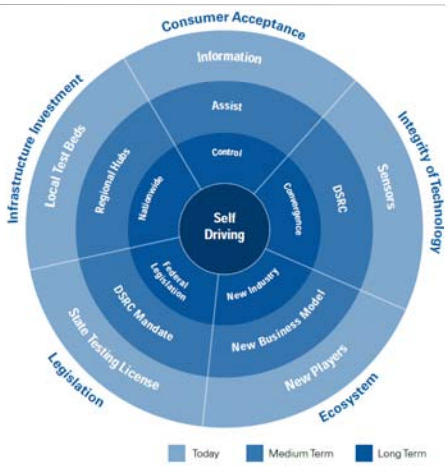
When?

- To realise a super intelligent transport system that can support SDV is complex and expensive.
- It will inevitably occur in phases based on need and economic return.
- At what point do we stop investing in the human driver transport ecosystem and start investing in the SDV ecosystem?
- The transition is going to be problematic and messy. Just like the transition from horse to motor vehicles.



From KPMG report on Self-driving cars: The next revolution

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When?

Official predictions

Major automobile manufacturers and technology companies have made numerous predictions for the development of SDVs.

2017-18

- The NHTSA hopes to mandate the adoption of V2V technology on all new automobiles.
- Volvo intends to launch a test fleet of autonomous models on Swedish roads.
- Google expects to release its autonomous car technology.

2020-2025

- Mercedes-Benz, Audi, Daimler, Nissan, Ford and BMW all expecting to be selling SDVs.

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When?

Forecasts

Expert members of the Institute of Electrical and Electronics Engineers (IEEE) have estimated that up to 75% of all vehicles will be autonomous by 2040.

ABI Research forecasts that SDVs would become a reality by 2020 and that 10 million such new cars would be rolling out on to United States' public highways every year by 2032.

Ford's global executive chairman, Bill Ford, great grandson of the company's founder Henry Ford, told a science conference in Barcelona in February 2014 that the fully self-driving car could be a reality by 2025 – just 11 years away.

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When?

When and how remains the open question.

I think it is directly proportional to the amount of pain the status quo is having on our social and economic well being.

Hopefully there will be SDVs in 25-30 years. By then I will not be safe to drive but will still want my mobility.

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America's Power Companies' advertisement from 1956, featuring futuristic self-driving cars

One day your car may speed along an electric super-highway, its speed and steering automatically controlled by electronic devices embedded in the road.

Highways will be made safe – by electricity!

No traffic jams ... no collisions ... no driver fatigue.

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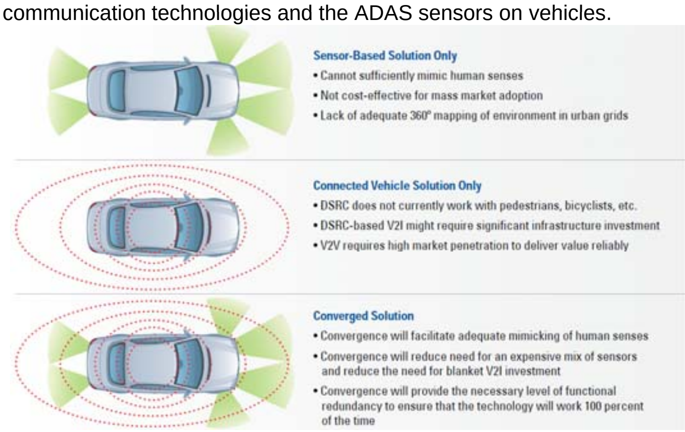
Enabling Technologies

Self Driving Vehicles (SDV)

To achieve Class 3 or 4 level of autonomy, convergence will be required of the V2V/V2I communication technologies and the ADAS sensors on vehicles.



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