Intelligent Transportation Engineering: What is Needed?

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Introduction

Rapidly growing interest in solving transport problems using innovative technology:

- advanced (e.g. real-time) traffic management;
- advanced vehicles (e.g. autonomous vehicles or AVs).

In late 1800s, horse manure was the main transport problem in large cities around the world:

- estimated depth on London streets in 50 years was 2.75 m.

Safety also a problem (53 road deaths per 10^6 inhabitants):

- now only about 28 road deaths per 10^6 inhabitants.

Introduction

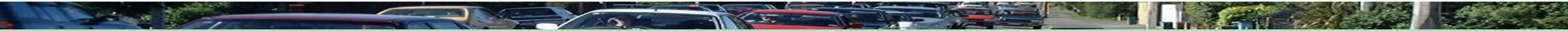
While road safety has improved greatly, one environmental problem has been replaced by others (e.g. GHG emissions).

- in NZ, 2016 transport GHG emissions (CO_2-e) 78% higher than 1990 (c.f. animal digestion emissions only 5% higher).

Intelligent transportation engineering involves solving existing problems without creating future problems:

- will simply adopting the latest ITS technology (especially AVs) meet this criterion?

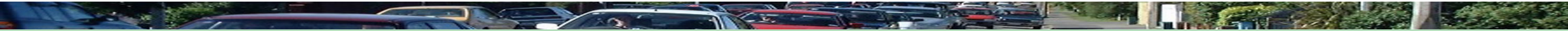
Intelligent Transportation Engineering



Intelligent transportation engineering involves:

- defining appropriate objective(s);
- identifying options with potential for achieving the objective(s);
- appraising those options thoroughly (including anticipating future problems);
- selecting & implementing the best option;
- recognising uncertainty & potential for ‘optimism bias’ in appraisal, & evaluating the implemented option.

NZ Transport Strategy (2008)



Vision: "an affordable, integrated, safe, responsive & sustainable transport system" (for people & freight).

Key objectives:

- ensuring environmental sustainability;
- assisting economic development;
- assisting safety & personal security;
- improving access & mobility;
- protecting & promoting public health.

My presentation will focus on sustainability, safety, affordability (plus legal & ethical issues) associated with AVs.

SAE Levels of Automation (I)

AVs can assist/undertake the dynamic driving task (DDT):

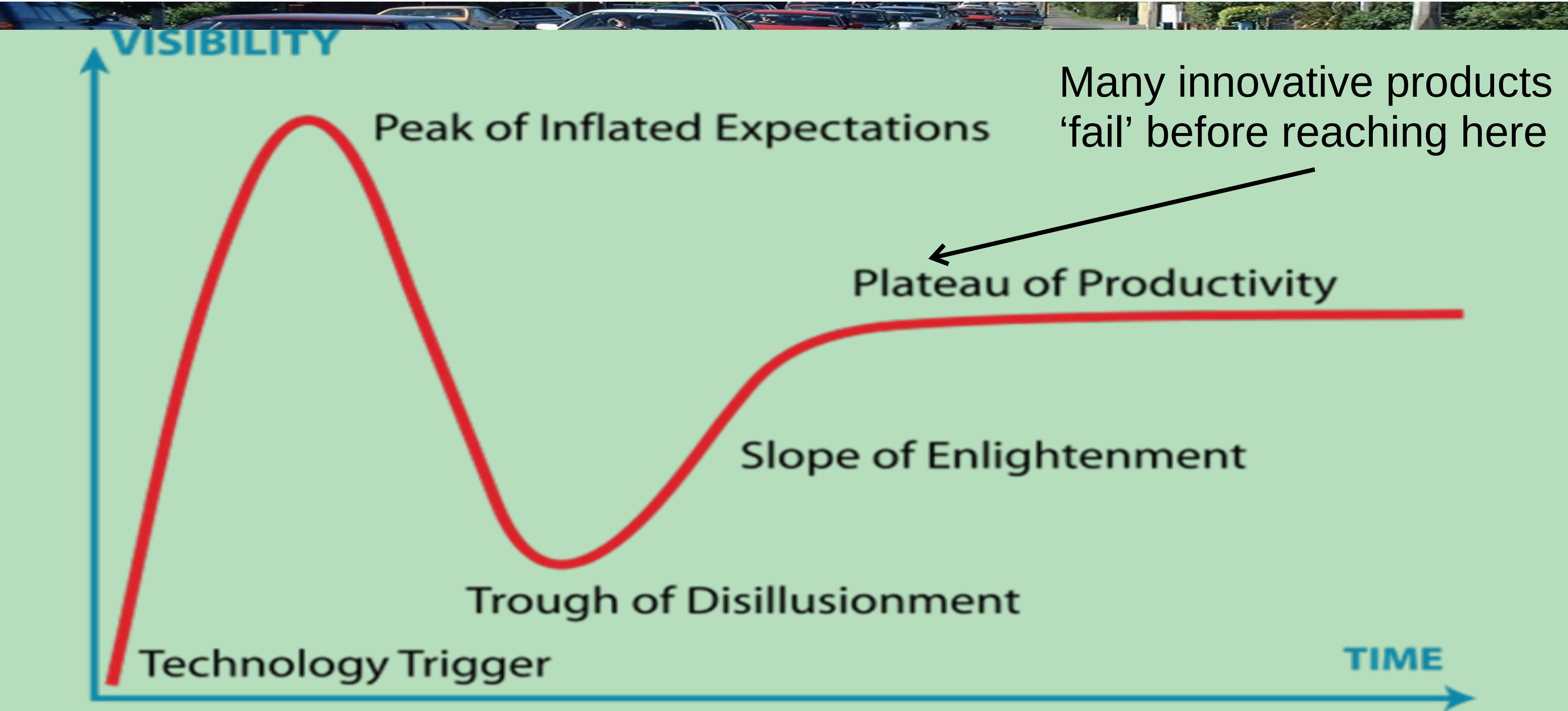
- operational tasks (e.g. steering, braking, roadway monitoring);
- tactical tasks (e.g. decisions on when to change lanes, turn).

A request to intervene (RTI) ~ automated driving system (ADS) requests human driver to begin or resume doing the DDT.

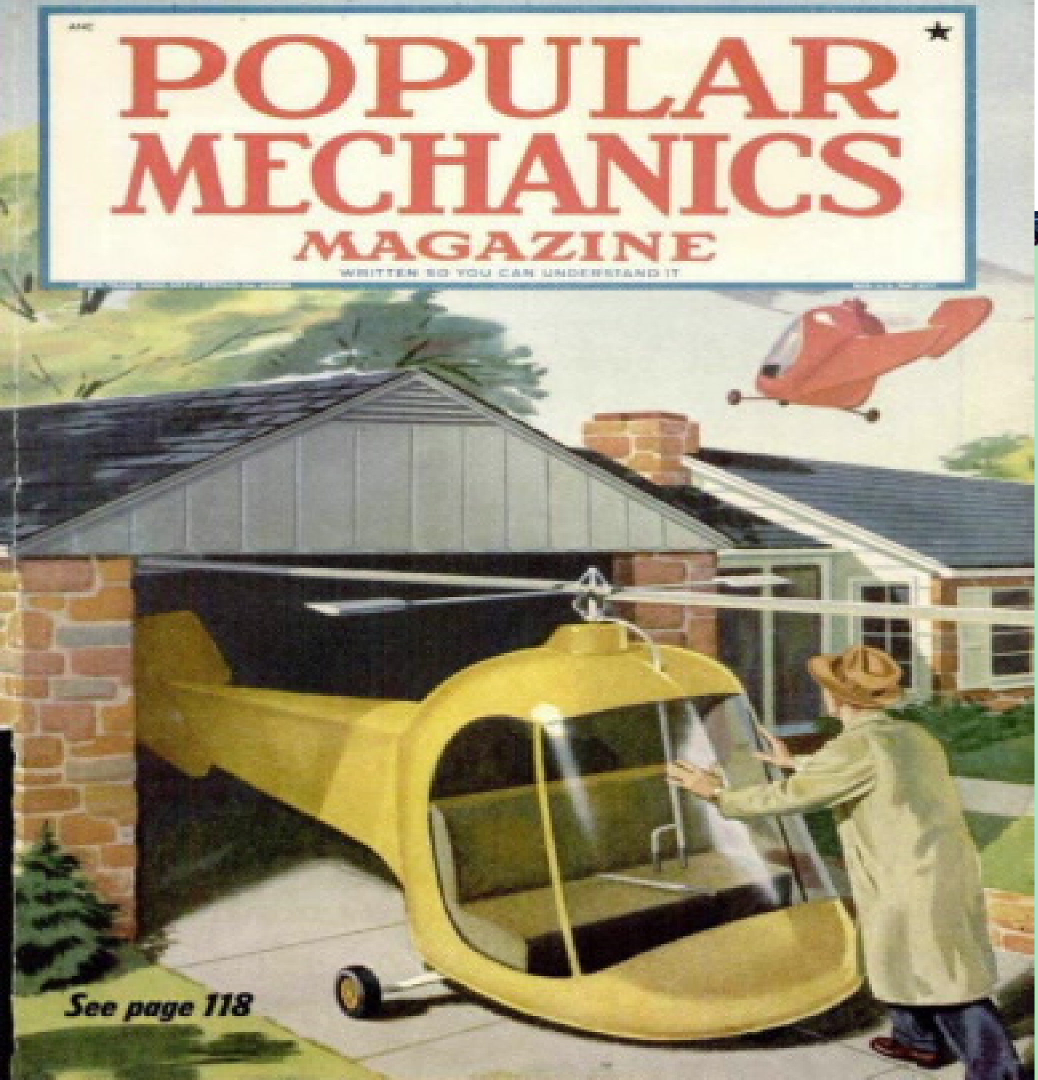
The SAE defined six levels of automation:

- Level 0: no automation;
- Levels 1– 4: ADS can issue RTI if unable to cope with DDT;
- Level 5: no RTI issued (ADS can always cope with DDT).

Gartner Hype Cycle



‘Cyclomer’ amphibious bicycle (1932)



Helicopter Coupe (1951)

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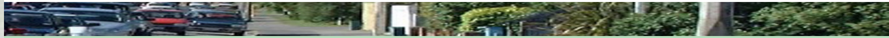
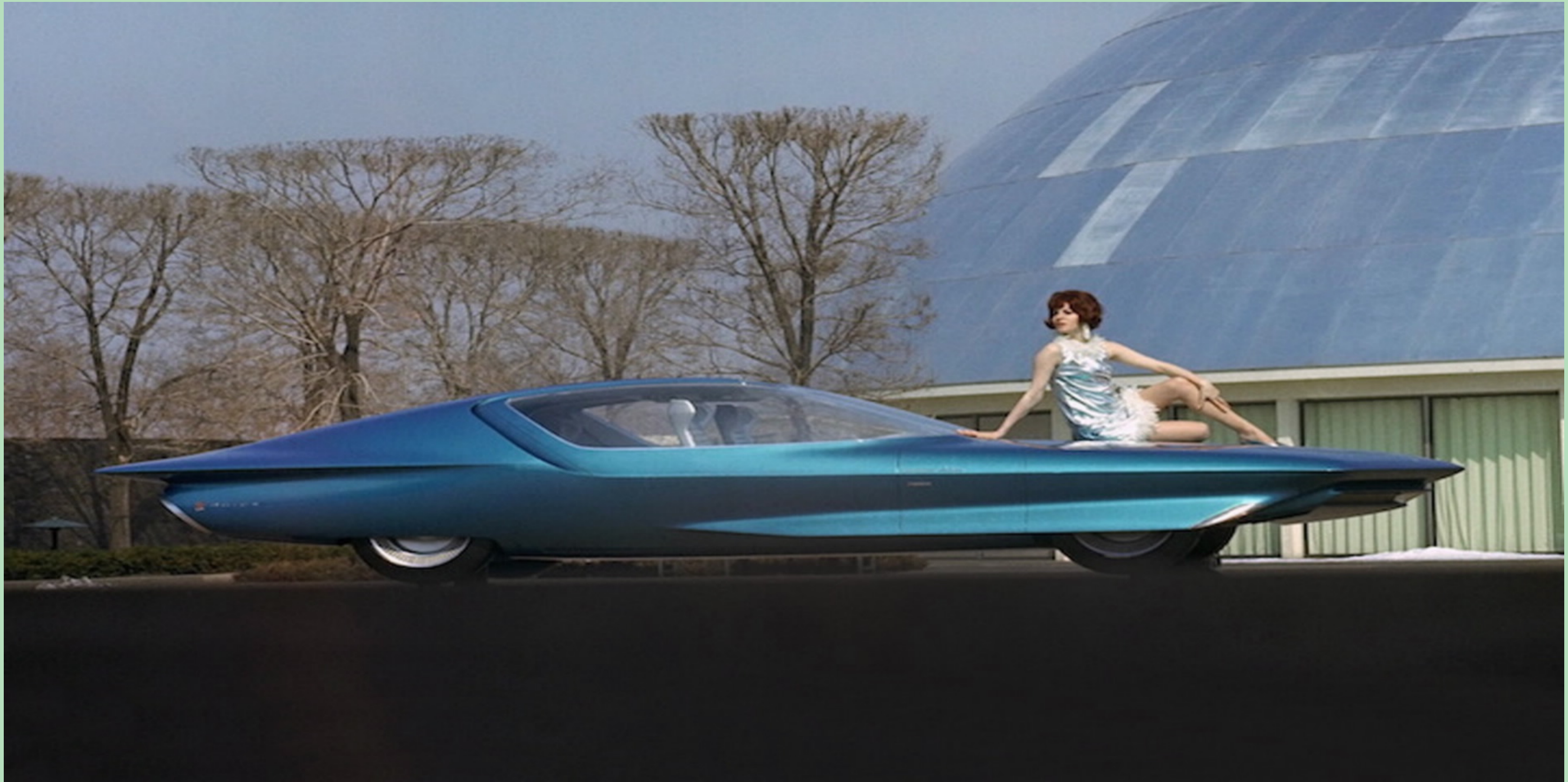


"Do you want helicopter that's small enough to land on your lawn and big enough to carry two people? A simple, practical, foolproof machine? It's in production." Clearly suggests helicopter coupe a viable alternative to automobile.

Amphicar amphibious automobile (1961)

GM Firebird IV (1964)



Tilting Cars (c.1995)

Driver feels more comfortable travelling faster (less body sway):

- but no increase in friction preventing vehicle from sliding off the curve (basic mechanics).

A classic example of ignoring ‘human factors’.

Gibbs Aquada (2004)

Elevated Bus (2016)

Uber Flying Car (2016)

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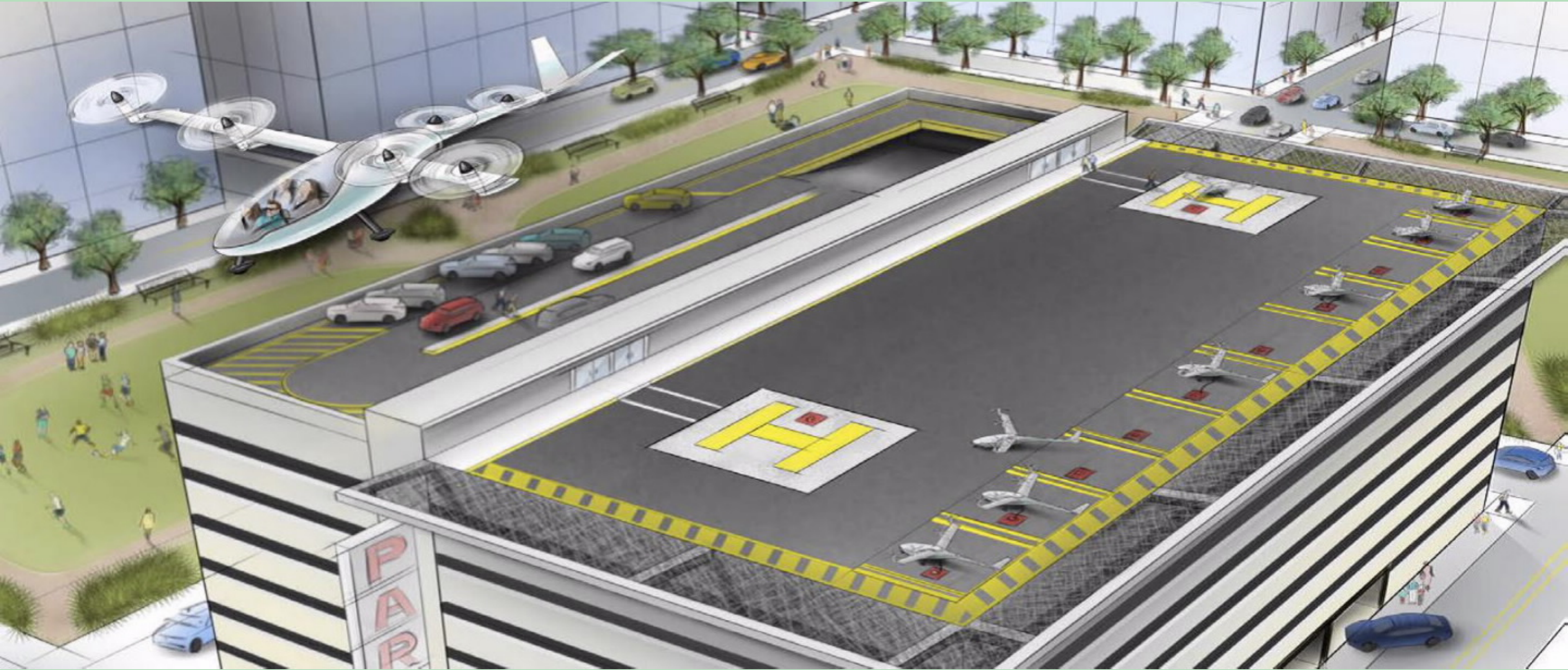
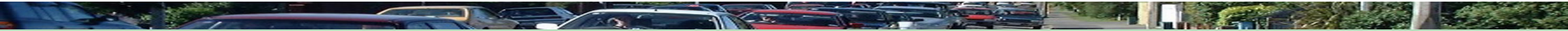


In-vehicle Speed Adaptation (ISA)



ISA technology developed in early 1990s, to improve road safety by preventing inadvertently exceeding the speed limit:

- trials in some countries (e.g. Sweden & Netherlands).

Lund trial found injury & fatal crash reductions of up to 25% & 32% respectively, based on observed changes in speed:

- clear case for implementing ISA, but vehicle makers not interested.

NB: Alcohol & seat-belt ‘interlocks’ have been available for over 20 years, but have not been widely adopted.

Automated Highway System

University of California (Berkeley) researchers in mid-1997, demonstrated a stream of cars (with V2V communication & radar sensors) travelling along a freeway lane at 96 km/h while 6.4 m apart;

- capacity c.4400 cars/hour/lane (i.e. a doubling);

NB: 112 km/h at 3.7 m spacing also achieved.

Funding for the research was terminated in late 1997:

- US DoT wanted to “focus on safety studies & technology with potential for near-term deployment”.

PATH: Automated Highway System

AVs & Link Traffic Flow Stability

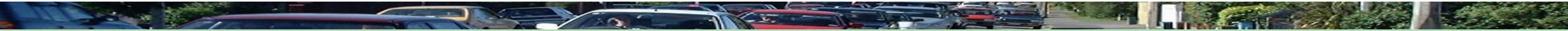
As traffic density increases, link flow becomes less stable:

- one recent study found flow stability improves as the proportion of connected (V2V & V2I) AVs increases;
- another recent study found flow stability is much better in dense traffic with only 5% of non-connected AVs.

Most studies of the effect of AVs has been on link capacity, but network capacity is generally governed by node capacity:

- must consider junction performance with AVs.

AVs & Network Capacity



AV occupants likely to expect lower acceleration rates than car drivers, so can do ‘other tasks’:

- lower acceleration rates mean larger critical gaps & follow-on headways (i.e. lower capacity & higher delays);
- microsimulation study (using acceleration rates appropriate for rail) found signalized junction delay greater for AVs than for driver-controlled vehicles.

Network capacity is very likely to reduce with AVs.

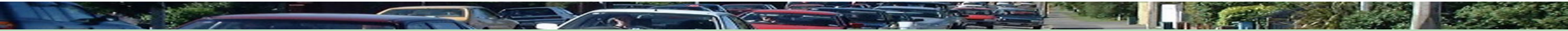
AVs & Amount of Travel

Studies of effect of AVs on veh-km of travel have produced widely varying estimates, e.g.

- 10% to 20% increase (per AV) ~ induced demand;
- 35% decrease to 20% increase (overall) ~ induced demand;
- 14% to 40% increase (overall) ~ more travel by youth, disabled, elderly.

Effect on veh-km (& GHG emissions) very uncertain.

Shared Autonomous Vehicles



OECD study assessed the impact of large-scale uptake of shared AVs in Lisbon:

- 2.8×10^6 inhabitants spread over 3000 km^2;
- 0.217 cars/person;
- 5 million person-trips/day:

  60% by car 14% by bus 11% by rail 8% by bus+rail 4% by car+rail 4% other

- assumed no change in number, distribution or timing of trips.

Shared Autonomous Vehicles

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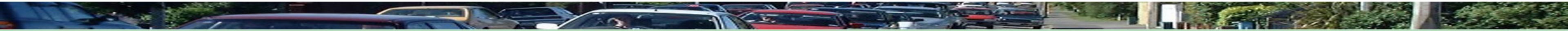
OECD study considered two options:

- AVs shared sequentially by single passengers (‘AutoVots’)
  - i.e. car sharing;
- AVs shared simultaneously by several passengers (‘TaxiBots’)
  - i.e. car & ride sharing.

AutoVots & TaxiBots assumed to replace all car & bus trips.

Shared Autonomous Vehicles



OECD study results indicated:

- 77%-90% decrease in required number of cars
- 33%-65% decrease in peak flow rates
  - bigger decreases if have rail service
- 6%-22% increase in veh-km of travel for TaxiBots
- 44%-89% increase in veh-km of travel for AutoVots
  - smaller increases if have rail service
- impacts generally better for TaxiBots than AutoVots

Shared Autonomous Vehicles

OECD study assumed no change in number & length of trips:

- much evidence that people make more &/or longer trips as cost (time plus vehicle operating cost) decreases.

Australian study concluded AVs will result in longer trip distances, higher veh-km & urban sprawl:

- due to lower value of travel time (more scope for other activities while travelling) & higher trip speeds;

NB: AVs likely to result in increased transport GHG emissions.

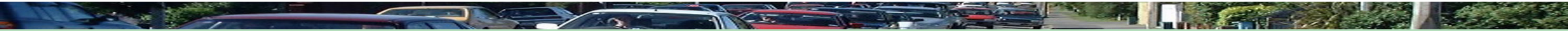
Demand for Autonomous Vehicles

Demand for AVs depends upon their affordability.

The results of willingness-to-pay (WTP) studies have found:

- average WTP is c.20% more than non-AV;
- 20%-30% of people willing to pay no more than for non-AV;
- c.5% of people willing to pay lot more;
- WTP higher for males than females;
- WTP increases with income & distance driven;
- WTP decreases with age.

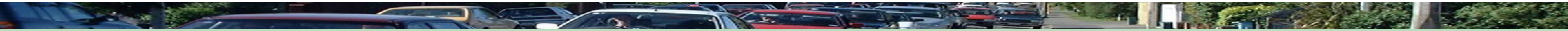
Demand for Autonomous Vehicles



- private AV & shared AV similarly attractive for people with ‘pro-AV attitude’;
- people who ‘enjoy driving’ strongly prefer private non-AV;
- people ‘concerned for environment’ strongly prefer shared-AV;
- main attraction of AVs is greater safety & lower travel times;
- main areas of concern are security (software hacking/misuse), plus legal issues & reduced safety.

Demand for AVs is very uncertain.

Autonomous Vehicle Safety



Advocates of AVs suggest crashes will be reduced by c.90% (i.e. the proportion of crashes involving driver factors):

- road environment factors & vehicle factors are typically involved in c.30% and c.10% respectively);
- eliminating driver ‘error’ will not reduce crashes by 90%.

Will AV’s recognise & cope with road environment deficiencies?

- warning signs inappropriate or too close to the hazard?
- variations in skid resistance of road surface?
- worn pavement markings?

Autonomous Vehicle Safety

Human factors researchers very concerned about the transition of control after ADS issues an RTI:

- needed unless ADS can master all possible traffic situations & weather conditions & will never fail;
- if planned (e.g. driver takes control when leaving motorway), driver actions initially slow & error-prone;
- if acute (i.e. driver takes control when ADS fails), driver lacks situation awareness & probably unable to avoid crash.

Autonomous Vehicle Safety

Study of Google AV safety (based on 1.3 x 10^6 veh-miles on-road use) found crash rate c.40% higher than USA mean.

Another study found that if the true fatality rate for AVs is 20% lower than that for human drivers, then need 5 x 10^9 veh-miles for statistical significance (95% confidence):

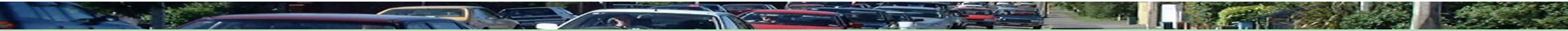
- 100 AVs, driven 24 hours/day for 365 days/year at 25 miles/hour for 225 years;
- impossible to show AV safety significantly better than human driver safety prior to releasing AVs for general use.

Legal Liability

Extract from advert for flier for International Driverless Vehicle Summit in Adelaide (16-17 November 2017):

"Driverless vehicle technologies promise fewer vehicle crashes and less insurance claims. But who is to blame when things go wrong in a driverless vehicle? This is just one of the controversial issues that will be explored during the Insurance and Liability panel session …"

Legal Liability



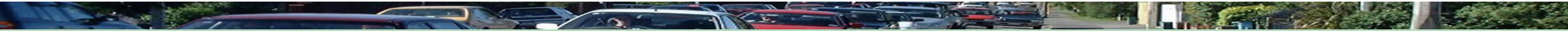
When AV crash occurs, apportioning liability (between driver, AV maker & road authority) will be very difficult.

Two types of liability:

- civil liability for loss/harm due to malfunction arising from breach of duty of care;
- criminal liability for loss/harm due to intentional act.

Might get insurance for first but not the second.

Legal Liability



Strict liability ~ liability imposed on AV supplier without any finding of intent or failure of duty of care:

- some AV suppliers have said they will accept this if AV in ‘autonomous mode’ (i.e. no driver intervention);
- is it reasonable to expect drivers not to intervene if a crash seems imminent?
- will AV suppliers accept strict liability if/when large damages awards are made by Courts?

Uber AV Red-Light Violation (I)

Uber AV Red-Light Violation (II)

Uber AV Red-Light Violation (III)

Ethical Issues

There are ethical issues to be considered:

- is it ethical to sell (or use) AVs if AVs less safe?
- is it ethical to drive non-AVs if AVs more safe?
- is it ethical to force very good drivers to use AVs if less safe for them? (i.e. need to balance lower safety for very good drivers against higher safety for poor drivers).

Imagine a car proceeding along a road with pedestrians on the footpaths alongside, when one pedestrian suddenly steps onto the road & into the path of the car.

Ethical Issues

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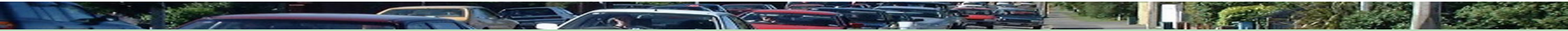


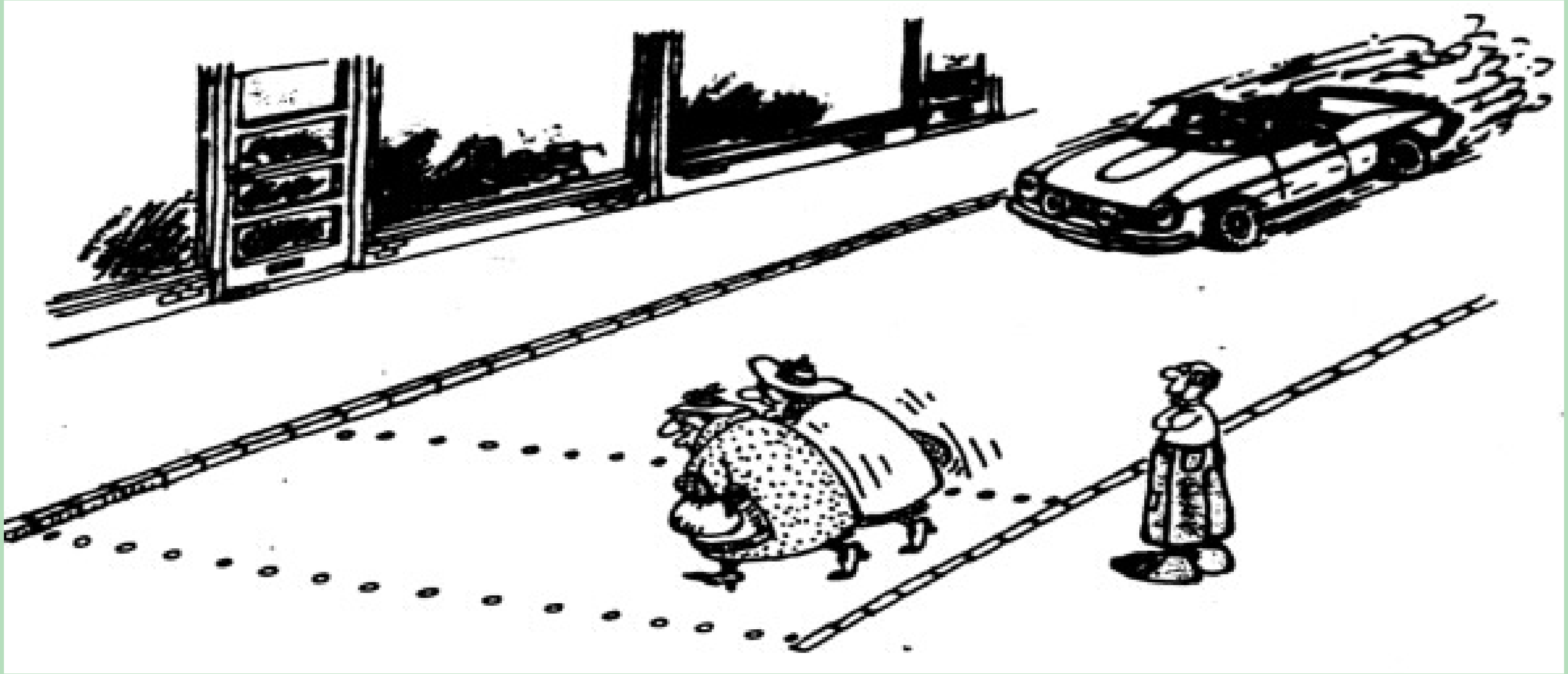
Assuming the pedestrian stepping onto the road is detected, who should make the choice between:

- braking without swerving & killing/maiming that pedestrian;
- swerving & killing/maiming other pedestrians;
- swerving & hitting a pole & injuring car occupants?

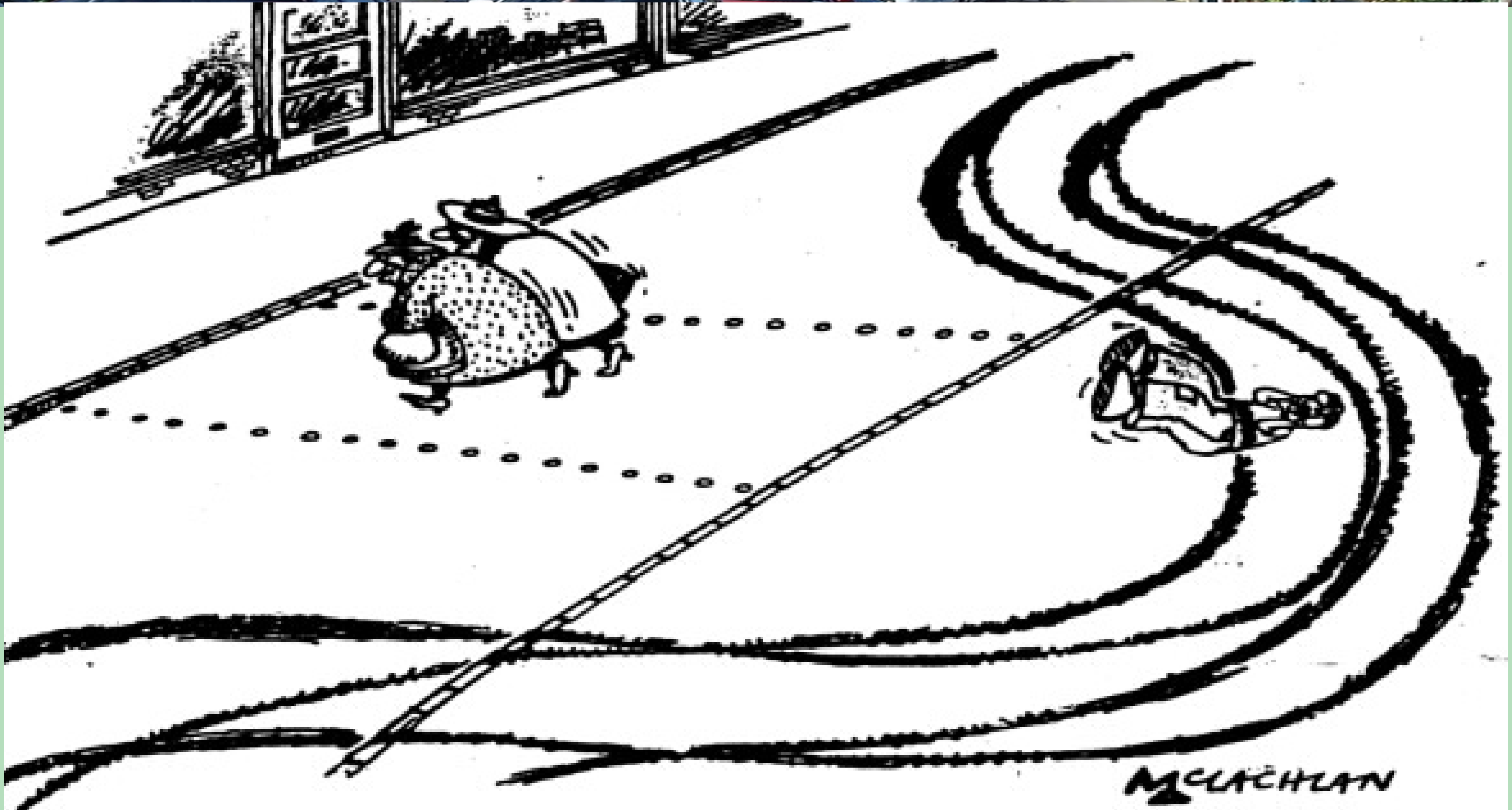
Should it be a human driver, who can assess the particular situation & merits of the options?

Should it made a programmer producing AV software?

Ethical Issues



Ethical Issues



“Secret flying car tested in Canty”

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The Press, 14 March 2018

CAA Deputy Director said 2015 Rule provided a “sound basis” for operating unmanned aerial vehicles but there are "significant" regulatory challenges relating to:

- sharing of airspace;
- how the rules would work when vehicle is out of sight of those overseeing it from the ground.

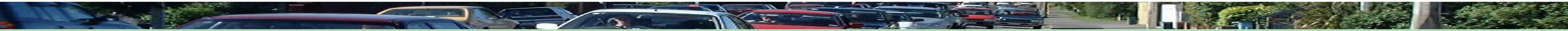
The Role of Hi-Tech Options

"It comes as no particular surprise to discover that a scientist formulates problems in a way which requires for their solution just those techniques in which he himself is especially skilled."

- A. Kaplan (1964). *The Conduct of Inquiry: Methodology for Behavioral Science. Chandler Publishing Co., San Francisco, USA.*

Does this explain the promotion of AVs as the solution for current transport problems?

Conclusion



Intelligent transportation engineering requires a more discerning approach, recognising the hype & vested interests associated with high-technology options (e.g. AVs);

Decisions should be based on evidence & not ideology.

Good low-technology options for achieving some objectives (e.g. improving traffic safety) should be implemented ~ don’t wait for development of high-technology options.

Transportation engineers should be pro-active in setting objectives & specifying what is needed to achieve them ~ we should not be passive recipients of new technology.