



# Taking a systems approach to car lightweighting

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## *Outline*

- Linear cause-and-effect
- Accumulation
- Feedback
- Conclusion



## *Linear cause-and-effect*

- Common assumptions:
  - Cause-and-effect occur close in time
  - Scalability is linear
  
- e.g. Life Cycle Assessment
  - ‘Functional units’ are compared
  - ‘Functional units’ can be scaled



## *Linear cause-and-effect*

- Sometimes:
  - Cause-and-effect are non-linear
  - Therefore, scalability is non-linear
  
- Because of:
  - Accumulation
  - Feedback



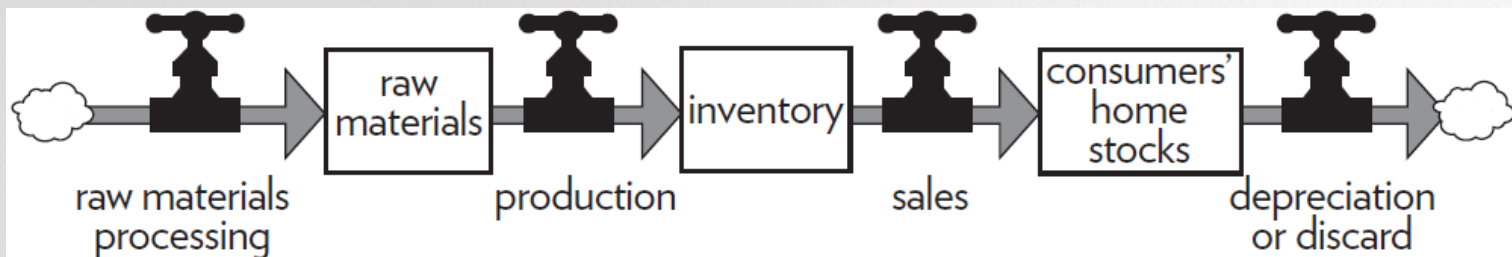
# Accumulation

- Filling and draining a stock



(Meadows 2009, p97)

- Finite rates
- Delay
- Inertia



(Meadows 2009, p96)



## *Accumulation*

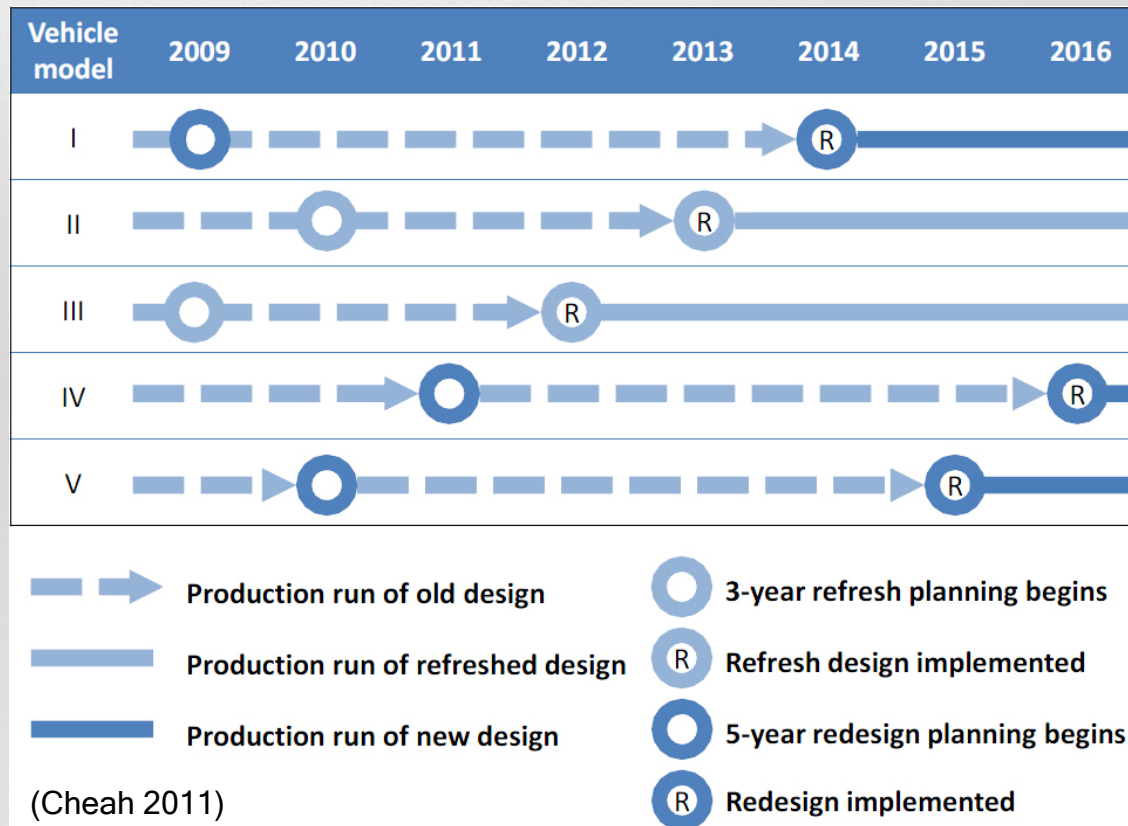
### **Development and production**

- Refresh cycle (2-3 years)
  - No lightweighting changes
- Redesign cycle (2.5-5 years):
  - Major lightweighting changes
  - Major design parameters set, 6-12 months
- Production (4-5 years)



# Accumulation

## Development and production





## *Accumulation*

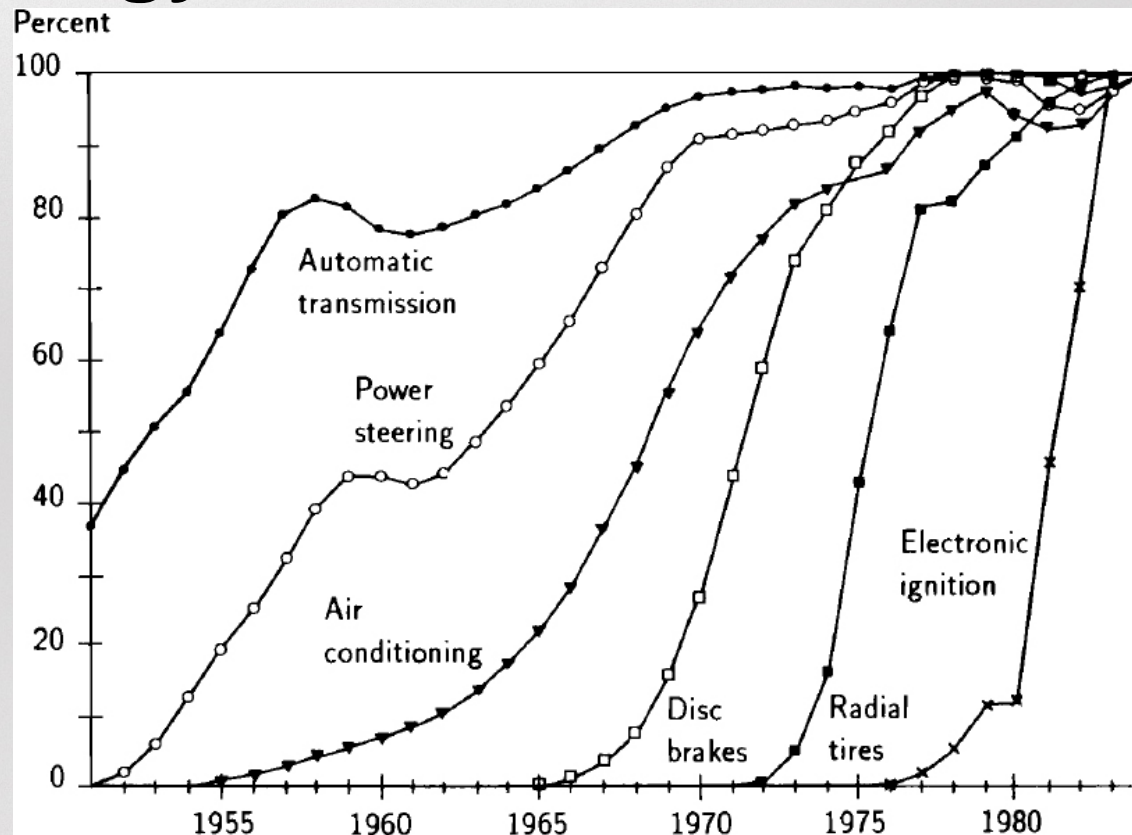
### **Technology diffusion**

- Order of years to decades
- S-shaped
- Cost effective technologies usually diffuse faster and wider
- Costly and complex technologies usually diffuse slower



# Accumulation

## Technology diffusion



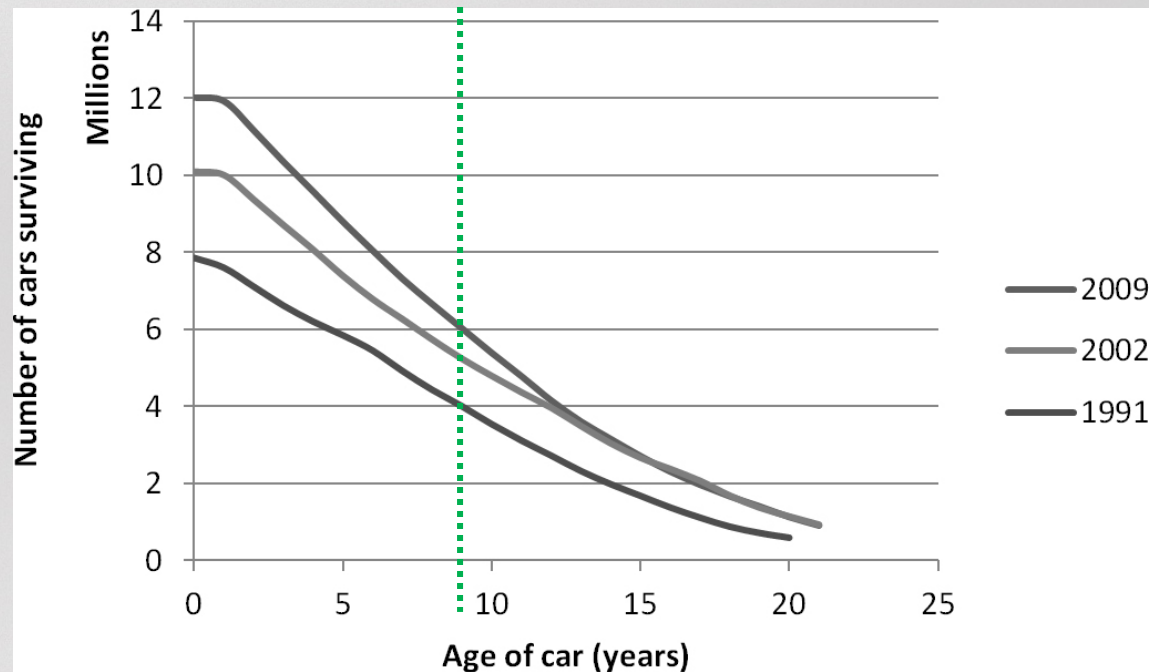
(Jutila and Jutila 1986 cited in Grüber 1991)



# Accumulation

## Fleet turnover

- 50% still in use after 9 years



(adapted from ABS cited in Australian Automotive Intelligence 2010, p 44)



## *Accumulation*

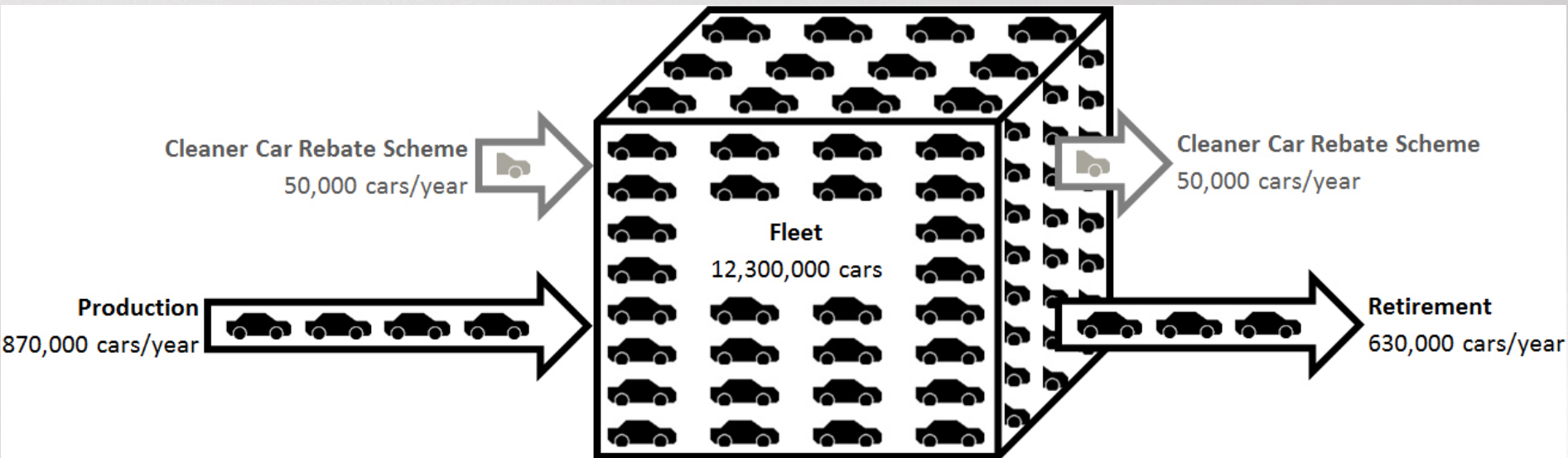
### **Fleet turnover: Cleaner Car Rebate**

- 2011 to 2014
- Scrap pre-1995 car
- \$2000 rebate towards a new car (emissions similar to the fleet average)
- About 200,000 rebates



# Accumulation

## Fleet turnover: Cleaner Car Rebate

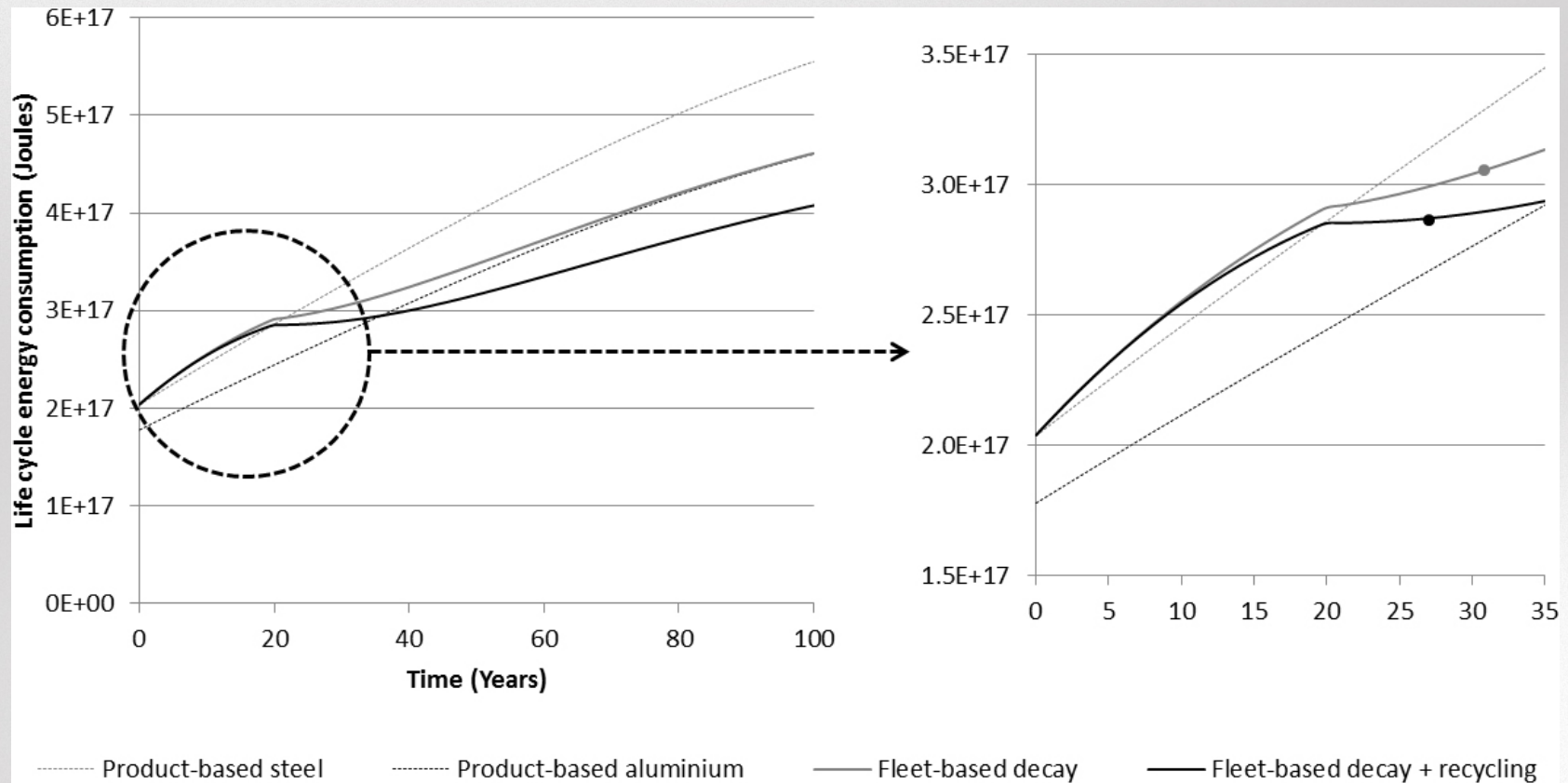


(adapted from Australian Bureau of Statistics 2011)



# Accumulation

## Fleet turnover: aluminium body-in-white

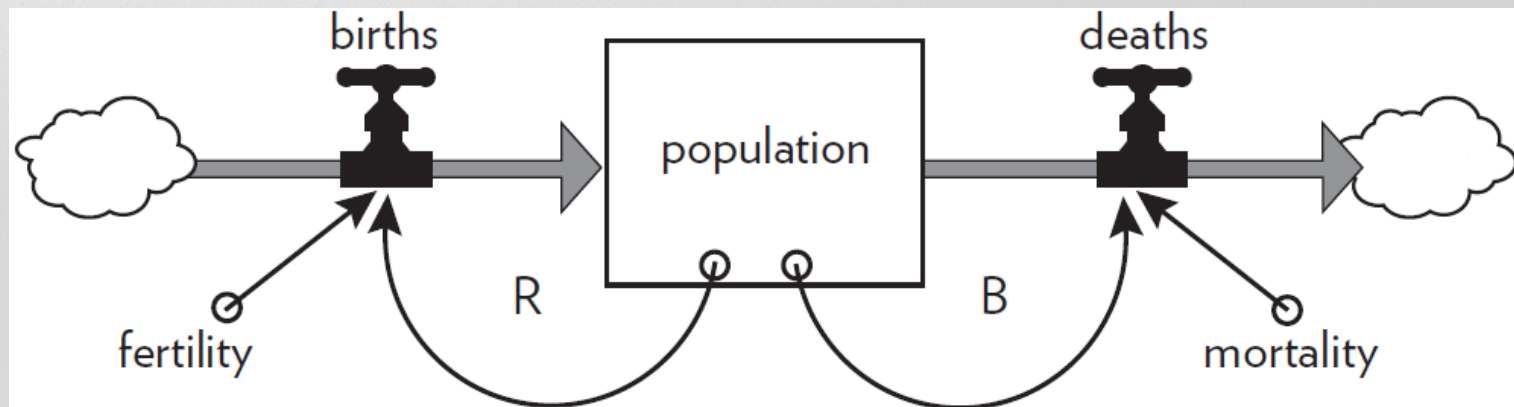


(Stasinopoulos et al. 2011)



# Feedback

- A change in a stock feeds back around a loop to adjust the original change



(Meadows 2009, p42)

- Reinforcing: amplifies change
- Balancing: resists change



## *Feedback*

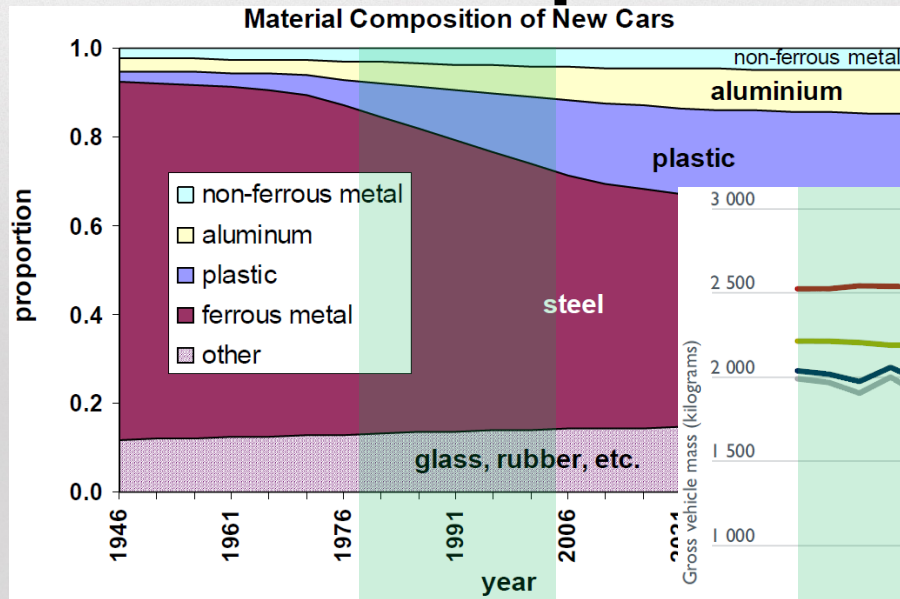
### **Material composition (balancing)**

- 1980 to 2003
- Steel decreased
- Plastic and aluminium increased
- But gross vehicle mass remained stable
  - More components
  - Heavier components
  - Better safety and comfort

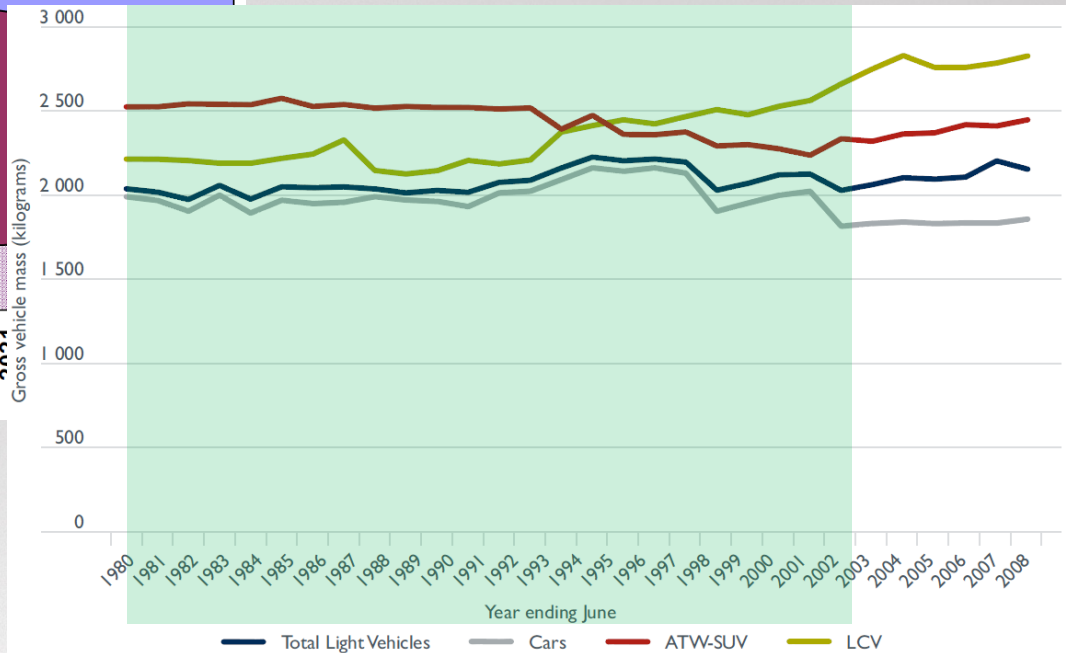


# Feedback

## Material composition (balancing)



(AGO 1999 cited in Dunlop et al. 2004, p 30)

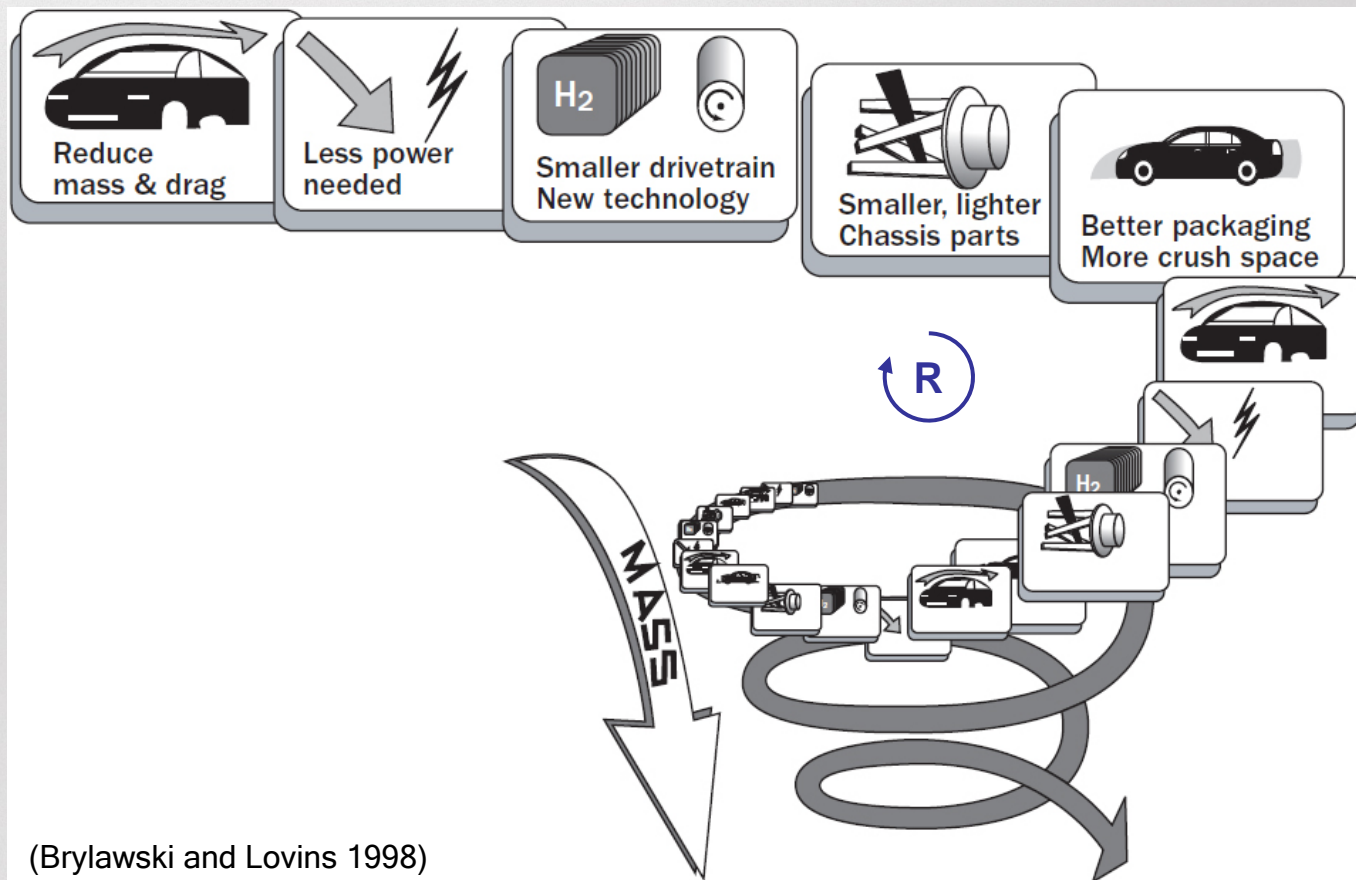


(Bureau of Infrastructure, Transport and Regional Economics, 2009)



# Feedback

## Mass decomponding (reinforcing)

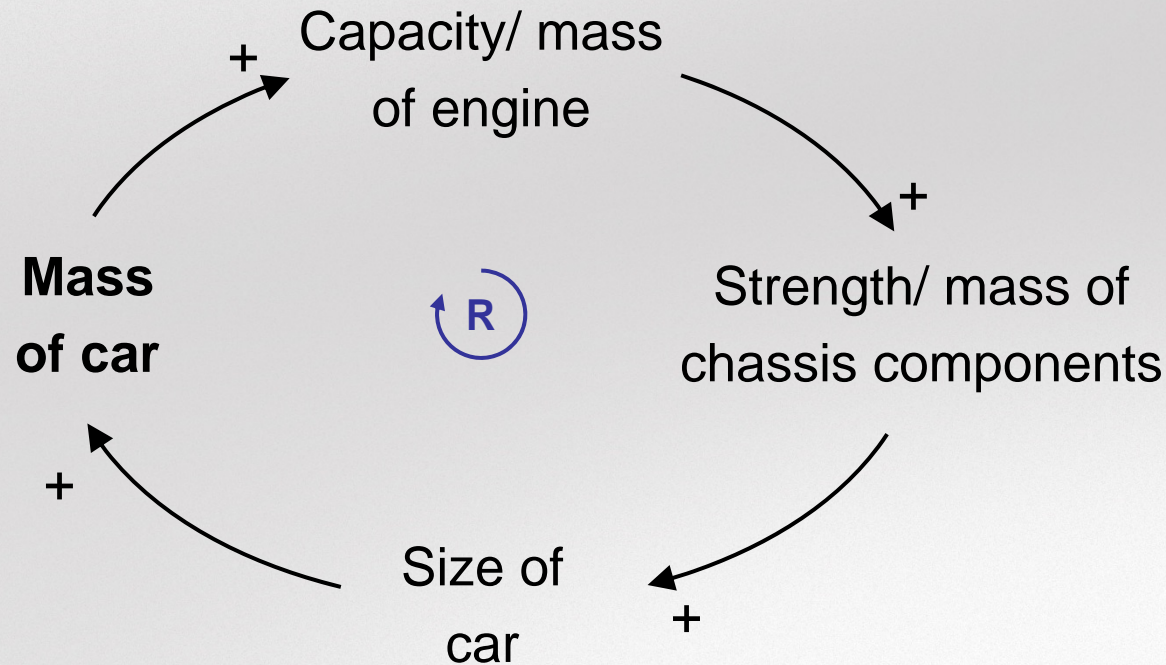


(Brylawski and Lovins 1998)



# Feedback

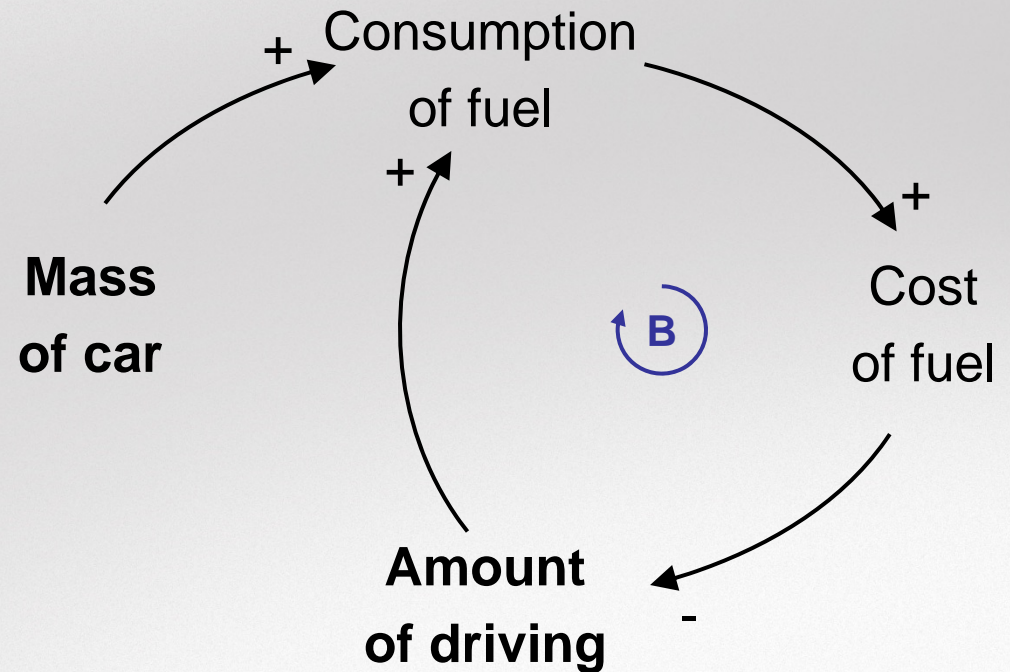
## Mass decomponing (reinforcing)





# Feedback

## Induced driving (balancing)





## *Feedback*

### **Occupant bodyweight (balancing)**

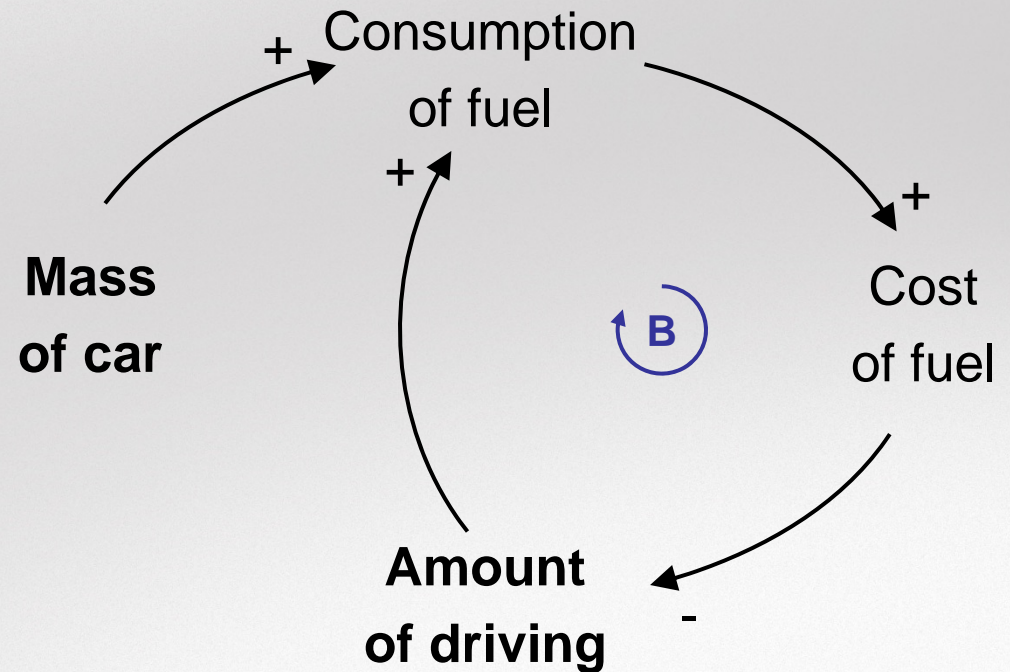
- US: excess bodyweight
  - 0.8% of transportation energy
- AU: trips to school/ work
  - 1970s-2010s
  - Increase by car, decrease by walking
- Increased driving increase risks of:
  - Overweight/obesity
  - Inadequate physical activity



# Feedback

## Occupant bodyweight (balancing)

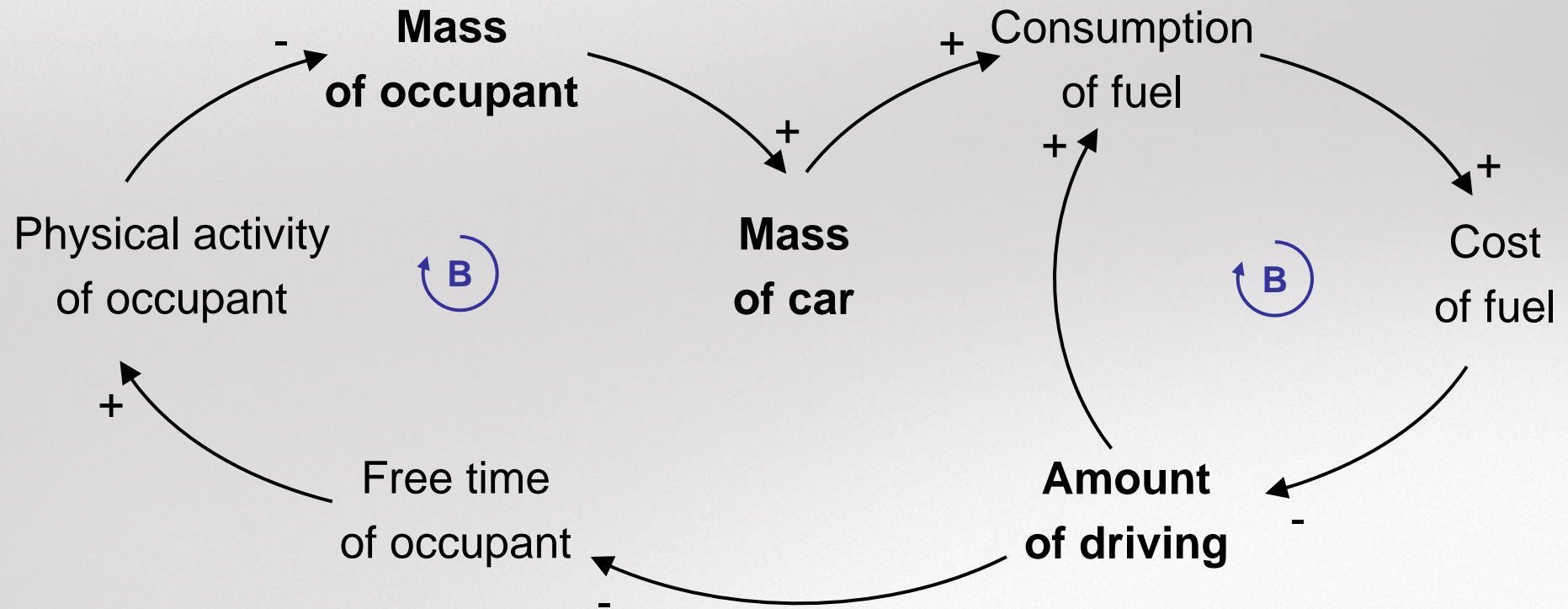
*(Induced driving)*





# Feedback

## Occupant bodyweight (balancing)





## *Feedback*

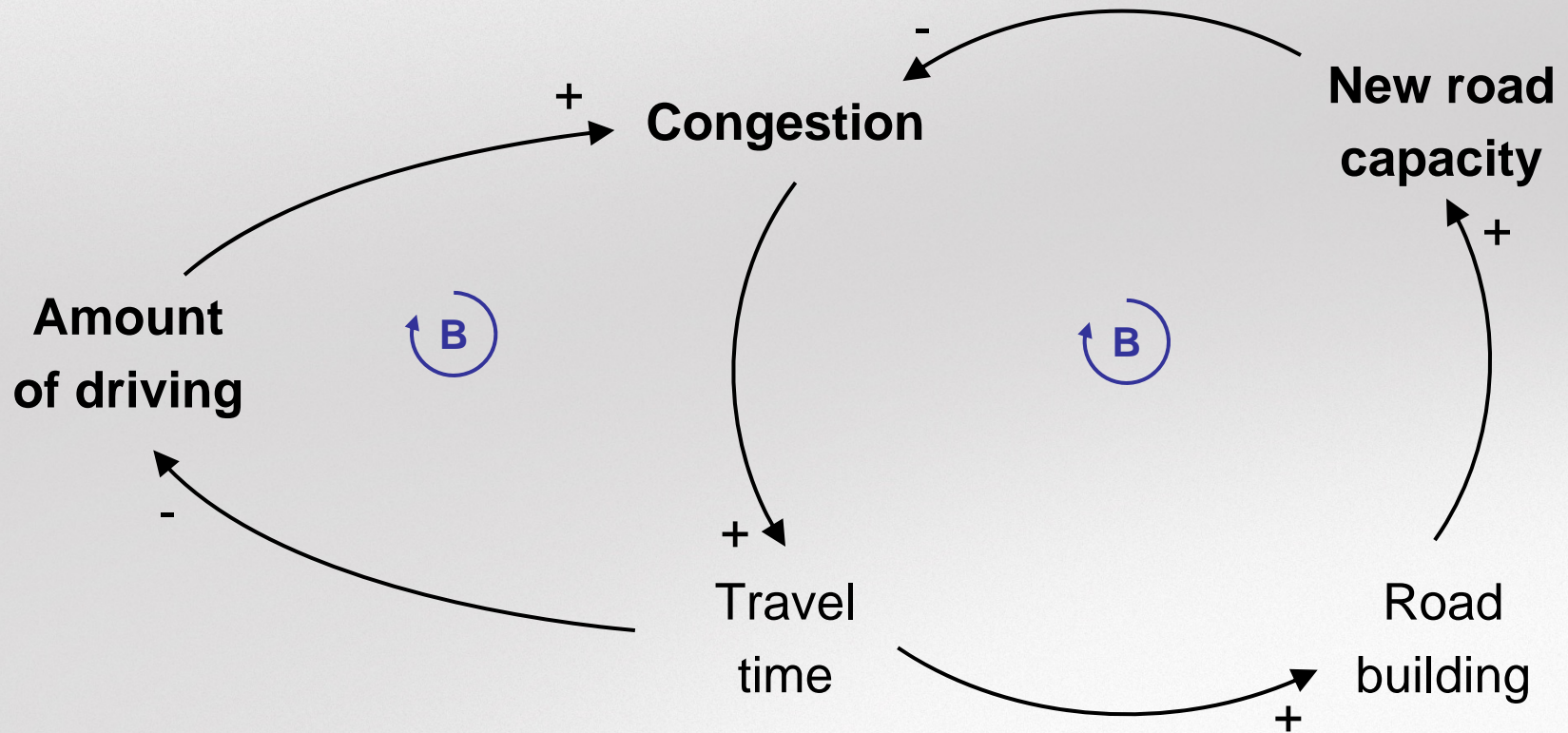
### **Induced traffic (balancing)**

- Congested urban areas, suppressed traffic
- Increased road capacity
  - Increased flow from new traffic
  - Not less congestion
  - Not increased speed
- 1 year: 10-60% of new traffic growth
- 3-10 years: 50-100% of new traffic growth



# Feedback

## Induced traffic (balancing)





## *Accumulation + Feedback*

### **Fleet turnover: fuel consumption**

- Accumulation

- Car fleet turnover

- Feedback

- Induced driving, induced traffic

- Improved car performance

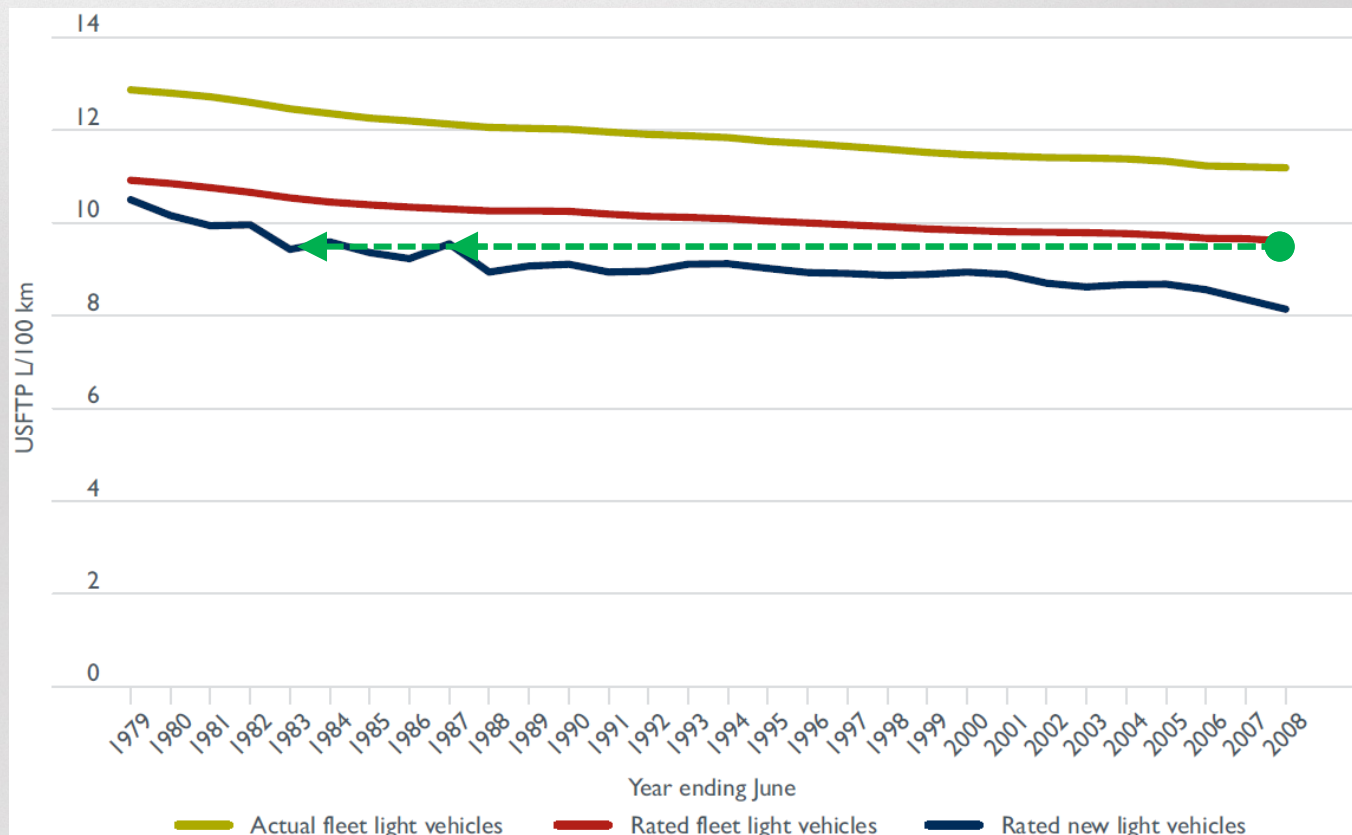
- > more aggressive acceleration and braking

- Net effect: 20-25 year delay



# Accumulation + Feedback

## Fleet turnover: fuel consumption



(Bureau of Infrastructure, Transport and Regional Economics 2009)



## *Conclusions*

- Many non-linear effects of lightweighting
- Linear analysis will have significant error
  - Long lifecycle, large quantity
- Accumulation
  - Large stocks/ long delays are significant
- Feedback
  - More balancing loops than reinforcing loops
- Accumulation + feedback simultaneously



Questions?