Sustainability and Safety in Tunnels

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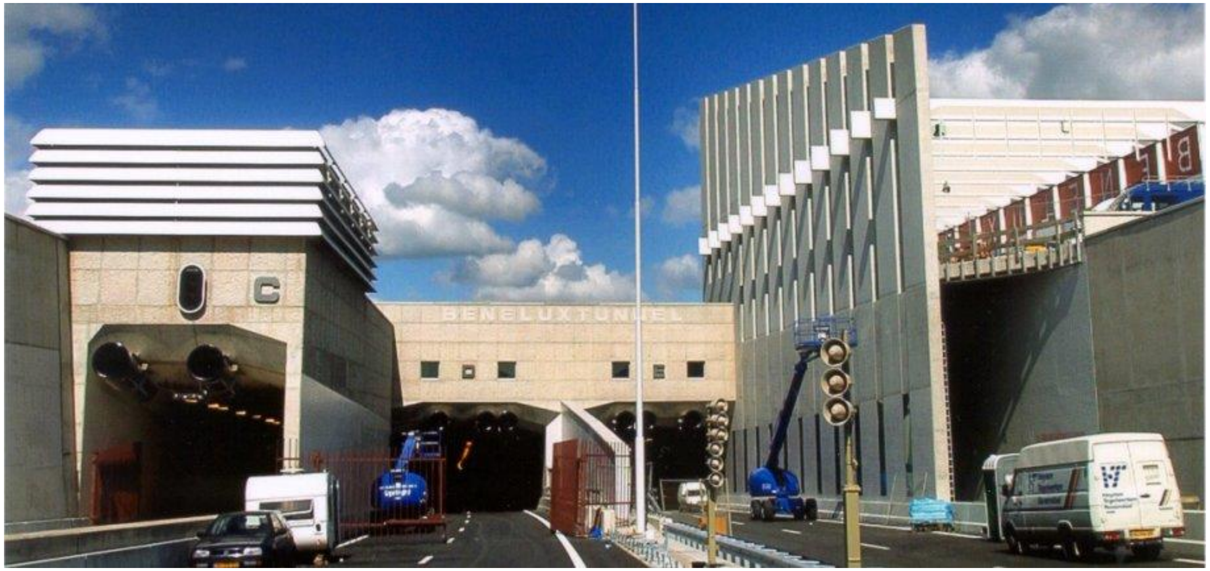

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Motivation

- Tunnel ventilation and lighting can consume substantial power, as well as requiring expensive structural space.
- Is this consistent with sustainability?

Agenda

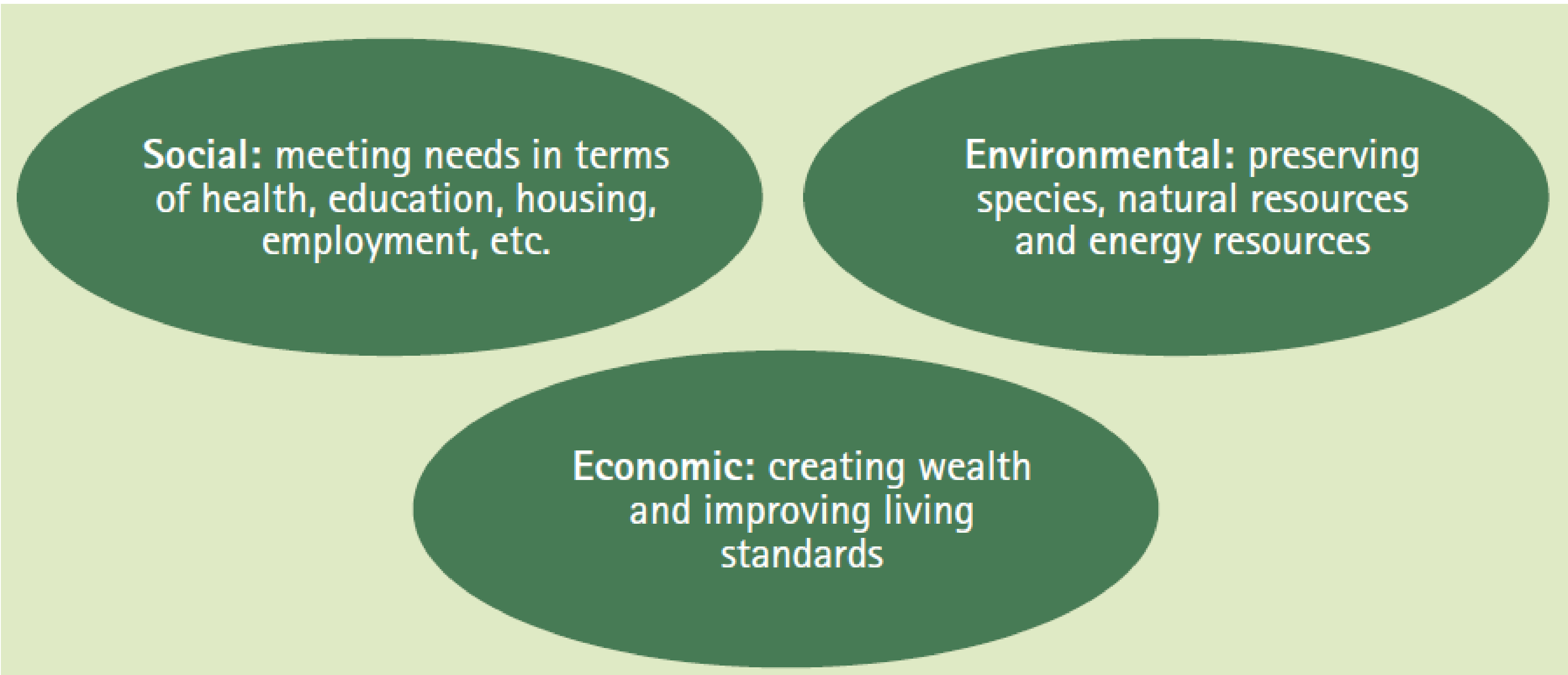
1. Sustainability concepts
2. Tunnel life cycle
3. Tunnel ventilation requirements
4. Tunnel lighting requirements
5. Technical innovations
6. Unnecessary installations
7. Future sustainability

1. Sustainability Concepts

Brundtland Report to UN, 1987

Sustainable development = "the kind of development that meets the needs of the present without compromising the ability of future generations to meet their own needs"

The Three Pillars of Sustainability



2. Tunnel life cycle

Tunnel Project Phases

Project phase	*Estimated impact*
Design / study (3-10 years)	60 – 80 per cent
Build / construction (2-3 years)	10 – 30 per cent
Operate / tunnel lifespan (5-20 years)	10 – 30 per cent

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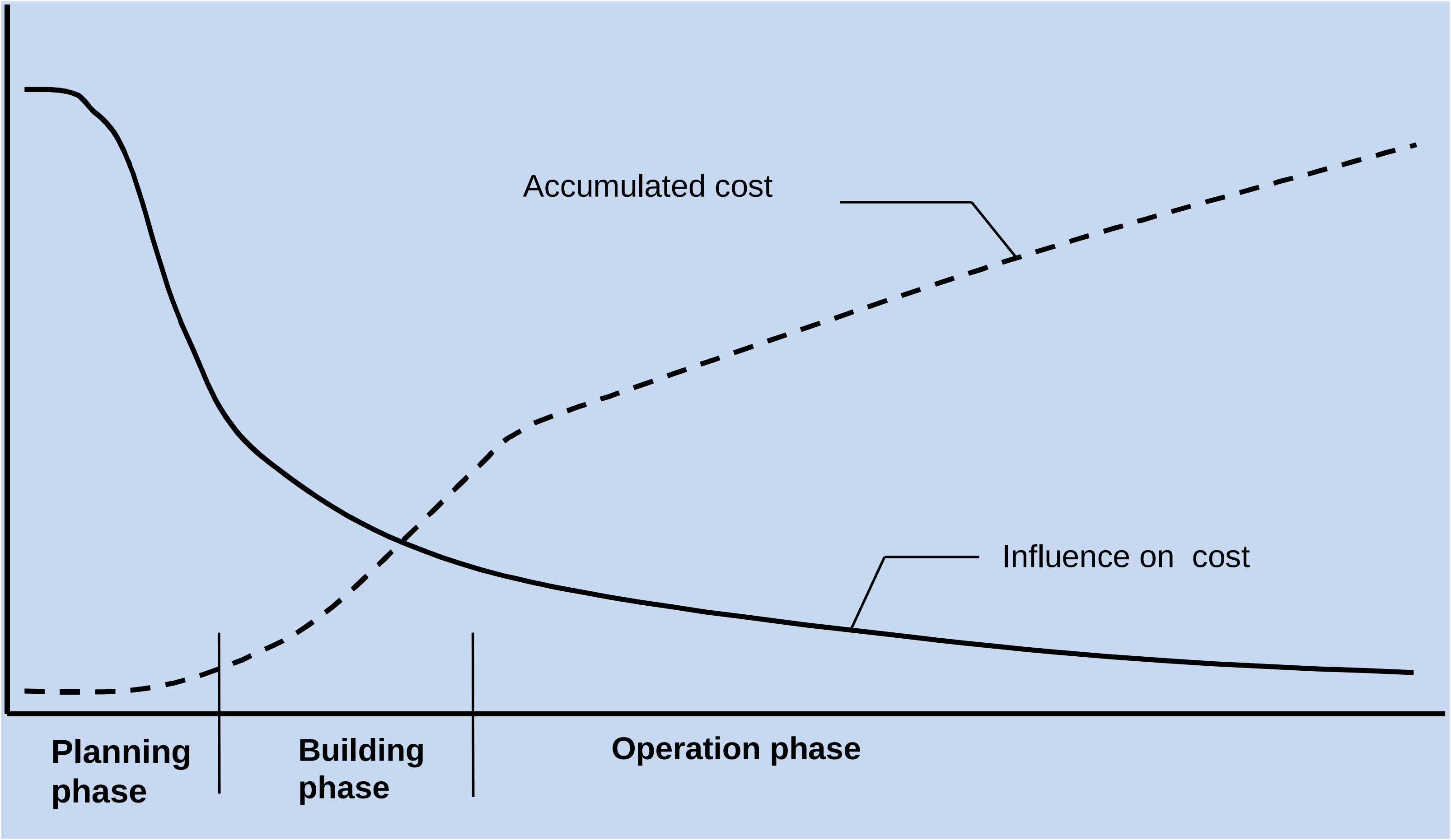
Tunnel Life-Cycle



3. Tunnel ventilation requirements

Is tunnel ventilation required?

- Short tunnels:
  - ≤ 500m (EU Directive on Road Tunnel Safety)
  - $<$ 300m (NFPA 502 road tunnels)
  - $<$ 300m (NFPA 130 rail tunnels)
- Natural air movements due to meteorological effects
- Piston effect of moving traffic

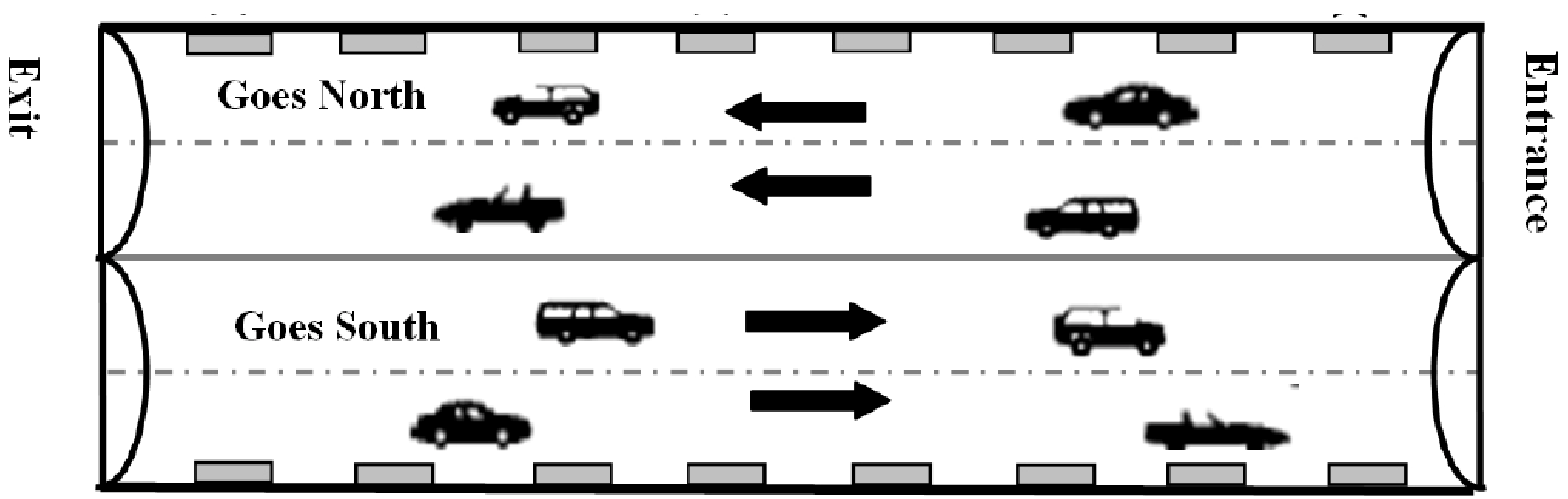
Long tunnels

Mechanical tunnel ventilation depends on:

- Tunnel length
- Vertical gradient
- Traffic flow
- Vehicle mix
- Number of lanes
- Risk of fires

Piston Effect

- Many road tunnels less than 3km do not require any mechanical ventilation to preserve air quality
- Possible exception of rush-hour traffic



Mersey Kingsway and Queensway Tunnels

Kingsway:
unidirectional traffic,
two bores, 2.4 km

Queensway:
bidirectional traffic,
single bore, 3.24 km

Use of Piston Effect

- Substantial savings in Queensway and Kingsway Tunnels by switching off mechanical ventilation
- Tidal flow in Queensway Tunnel during rush hours
- Air quality maintained by piston effect

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Smoke Ventilation

- Life safety: compliance to codes or via risk assessment
- Determining criterion for mechanical ventilation is smoke control, not air quality
- Reduce power consumption by switching on all available fans at lower speed, and by including “redundant” fans in operating cycle

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External Air Quality

- Tunnels do not create any emissions – rather, they contain and redirect emissions to outlet portals and ventilation stacks.
- The discharge of vitiated air can impact on the health of residents living close to the exit portals.
- Polluted air can be extracted up through exhaust stacks and dispersed.

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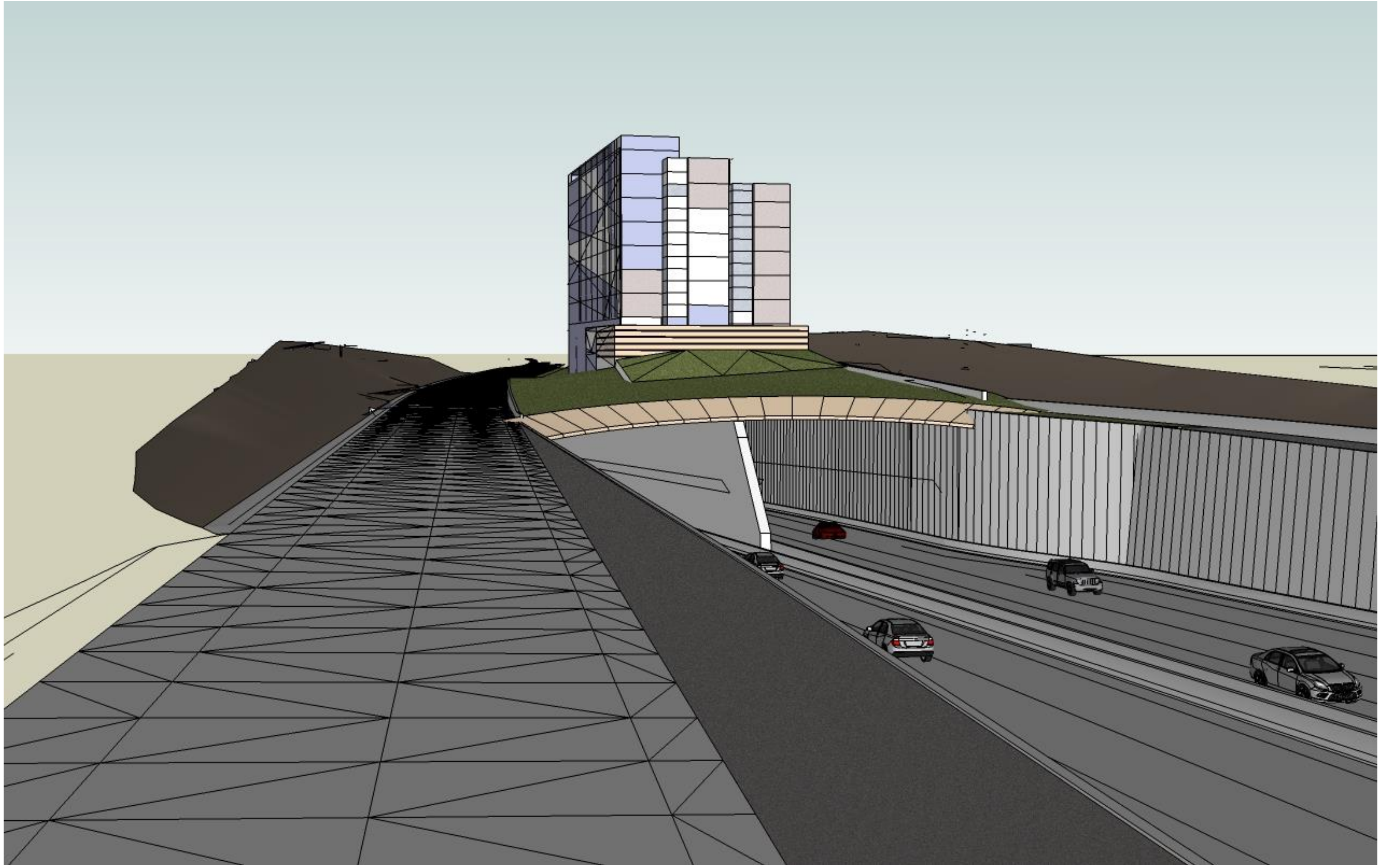
Exit Portal Stack



Power Consumption for "Zero Portal Emissions" (Australia)

Project phase	*Electricity consumption (MWh/annum)*	*Total (two way) tunnel length (km)*	*Traffic (vehicles per day)*	*MWh/km per annum*
Eastern Distributor Tunnel	4,400	3.2	110,000	1,375
Lane Cove Tunnel	15,400	7.2	70,000	2,139
CityLink Tunnel (Mel-bourne	21,500	5	100,000	4,300
M5 East Tunnel	54,000	8	100,000	6,750

The M5 East ventilation system energy use is equivalent to that of 7,400 households – is that sustainable?

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Improved Power Consumption

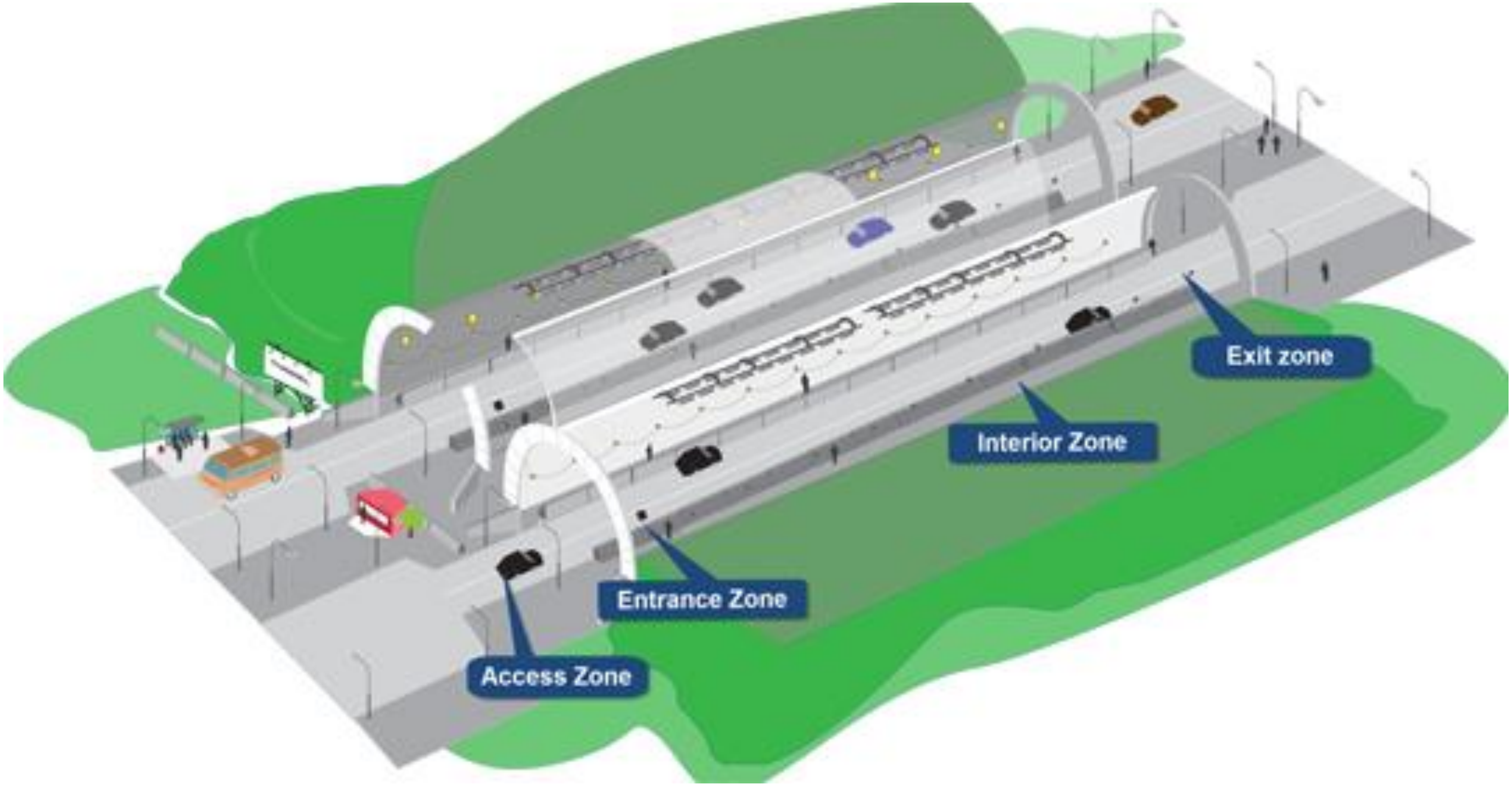
- Trials involving switching off the portal extract systems for the CityLink and Lane Cove Tunnels overnight and during low traffic conditions have been undertaken.
- Little impact on the ambient air quality levels reported.

4. Tunnel lighting requirements

Tunnel Lighting

- Dominant source of power consumption for short tunnels (up to 1 km long)
- Important for driver visibility
- Essential for evacuation and emergency services in case of emergencies

Tunnel Lighting Zones



Opportunities for Energy Savings

1. Lighting stages management (dimming)
2. Closer to to CIE 88 curve
3. Adjust lighting levels to traffic speed
4. Control systems
5. LED technology

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Typical Energy Savings

- Compared to high-pressure sodium luminaires in entrance zone + fluorescent lamps
- Hybrid installations: 15 to 20% savings
- 100% LED installations: 20 to 25% savings

5. Technical innovations

Low-Speed Fans

- Large diameter (3-5 m)
- Low speeds (less than 200 rpm)
- No sound attenuation required
- 75% reduction in power consumption

Spier Tunnel, Switzerland

Low-Speed Fans - Drawbacks

- Less static pressure generated
- More susceptible to piston & wind effects
- No operational experience

MoJet

- Energy-efficient jetfan
- Uses shaped nozzles to reduce the Coanda effect
- Up to 25% increase in energy efficiency

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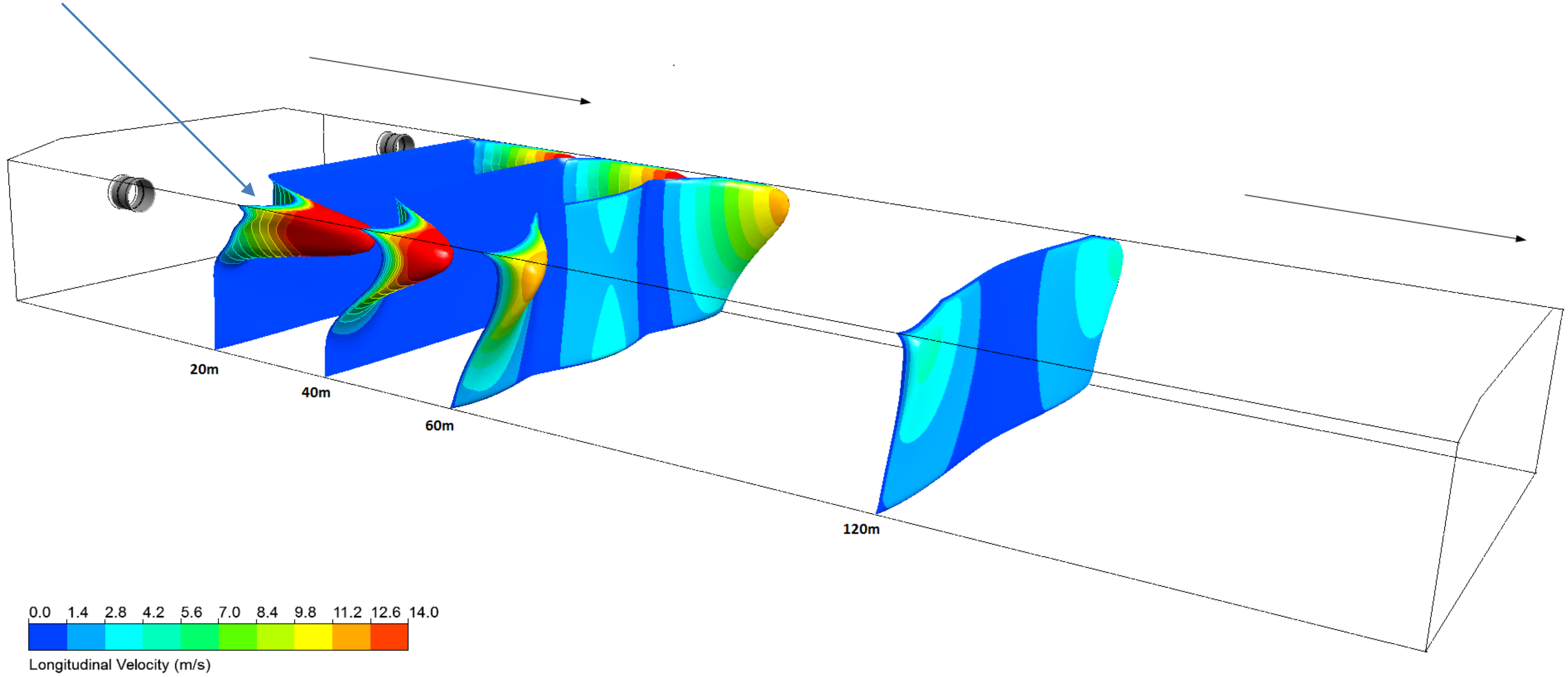
Conventional Jetfan

Jet sticks to tunnel soffit and wall, creating friction and losing thrust



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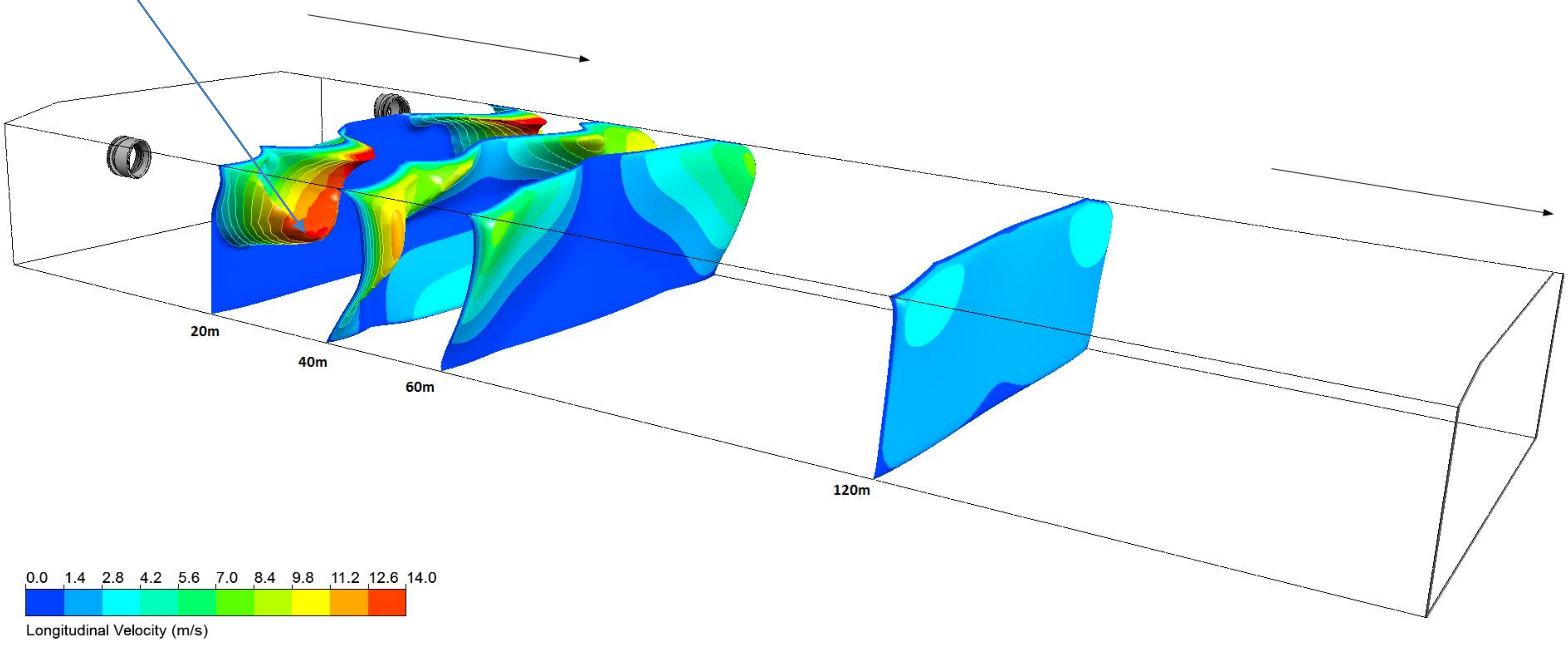
MoJet

Jet turned away from tunnel soffit and wall, reducing friction and enhancing thrust



MoJet Installations

- Grimstad Port Tunnel, Norway
- Byfjord Tunnel, Norway
- Mastrafjord Tunnel, Norway
- Hvidovre Tunnel, Denmark

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6. Unnecessary installations

Air Filtration Systems

- Filtration plant for NOx and particles within the Opera tunnel in Oslo + 6 other tunnels in Norway deactivated
- Excessive energy consumption, large maintenance and operation costs and low efficiency
- Filtration plants in M30 tunnels in Madrid hardly used, due to low vehicular pollution
- Air cleaning in Chiyoda and Yamate tunnels in Tokyo still operational

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7. Future sustainability

- Consider social, economic and environmental impacts
- Over tunnel life cycle
- Holistic strategy
- Consistency with life safety, asset protection and operational continuity
- Clear targets and plans

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Conclusions

- Sustainable designs can save costs and improve the environment – but a long-term horizon is required
- Emphasis on design and operation
- Challenge for innovation