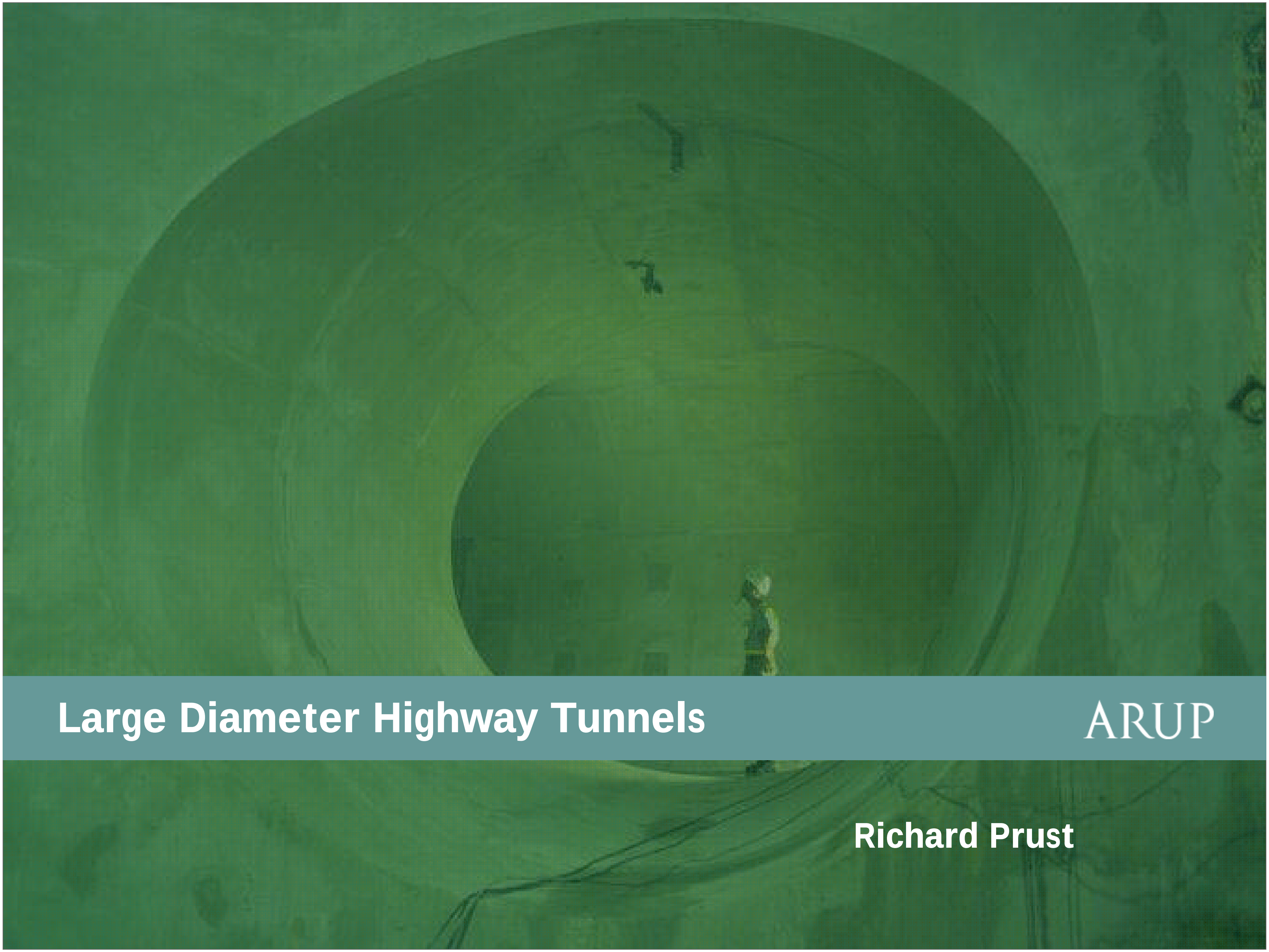


# Large Diameter Highway Tunnels

ARUP

Richard Prust

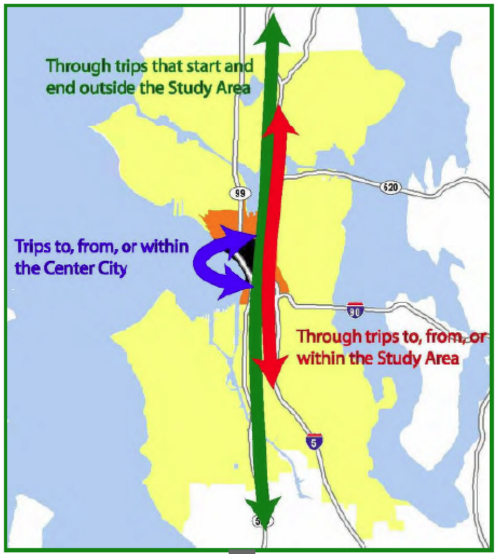
**Need**

**Feasibility**

**Whole-life cost**

# Corridors for through trips

## SR-99 carries a significant proportion of total through trips




SR-99 corridor

I-5 corridor

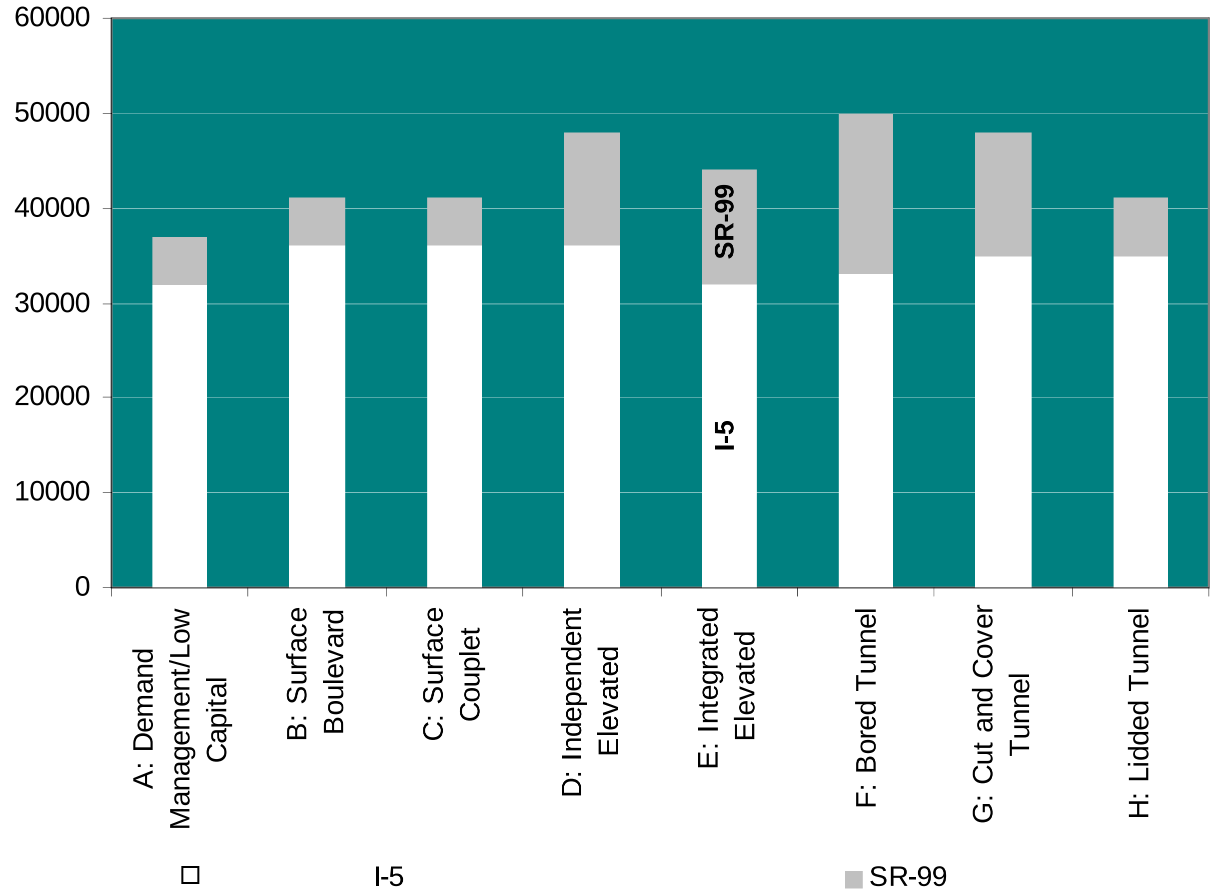
Surface Streets

| | SR-99 | I-5 | Surface |
|---|---|---|---|
| PM Peak Period Vehicle Trips | 30,000 | 57,000 | 26,000 |
| Percent through trips | 60% | 56% | not reported |
| Through trips | 18,000 | 32,000 | not reported |

Figures based on Stakeholder Advisory Committee Nov 13 2008 Guiding Principle #2 Briefing

# SR-99 and I-5 peak period corridor through trips

**Of the proposed options the bored tunnel best maintains the % of through traffic**




"I-5 reached it's capacity many years ago and travel demand exceeds the road's capacity."

Figures based on Stakeholder Advisory Committee Nov 13 2008 Guiding Principle #2 Briefing

# Lower Manhattan - Micro-simulation


**Micro-simulation provides better understanding of congestion in downtown streets**

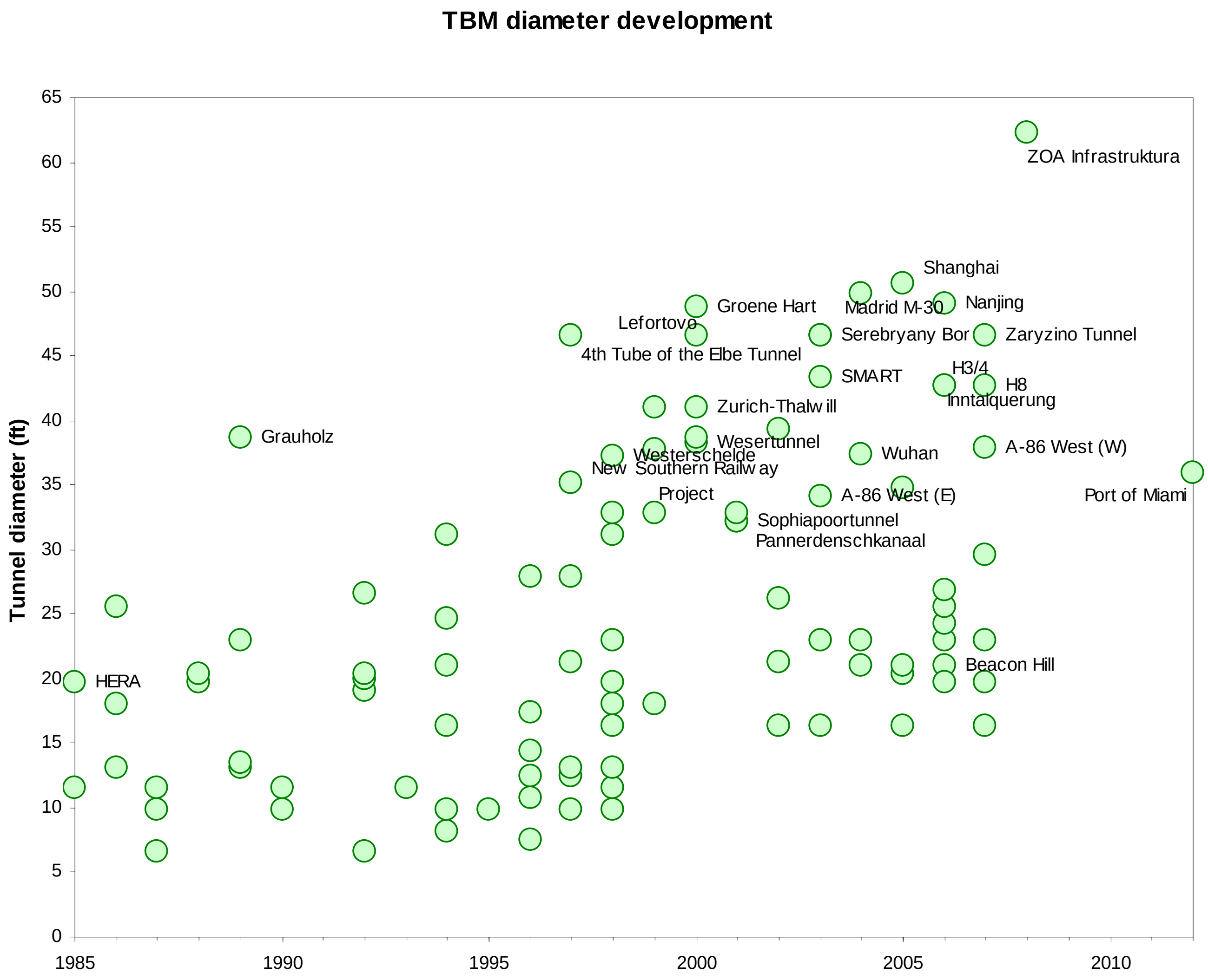
Need

**Feasibility**

Whole-life cost

# Tunneling machine diameters

**Tunnel diameters continue to increase. Highway tunnels are routine.**

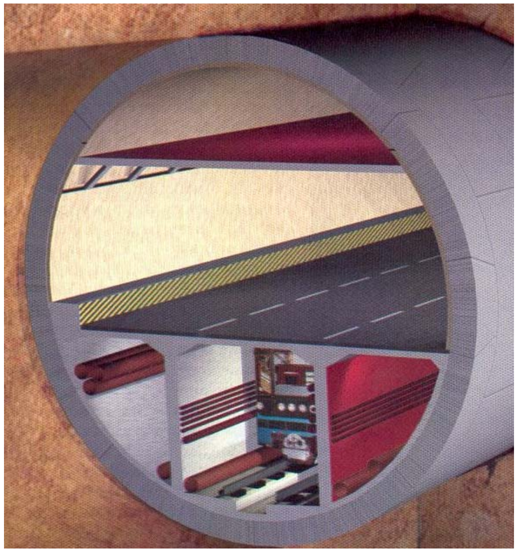




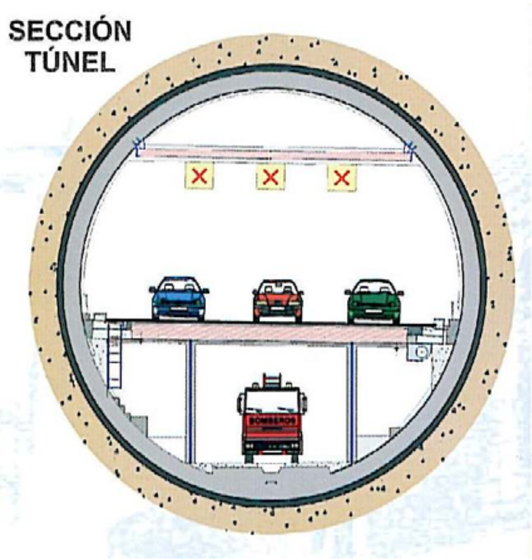

ARUP

# Versatility of tunnel configurations

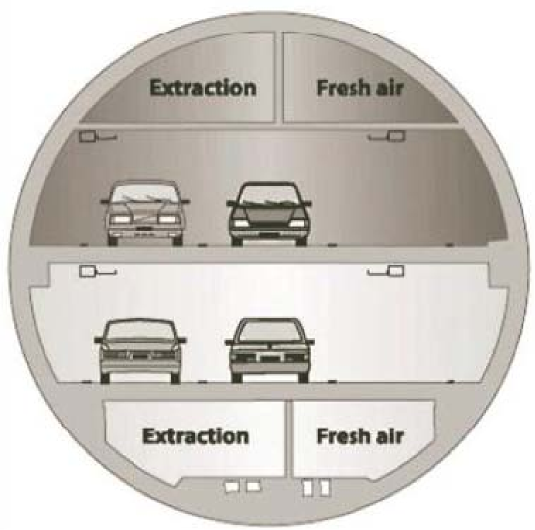
**Larger tunnel diameters allow for greater versatility in usage, combining highways, transit, emergency corridors etc.**



Silver Forest
Moscow




M-30 Madrid

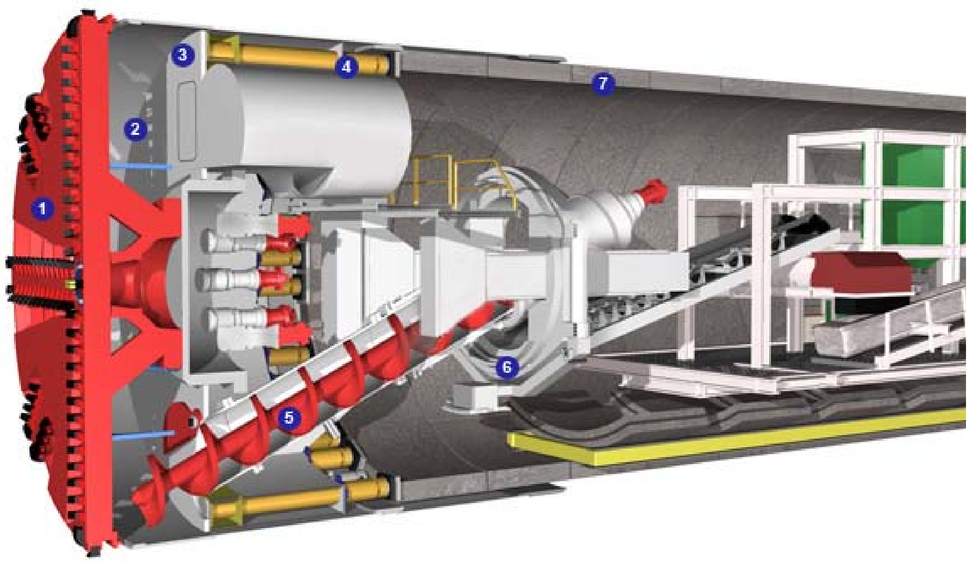



A-86 Paris

# Improved TBM technology

**Recent technological advances allow larger reliable tunnels**

- More powerful motors to drive head
- Real time monitoring of tunneling conditions
- More sophisticated foams and additives to support face
- Increased understanding of abrasivity
- Improved design of cutting tools
- Electronic sensors in cutting tools to assess wear
- Maintenance from within TBM – avoid interventions under pressure
- Improved design of seals – control higher water pressures
- Ground penetrating radar to identify obstructions – allow advance planning



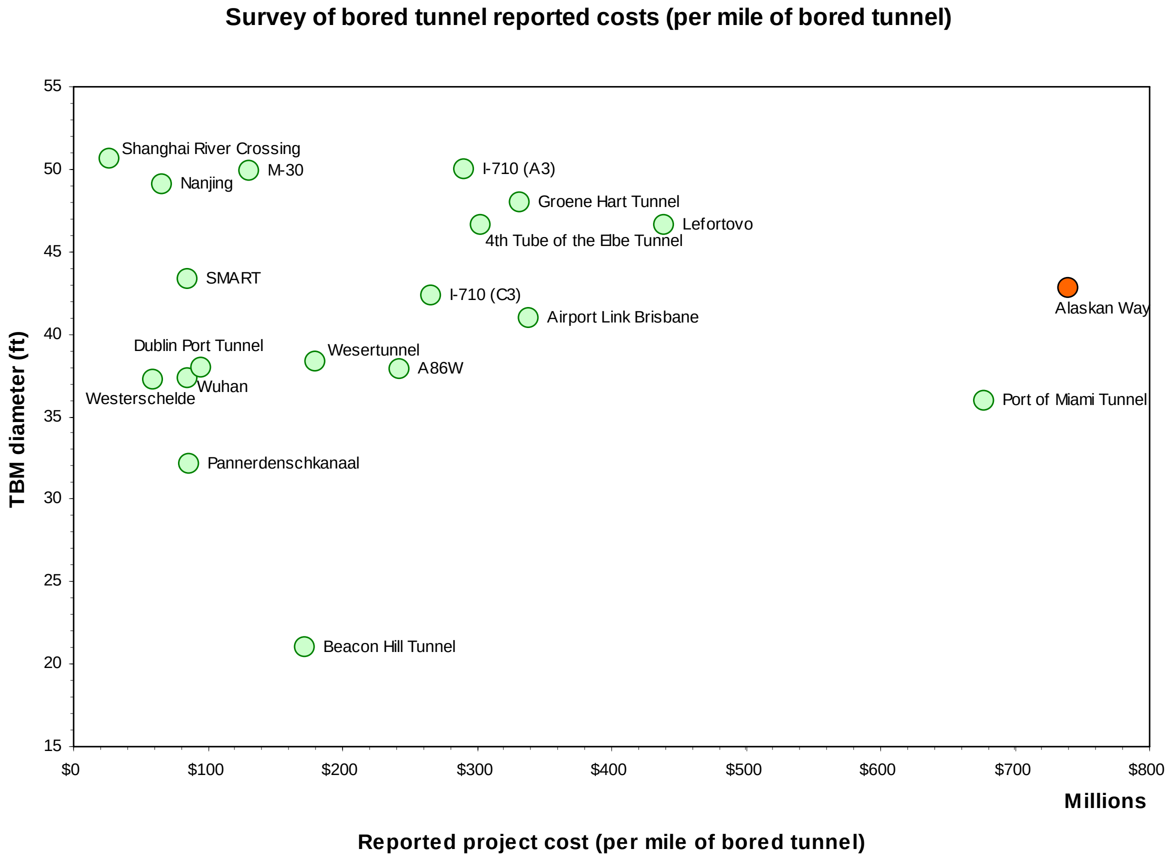
**Need**

**Feasibility**

**Whole-life cost**

# Survey of reported costs

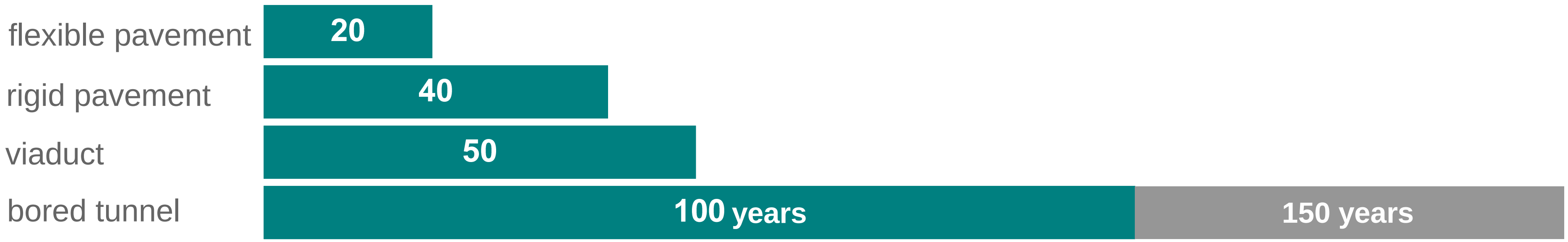
## Majority of projects indicate a cost per mile of single tunnel of less than $350M. This equates, for two tunnels 10,000 ft long, to $1.3Bn.




*Notes*:
- Costs are reported project costs, and have been normalized to indicate the cost of a mile of single tunnel
- No price escalation has been incorporated
- Costs for I-710 project in Los Angeles are from feasibility study – project is not built
- Alaskan Way figures based on $2.8bn for twin 10,000ft long tunnels

## Comparative design life

**Tunnels have a design life of 100 to 150 years.  Need to build 2 to 3 viaducts over life of a tunnel solution.**



# Typical whole-life cost breakdown

**Concessionaires, when considering private financing of a project, view whole life costs. Construction costs typically considered a small risk.**


Figure based on cost analysis of another tunnel project

# Comparative life cycle costs

## Tables from OpEd in Tunnels and Tunneling magazine indicating impact of assessing costs over life span of project for various alternatives

**Table 1: Project cost**

| | Soft cost | | | | | Construction cost | | | Total project cost (1) |
|---|---|---|---|---|---|---|---|---|---|
| | EIS/EIR | Design fee | Right of way | Productivity loss | Construction management | Traffic relocation & maintenance | Utility relocation & support | Structures | |
| Weighted % Average / Range | 4.5<br>3 - 6 | 13.5<br>12 - 15 | 11.5<br>8 - 15 | 3.5<br>2 - 5 | 13.5<br>12 - 15 | 16.5<br>8 - 25 | 11.5<br>8 - 15 | 25.0<br>15 - 35 | 100 |
| At grade = baseline | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.0 |
| Elevated structure/viaduct bridge | 1.4 | 1.4 | 1.8 | 1 | 2 | 1 | 1.2 | 7 | 2.8 |
| Tunnel cut & cover | 1.4 | 1.6 | 1 | 1.5 | 1.6 | 1.5 | 2 | 10 | 3.7 |
| Tunnel mined (NATM, TBM) | 0.3 | 1.4 | 0.3 | 0.3 | 0.7 | 0.3 | 0.3 | 11 | 3.2 |

Notes: (1) Refer to Table 2 for life time costs (Environmental pollution, property tax, maintence costs, social divide, life time factor)

**Table 2: Annual cost**

| Life span in years | Project cost per annum (1)(2) | | | | Annual costs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Life span relation | Total project cost | Total | | Environmental pollution | Loss of property taxes | Social divide | Maintenance cost | Total |
| | - | - | 100 | Weighted % Average / Range | 25<br>20 - 30 | 25<br>20 - 30 | 15<br>10 - 20 | 35<br>30 - 40 | 100 |
| 100 | 1 | 1 | 1 | At grade = baseline | 1 | 1 | 1 | 1 | 1 |
| 50 | 2 | 2.8 | 5.7 | Elevated structure/viaduct bridge | 1.2 | 1 | 0.8 | 2 | 1.4 |
| 100 | 1 | 3.7 | 3.7 | Tunnel cut & cover | 0.05 | 0.2 | 0 | 1.3 | 0.5 |
| 150 | 0.66 | 3.2 | 2.1 | Tunnel mined (NATM, TBM) | 0.05 | 0.2 | 0 | 1.1 | 0.4 |

Notes: (1) Refer to Table 1 (2) Interest not included

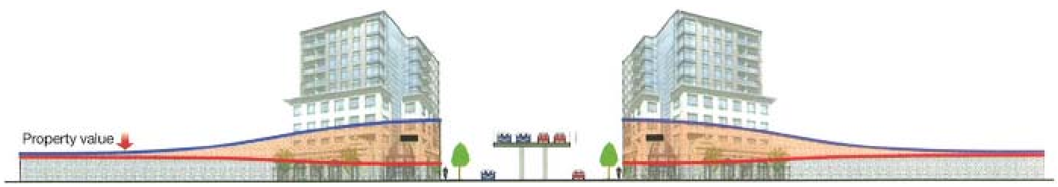
*Based on international experience in urban areas*

# Comparative economic impact

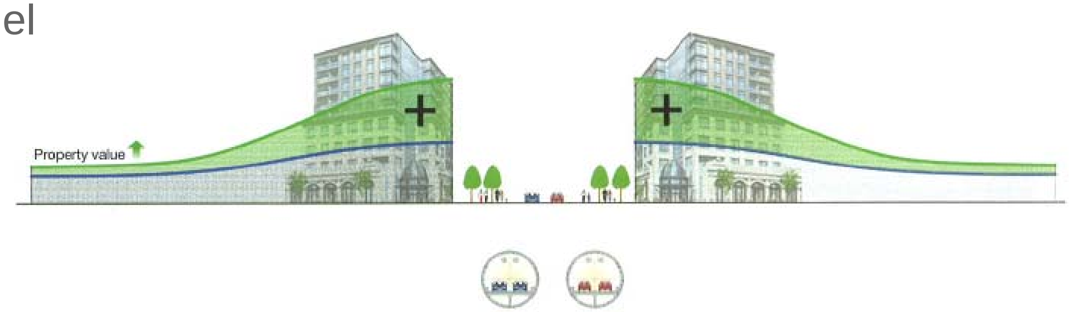
**Data from OpEd in Tunnels and Tunneling magazine indicating economic impact of various project alternatives**

Urban street


Elevated urban highway
Local access road




Urban street with traffic calming measures
Urban highway tunnel



# Summary of bored tunnel benefits

- Greater opportunity to provide public amenity – Socially responsible use of surface space
- Increased property values
- Greater seismic resilience
- Removes congestion and pollution from downtown streets
- Development opportunities where land is released by placing facility below ground - particularly at portals
- Allows existing viaduct to be retained during tunnel construction - greatly reducing construction impacts
- Reduced disruption to businesses during construction
- Reduced downtown street impacts to pedestrians and vehicles during construction
- Reduced utility relocations

## Need

- Through traffic on the SR-99 is significant. The economic impact of reducing the SR-99 corridor could be significant.
- A bored tunnel retains the existing proportion of through traffic.

## Feasibility

- Large bore highway tunnels are feasible and common throughout the world.

## Whole-life cost

- Whole life costs represent true cost to owners
- Major transportation projects must recognize the wider impact to the community