LCA applied to Tunnels: Potential environmental impacts of construction materials

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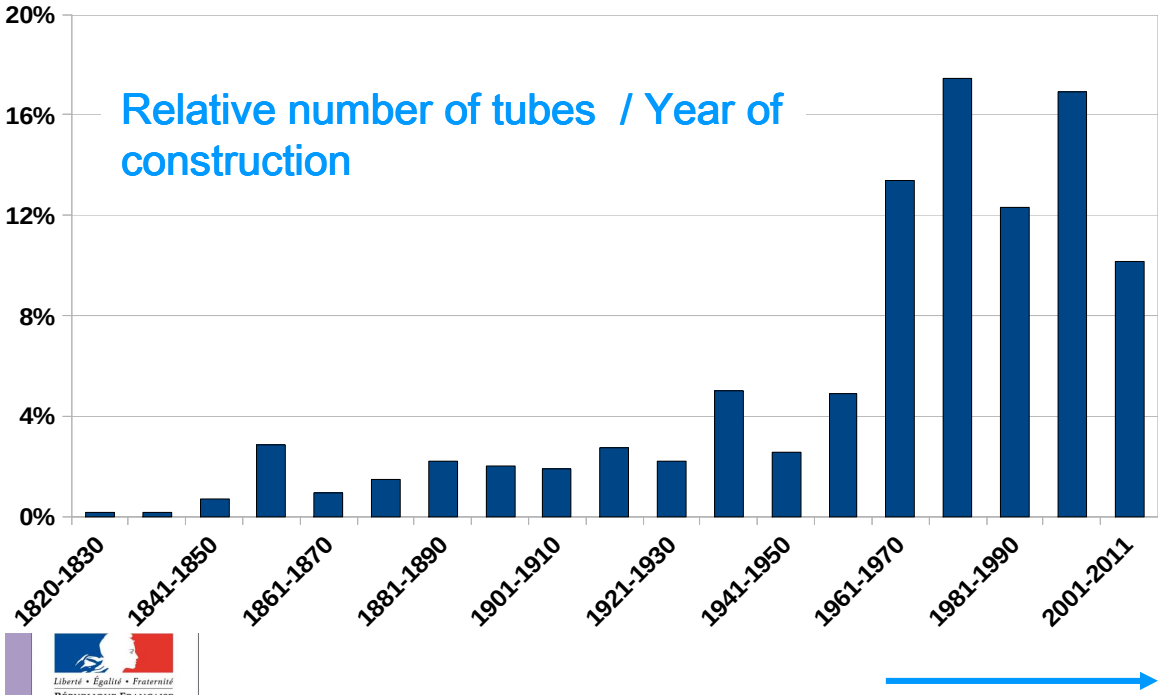
Outline

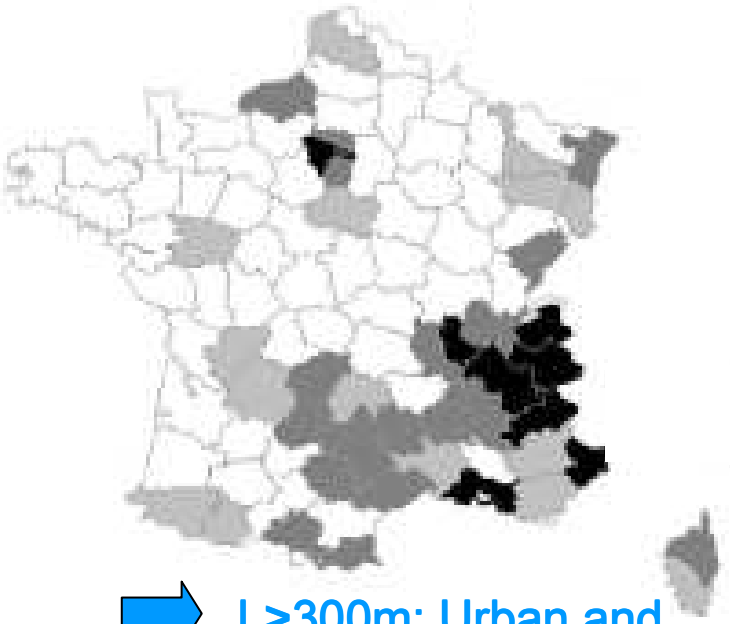
- **Introduction:** Applying LCA to Tunnels
- **Modelling and impact assessment**
- **Analysis of results**
- **Conclusion**

Introduction:
Applying LCA to Tunnels

Road tunnels in France

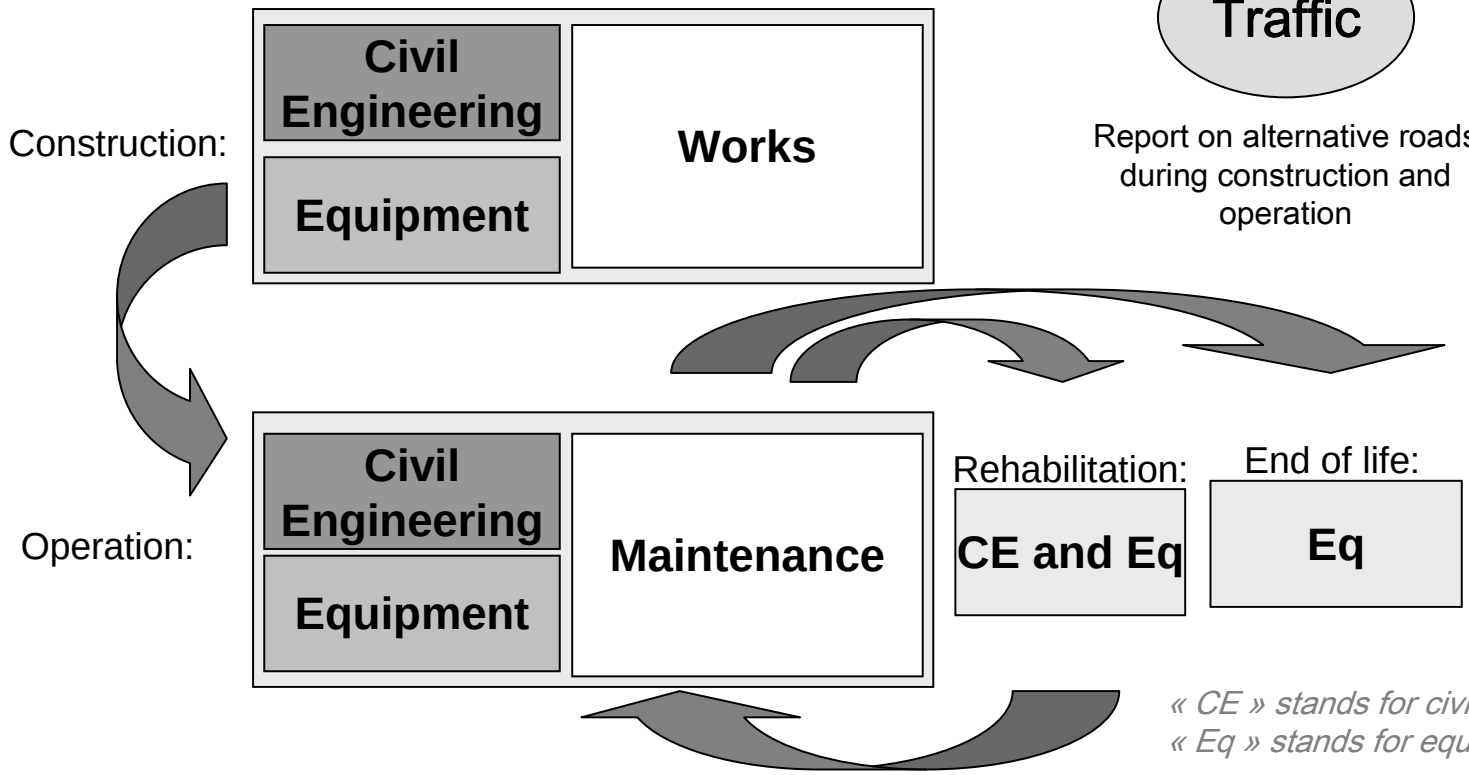
- **942 tunnels** / 22% L> 300m → Specific equipment and provisions according to security requirements
- **Total length: 355 km**
- 72% of the total length was built after 1960 (same « state-of-the-art »!)





L>300m: Urban and mountain areas

Life Cycle of a Tunnel



- « Long » service life: 100 years → **End of life = End of operation !**
  Operation → electric consumption of Equipment
- Functional unit (UF): **the tunnel itself (location, traffic (geometry and clearance) and service life)**

Applying LCA to Tunnels

- **Life Cycle Assessment (LCA) (ISO 14040 and ISO 14044) :**
  - Developed for « Products and Services » → Applied to « Buildings and Structures »
- **Goals and scope:**
  - To identify the main challenges linked to sustainable development for the construction of a tunnel → **environmental impacts**
  - To evaluate the contribution of the different phases (construction, operation, etc.) to the impacts → **orders of magnitude**

→ **To develop tools to assist the owner to make a decision**

- **Life Cycle Inventory (LCI) / LC Impact Assessment (LCIA):**

→ **First study : « From the cradle to gate » for « Materials » + Electric consumption of Equipment during operation**

→ **7 indicators of impact have been selected (NFP 01010):**
Climate change, Consumption of energy resources, Depletion of resources, …

Modelling and Impact Assessment

Softwares and databases

- **Softwares:**
  - **E-TUNNEL:** developed by the CETU to evaluate the cost of a project → used to evaluate the **quantities of materials** involved into the construction
  - **TEAM:** developed by Ecobilan/PricewaterhouseCoopers (PWC) to evaluate the **potential impacts on the environment**
- **Databases:**
  - **DEAM** provided by Ecobilan/PWC with TEAM
  - **Specific data** provided by Ecobilan/PWC (e.g. explosives)

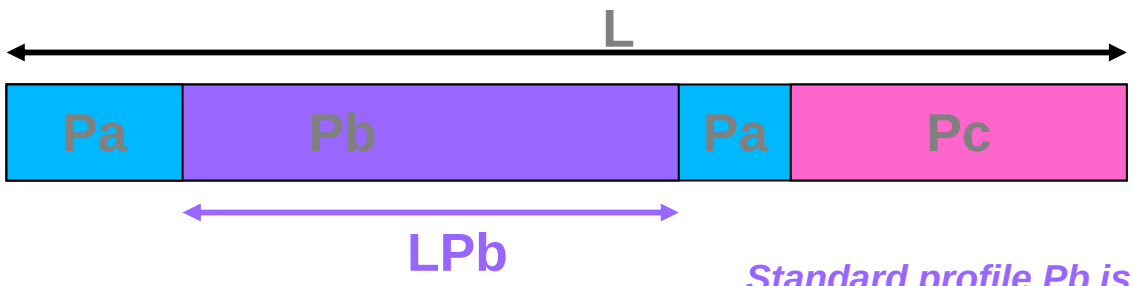
→ **Some results of E-TUNNEL are used as input data for TEAM**

→ **Economic and environmental analyses are available**

→ **Drill & blast tunnelling**

Modelling and standard profiles (1)

- **Successive phases of construction:**
  - **Excavation, support, watertightness, drainage, sanitation, roadbed and lining**
- **« Standard Profiles »:**
  - **Geometry:** road tunnel made of 2-lane and 3-lane unidirectional tubes (a 8.50 m and 11.50 m wide carriageway)
  - **Library** of already built tunnels covering all the possible technical solutions for support and lining: **11 « standard profiles »**

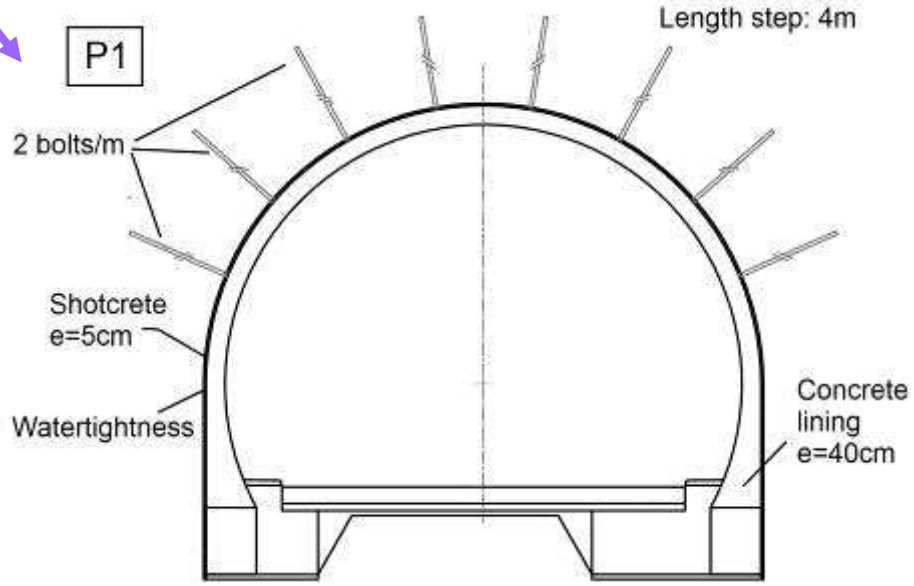


Standard profile Pb is applied on LPb

Definition of intermediate Functional Units : « one linear meter of each Standard Profile Pi … »

Modelling and standard profiles (2)

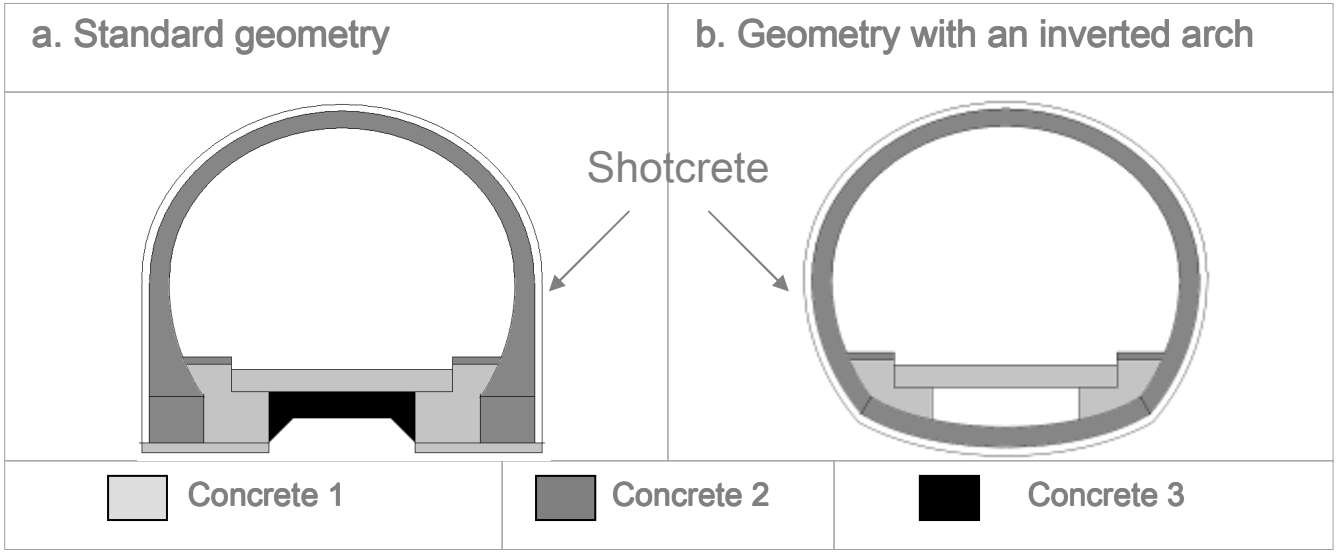
	Step (m)	Lateral support	Face support	Pipe Umbrella	Lining
P1	**4**	**5cm shotcrete+2 bolts/m**	**None**	**No**	**40cm**
P6	**1.5**	**25cm shotcrete + 1 HEB200 rib beam**	**Light**	**No**	**40cm**
P11	**1**	**25cm shotcrete + 1 HEB200 rib beam + inverted arch**	**heavy**	**yes**	**80cm**



Focus on technical details: concretes

- **Concretes:**
  - **3 standard mixes + shotcrete**
  - **Reinforcement:** 120kg/m3 if necessary

Concrete 1 (1m3)	Concrete 2 (1m3)	Concrete 3 (1m3)
cement CEMI: 280kg coarse aggregates: 1300kg sand: 800kg	cement CEMI: 350kg coarse aggregates: 1200kg sand: 800kg	cement CEMI: 200kg coarse aggregates: 1560kg sand: 130kg



Impact Assessment

- **Parameters:**
  - **« Materials » of civil engineering** involved during the different phases of construction **+ electric consumption of equipment**
  - **Standard Profiles: P1**, **P6** and **P11**
  - **2-lane tubes** (and 3-lane tubes)

- **Impact Indicators (NFP 01010:** *Environmental quality of construction products – Environmental and health declaration of construction products, 2004)*

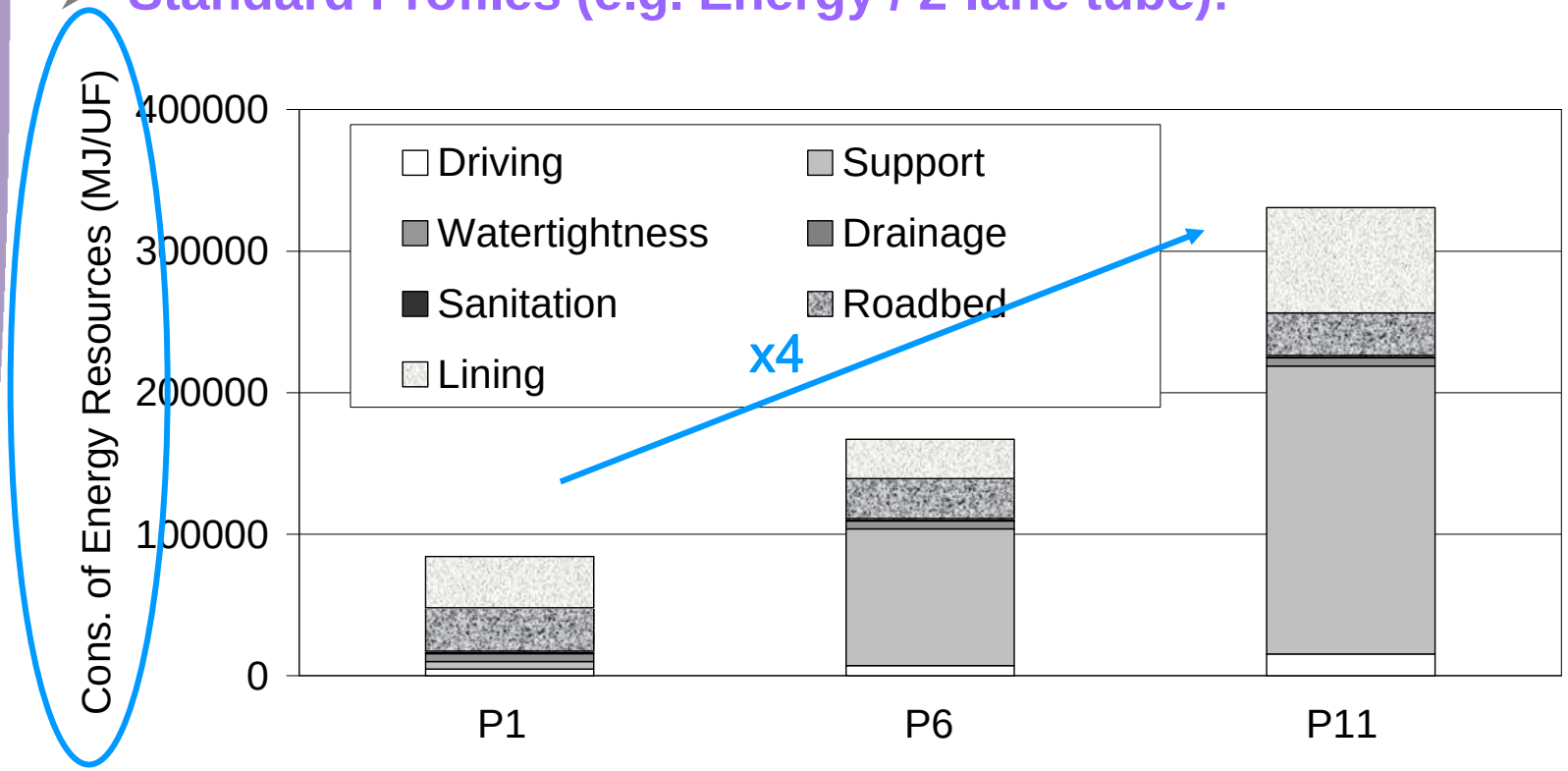
ER: Consumption of Energy Resources
CC: Climate Change
AP: Air Pollution
PO: Photochemical Ozone

DR: Depletion of Resources
AA: air Acidi
V

Analysis of Results

Contribution of Construction Materials

➢ **Standard Profiles (e.g. Energy / 2-lane tube):**

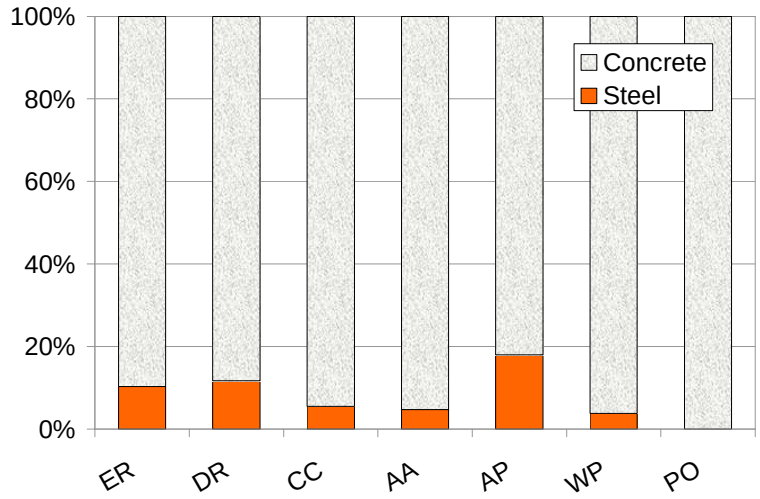


P1: Significant contributions of lining and roadbed
P6 and P11: … support, then lining and roadbed
Impact indicator is about 4 times greater between P1 and P11

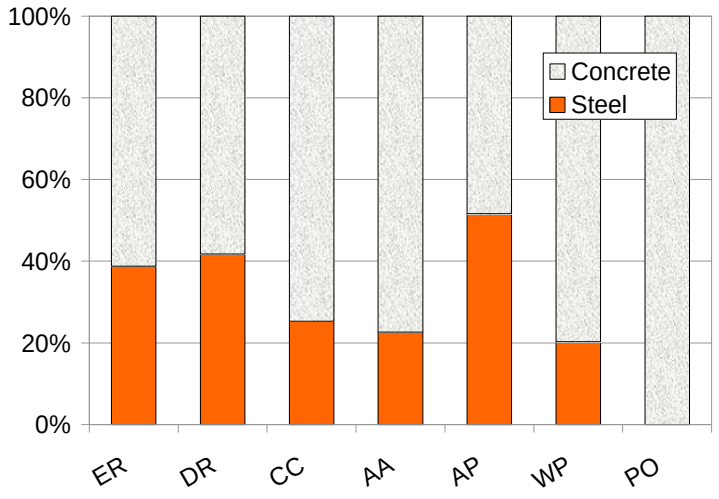
Relative contribution of concrete and steel

- **Relative contributions of concrete and steel to impact indicators are ranging from 80 to 95%**

P1



P11

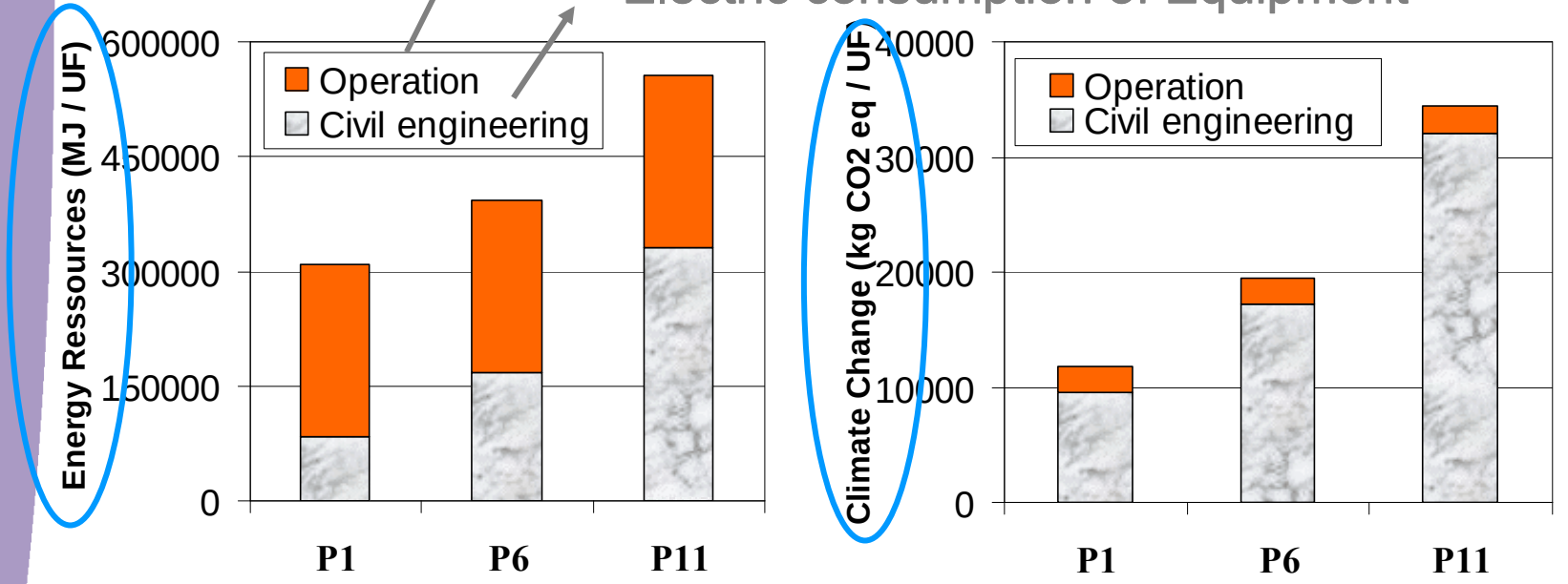


The relative contribution of steel is about 10% for the « lightest » standard profile P1 and about 30 to 40% for the « heaviest » standard profile P11

Materials/Electric consumption

= Materials

= Electric consumption of Equipment



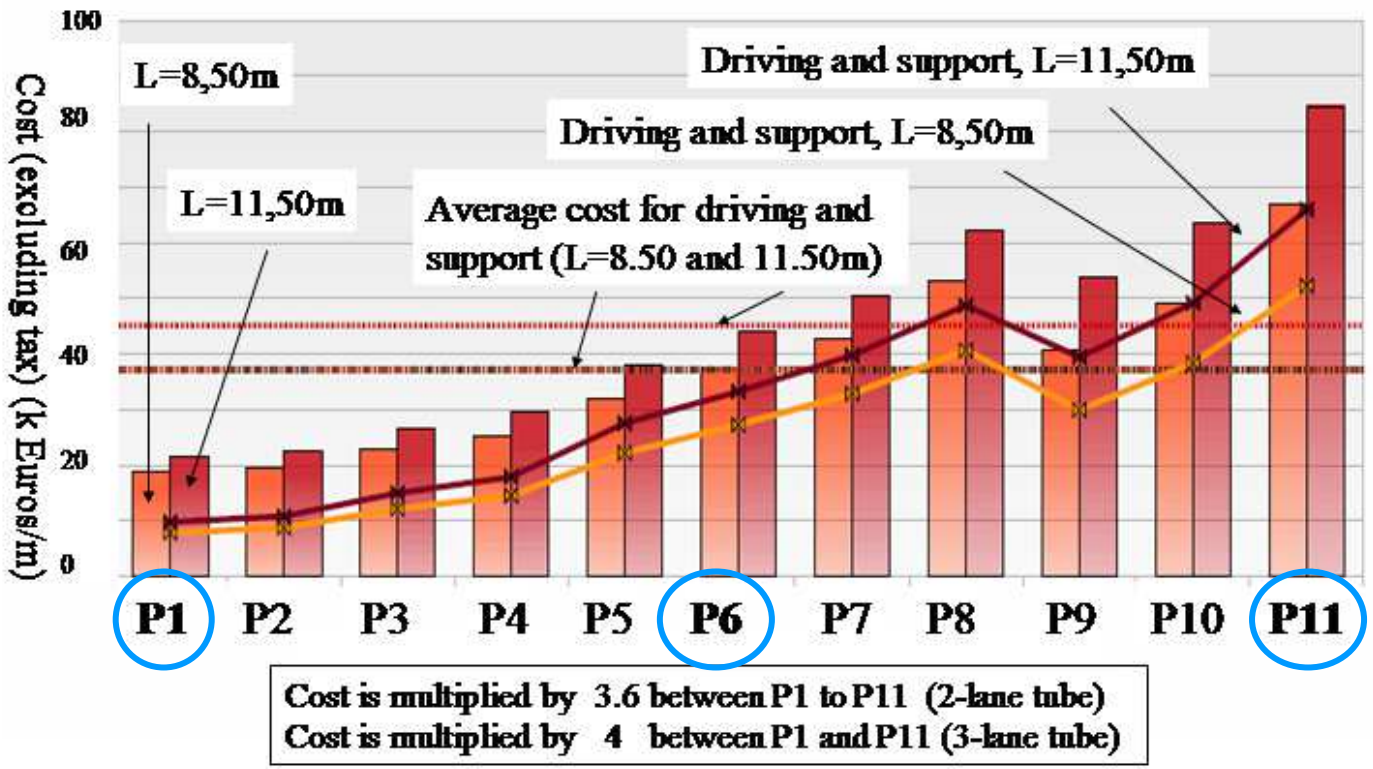
Standard Profiles

The relative contribution of materials to impacts depends on the indicator and on the standard profile: ~~20~~ to 60% (Energy ressources) and ~~85~~ to 95% for climate change

~~20~~ → 35%

~~85~~ → 10%

Economic Analysis



- Cost is also about 4 times greater between P1 and P11
- Good correlation between environmental and economic considerations
- Excavation and support are particularly significant in the case of heavy standard profiles

Conclusion

Conclusion and needs for future research

- **Orders of magnitude** of impact indicators are now available for each standard profiles → … any tunnel
- About **80 to 95%** of the impacts are due to **steel and concrete**
- **A critical review** enables to give more confidence to the approach and results (Gingko 21)
- **Ongoing studies:**
  - Sensitivity analyses (databases)
  - Availability of other environmental reliable data
  - Refining the modelling (concrete mixes and steel pieces)
- **Data are collected to complete the modelling of the life cycle of tunnels** (works, operation, recycling of equipment, etc.).

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Thank you for your kind attention

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