Environmental impact: TBM versus D&B

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Overview

1: Methodology

Goal & scope
Inventory analysis
Impact assessment
Interpretation
Applications: Focuses on improvements, product development, planning, procurement, etc.

2: LCA model

TBM
- VW excavation
- Rock support
- Preliminary work

Drill & blast
- VW excavation
- Rock support
- Preliminary work
- Ash tunnels

3: Results

4: Implications

Feasibility
Concept study/design
Execution/excavation
Detailed design

5: Conclusions
Life Cycle Assessment (LCA)

- Goal & scope
- Inventory analysis
- Impact assessment
- Interpretation

Applications
- Process improvement,
- product development,
- planning,
- procurement,
- etc.
Life Cycle Assessment (LCA)

**Goal & scope:** Function
- Transportation system?
- Road infrastructure?
- Tunnel?

**Applications**
- Process improvement,
- product development,
- planning,
- procurement,
- etc.

**Components:**
- Goal & scope
- Inventory analysis
- Impact assessment
- Interpretation
Life Cycle Assessment (LCA)

Goal & scope: Function

Apples or oranges? Comparisons must be **fair**

Applications

*Process improvement, product development, planning, procurement, etc.*

Goal & scope

Inventory analysis

Impact assessment

Interpretation
Life Cycle Assessment (LCA)

Goal & scope: Function

Functional unit: 1 km main tunnel

Applications
- Process improvement,
- Product development,
- Planning,
- Procurement,
- etc.

Goal & scope

Inventory analysis

Impact assessment

Interpretation
Life Cycle Assessment

**Goal & scope**

**Inventory analysis**

**Impact assessment**

**TBM**
- TBM tunnel
  - TBM excavation
  - Rock support
  - Preliminary work

**Interpretation**
- Applications: Process improvement, product development, planning, procurement, etc.

**Drill & blast**
- D&B tunnel
  - D&B excavation
  - Rock support
  - Preliminary work
  - Adit tunnels
Life Cycle Assessment (LCA)

- **Raw material manufacture**
  - By-products, waste
  - Machinery, fuel, etc.

- **Manufacture of TBM or drill rig**
  - Intermediaries, energy, etc.

- **Excavation**
  - By-products, waste
  - Fuel, trucks, ventilation, lighting, etc.

**Function:** Tunnel
**Functional unit:** 1 km tunnel with a lifetime of 60 yrs
Calculate the inputs from nature and outputs to nature for all processes we have in our system. (inputs/outputs = elementary flows)
Tunnel Boring Machine (TBM) vs. Drilling and Blasting (D&B)

- 2 technologies:
  - TBM
  - D&B
- 3 levels of rock support for each technology:
  - No support (low)
  - Medium support
  - High support
- In total: 6 scenarios

Global warming potential per tunnel length (0-1 km)
Tunnel Boring Machine (TBM) vs. Drilling and Blasting (D&B)

- 2 technologies:
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**Low level**
No rock support

**Medium level**
Rock support in demanding hard rock conditions, crossing several weakness zones and with strict requirements of water ingress

**High level**
Rock support with 1) very strict requirements on water ingress and tunnel lining and/or 2) in very poor rock conditions with heavy rock support is needed for the whole tunnel length.

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NOTE: The medium and high rock support scenarios are technology specific. The material types and amounts differ for TBM and for D&B.
Break even, D&B vs TBM
Low support: 700 meter
Medium support: 880 meter
High support: TBM always highest

Slope
Rock support is the main cause
Adit tunnels are minor cause

GWP rate of change:
$\Delta TBM \text{ high} > \Delta D&B \text{ high}$
$\Delta TBM \text{ medium} < \Delta D&B \text{ medium}$
$\Delta TBM \text{ low} < \Delta D&B \text{ low}$

0 km
TBM has higher initial impact due to heavier machinery and longer transportation distance.

Global warming potential per tunnel length (0-1 km)
Tunnel Boring Machine (TBM) vs. Drilling and Blasting (D&B)

**Global warming potential**

**Acidification potential**

- **Excavation**
- **Rock support**
- **Transport machines**
NB! Beware of differences in scale and units.
1 kg CO2 is not equal to 1 kg of SO2 (apples and oranges).
Global warming is not directly comparable to acidification.

Tunnel Boring Machine (TBM) vs. Drilling and Blasting (D&B)
Core components, global warming: TBM versus D&B

<table>
<thead>
<tr>
<th>Tunnel type</th>
<th>Rock support level</th>
<th>Transport of machinery</th>
<th>Excavation</th>
<th>Rock support</th>
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<tr>
<td>D&amp;B</td>
<td>Low</td>
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<tr>
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</tbody>
</table>

**Global warming**

- Gas Low
- Gas Med
- Gas High
- TBM

**Ozone depletion**

- Gas Low
- Gas Med
- Gas High
- TBM

**Eutrophication**

- Gas Low
- Gas Med
- Gas High
- TBM

**Acidification**

- Gas Low
- Gas Med
- Gas High
- TBM

- Excavation
- Rock support
- Transport machines
Implications: Project stage

- Concept studies with environmental focus
- Ranking of various concepts (tunnel alignments, bridge vs. tunnel etc.)

- Estimate the environmental performance compared to the old road, railroad etc.
  - Validate feasibility

- Documentation
- Collection of material and energy data

- Procurement / supplier selection
- Validate concept study/design
Implications: Improvement potential

- Project level
  - Electricity source? (4000 kWh per meter)
  - Excavation: Loading and hauling?
  - Rock support: Cement and steel consumption?
  - Supplier selection: Environment as procurement criteria? (cement, steel, explosives possible with EPD. Why not TBM?)

Environmental product declarations can be made for:

- Steel
- Cement
- Explosives

Why not for TBM?
Implications: Improvement potential

• Project level
  • Electricity source? (4000 kWh per meter)
  • Excavation: Loading and hauling?
  • Rock support: Cement and steel consumption?
  • Supplier selection: Environment as procurement criteria? (cement, steel, explosives possible with EPD. Why not TBM?)

• Scope: What is the **function** your system?
  • Tunnel $\rightarrow$ waste to landfill
  • Tunnel and by-products $\rightarrow$ **less** waste to landfill
    • Construction aggregate
    • From muck to mineral: Glass, concrete, steel, etc.
Conclusions, TBM vs D&B

• Key parameters
  • Tunnel length and type of rock support
  • *Beware: Specific projects may vary significantly*
• GWP as a proxy indicator for life cycle environmental impact
  • Correlates well with many impact categories
  • But not all, e.g. acidification
• Improvement potential can be found at all levels

Think of function and system scope
Questions?