The modern Trolley Bus-System
Facts and Arguments
General advantages of trolley bus systems

- More popular and accepted by the customer
- Higher comfort compared to diesel/gas bus
- Overhead lines make PT visible, marketing-instrument
- Usage typically higher than for diesel buses (10-20%), higher revenues, socio economic advantage
- Good alternative to tram, trolley bus as „Light-Tram/Lighttram“
- Much cheaper than tram: investment and operation
- No local emissions (zero-emission)
- Silent, in operation and at stations
- Recuperation of breaking energy → energy efficiency
- Real cost advantages for traction energy: electric power ↔ diesel
The trolley bus performs very well in emissions

Greenhouse gases (CO₂)

Nitrogen oxide (NOₓ)

Hydrocarbon (NMHC)

Particle (< 2.5 μm)

Source: Dr. Peter Marti, Metron Verkehrsplanung AG, Brugg

1. in particular CO₂, more climate-relevant emissions are methane (CH₄) and nitrous oxide (N₂O), which are converted into CO₂-equivalents
The trolley bus performs very well in emissions

Cost for noise

- The trolley bus operates with zero emission locally, in contrast to diesel or gas bus.
- This is important for the quality of life in urban areas.
- Energy consumption is on the same level than for trams related to one passenger journey.
- The trolley bus is the most environment friendly and technically mature mode of public transport.

Rent

Health

Trolley bus better by ca. ... %

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Diesel bus</th>
<th>Tram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy consumption</td>
<td>40</td>
<td>-30</td>
</tr>
<tr>
<td>Greenhouse gases</td>
<td>75</td>
<td>0</td>
</tr>
<tr>
<td>Nitrogen oxide</td>
<td>80</td>
<td>40</td>
</tr>
<tr>
<td>Hydrocarbon</td>
<td>55</td>
<td>75</td>
</tr>
<tr>
<td>Particles - small</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Particles - big</td>
<td>25</td>
<td>60</td>
</tr>
<tr>
<td>Noise</td>
<td>90</td>
<td>25</td>
</tr>
<tr>
<td>Requirement for land</td>
<td>-25</td>
<td>0</td>
</tr>
</tbody>
</table>

3. Februar 2013/5 Quelle: Dr. Peter Marti, Metron Verkehrsplanung AG, Brugg
The trolley bus produces less than 20% CO₂ per passenger than a diesel bus.
Potential of electrical traction systems - particularly if socio economics will be taken into account

The development of energy prices is crucial for the right decision on PT systems.

In ten years the already existing difference might increase by additional 60%.

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In ten years the already existing difference might increase by additional 60%.
Trolley bus systems can be implemented fast and with favourable prices compared to tram systems

- Traction unit, electronics, infrastructure are derived from trams
- Lifetime of assets as similar to trams

Trolley bus = "Light-Tram/Lightram"

<table>
<thead>
<tr>
<th>Time</th>
<th>Tram</th>
<th>Trolley bus</th>
<th>Investment</th>
<th>Tram</th>
<th>Trolley bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>5-10 Y</td>
<td>1-2 Y</td>
<td>Infrastructure</td>
<td>1.000</td>
<td>100</td>
</tr>
<tr>
<td>Construction¹</td>
<td>5-10 Y.</td>
<td>1-2 Y.</td>
<td>Vehicles</td>
<td>300</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>10-20 Y</td>
<td>2-4 Y</td>
<td>Total</td>
<td>1.300</td>
<td>200</td>
</tr>
</tbody>
</table>

Moreover, cost for operations are less than 50% of trams

Trolley buses are often more reasonable than trams (realisation time, investment, cost for operations)

¹ Construction of infrastructure
For trolley, tram and metro at least one modernisation of interior is carried out during lifetime, typically.

Diesel and gas show higher wear and tear due to vibrations and more parts with mechanical move.

Relation of investment and lifetime is much better for trolley than for tram.
Clear economic decision Pro trolley bus in Salzburg

<table>
<thead>
<tr>
<th>Type of cost</th>
<th>Standard articulated trolleybus 20 years</th>
<th>Auxiliary engine articulated trolleybus 20 years</th>
<th>Articulated motorbus 13 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed costs (vehicle costs)</td>
<td>0.82</td>
<td>0.88</td>
<td>0.74</td>
</tr>
<tr>
<td>Capital costs (annuity)</td>
<td>0.74</td>
<td>0.80</td>
<td>0.66</td>
</tr>
<tr>
<td>Insurance</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>Variable costs</td>
<td>0.59</td>
<td>0.59</td>
<td>0.83</td>
</tr>
<tr>
<td>Energy</td>
<td>0.16</td>
<td>0.16</td>
<td>0.43</td>
</tr>
<tr>
<td>Maintenance incl. internal services</td>
<td>0.43</td>
<td>0.43</td>
<td>0.40</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>0.23</td>
<td>0.23</td>
<td>0.01</td>
</tr>
<tr>
<td>Total incl. infrastructure</td>
<td>1.64</td>
<td>1.70</td>
<td>1.58</td>
</tr>
<tr>
<td>Total excluding rectifiers and overhead conductor lines</td>
<td>1.41</td>
<td>1.47</td>
<td>1.57</td>
</tr>
</tbody>
</table>
Obviously no minimal size of a trolley bus system
Example: Landskrona

Initial targets:
- Zero emissions (NOx, CO2, Particles)
- Less noise
- Stable and reliable

System characteristics:
- Length: 3 km
- buses: 3 Solaris 12 m
- Headway: 7 - 10 min

Investment Mio. €
infra construction 1,8
substation 0,4
rolling stock 1,6
other 0,3
total 4,2

Schaffhausen (CH) decided PRO trolley bus in 2009
8 vehicles currently, system will be extended

Annual cost [€/km]
diesel trolley optimized
infrastructure - 0,72 0,43
rolling stock 0,47 0,70 0,55
energy 0,28 0,12 0,12
operations 1,62 1,86 1,55
total 2,37 3,40 2,65

Saving potential for capital cost: 225 T€ annually without infra 2,22

depending on utilisation; key obstacle for trolley-bus
relatively high
Supercaps gain a certain cost advantage in operations

Example: Solingen

- First time in Solingen, trolley bus can produce services on cost level of diesel-bus
- The developments in recent years support the effect from the supercaps

<table>
<thead>
<tr>
<th>Annual cost [€/km]</th>
<th>Trolley-bus</th>
<th>Trolley-bus with supercaps</th>
<th>Diesel-bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy / fuel</td>
<td>0.28</td>
<td>0.18</td>
<td>0.54</td>
</tr>
<tr>
<td>maintenance</td>
<td>0.32</td>
<td>0.32</td>
<td>0.40</td>
</tr>
<tr>
<td>capital</td>
<td>0.62</td>
<td>0.62</td>
<td>0.50</td>
</tr>
<tr>
<td>infrastructure</td>
<td>0.27</td>
<td>0.27</td>
<td>0.02</td>
</tr>
<tr>
<td>other operations</td>
<td>------------</td>
<td>identical</td>
<td>-----------</td>
</tr>
<tr>
<td>total</td>
<td>1.49</td>
<td>1.39</td>
<td>1.46</td>
</tr>
</tbody>
</table>

depending on difference in energy cost (VAT, special taxes), trolley-bus is cheaper in total
For sound comparisons LCC-analysis* is necessary
Example: Leipzig - feasibility study

*Trolley is a longterm investment due to higher investment

*LCC = life cycle cost
Cost per passenger for traction energy
Euro/100 passkm*

Energy consumption in terms of cost per passenger and 100 km for different traction modes

- Cost for energy
  - 0.95 €/l diesel
  - 0.10 €/kWh electricity
  - 0.70 €/kg CNG (without fuelling station)
  - 4.00 €/kg green H2 (without fuelling station)

- Use of fossil H\(^2\) with 1.4 €/kg and compressor at fuel station
- In electric operation
- Incl. infrastructure/overhead catenary system

* based on national tax rules of Austria
Maximum lifetime at intensive use

- Only short experience under European circumstances
- Technical lifetime of energy storage
- Renewal of battery ca. every 2 years

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Maximum capacity in terms of passengers

- Heavy weight of technology = decreased capacity
- Not in hilly areas
- With standees

Bar chart showing capacities:
- 9-Meter: 190
- 12-Meter: 190
- 18-Meter: 190
- 24-Meter: 190

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Looking at the cost mechanisms the do's and don'ts are getting obvious

- trolley bus with higher proportion of fixed costs than diesel-bus
- hence, stronger effect on fixed cost if services are increased
- in case of tight schedule and short headways, a trolley bus can realise its advantages
- particularly with regard to fuel prices the economic situation gets better for trolley buses
Trolley bus realises clear economic advantages under certain circumstances

1. Urban quarter with high building density
   Low noise and no local emissions allow for high quality of life

2. Hilly topography
   Recuperation of breaking energy reduces cost

3. Compact network and short headways
   Optimal use of investments in infrastructure and vehicles

4. High passenger demand
   Capacity of trolley bus are sufficient to substitute tram systems,
   moreover, higher revenues can be gained ("railway bonus")

5. Sustainable development of cities
   The infrastructure defines development corridors and creates sound
   conditions for private and commercial investors. Price of land,
   employment and taxes are increased
Summary and conclusion

- Trolley bus systems are not necessarily more expensive than diesel/gas bus systems
- Hybrids are actually much more expensive than trolleys
- Trolley buses are a good alternative to trams, particularly if no tram system is in place
- Business economic advantages are possible for trolley against diesel (gas), if specific requirements are fulfilled
  - high usage of infrastructure and vehicles (fixed cost), which needs good planning (infra and operations)
  - energy cost are developing like the last years
  - opportunities of recuperation are used optimally
  - maintenance is optimised
  - rail bonus for revenues can be achieved
Summary and conclusion

- A high utilisation in terms of services provided is essential for competitive unit cost (€/km).
- Cost advantage of a trolleybus system appears in traction energy in particular.
- Do not use diesel buses driving under an existing overhead catenary system.
- Socio economic advantages are clear for electrical systems.
- Quality of PT depends not on the mode, but on attractiveness of service (low floor, air conditioned, dedicated lanes for speed, etc.)
Trolleybus: Economy, Ecology, Capacity, Priority