Energy consumption of electrical driven regular buses dependent on route characteristics and operational requirements

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Structure

1. The calculation program
2. Vehicle data
3. The route
4. Results
5. Conclusion

1. The calculation program

Matlab program to dimension the battery for electrical, serial- and parallel hybrid buses.

vehicle data

electrical equipment

↓

electrical power consumption

weight, air drag coefficient, etc.

\+ **route data** (speed, height,etc.)

↓

air- , rolling- , gradient- and acceleration resistance energy – recovering energy at downward slope and from braking

➔ temporary dimension of the battery
➔ energy consumption including the weight of the battery
➔ final dimension of the battery

2. Vehicle data

Mercedes Benz Citaro
12 m solo-bus
200 kW engine
12 t empty load
6t, 3t and 1.5t loading

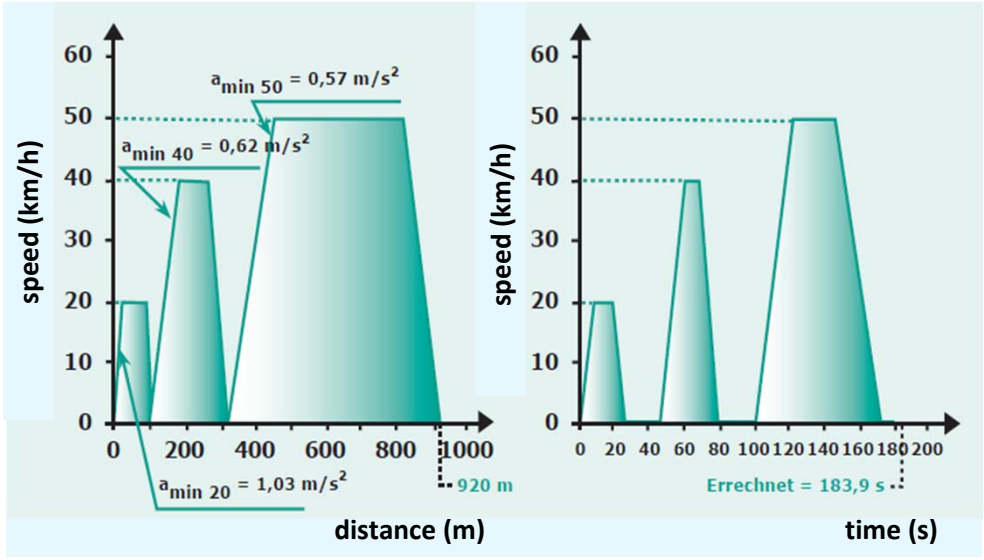
Mercedes Benz Citaro Picture: Daimler

Power consumption of the electrical equipment
from the research „energy saving calculation tool“
of Professor Ralph Pütz.

3. The route

SORT 2 cycles

- Standardised On-Road Test cycles for local public traffic
- mixed urban- and suburban traffic
- developed from statistical data of various european transportation companies
- average speed of 18 km/h
- 33% stop time
- lenght of 920 m



SORT 2 Cycle

Picture: International Association of Public Transport

4. Results

On each of our routes build out of SORT 2 cycles these consumptions are equal.
It is inconsiderable if the route is flat or with a grade.

	consumption
air resistance	0.098118 kWh/km
el. equipment	0.608372 kWh/km
air conditioning	0.959556 kWh/km

load	consumption - rolling resistance
6 t	1.471500 kWh/km
3 t	1.226250 kWh/km
1.5 t	1.103625 kWh/km

4.1 Results route 1

flat diameter line

- 22 sequent SORT 2 cycles → ca. 20km total length
- flat terrain
- journey time over 1h, plus 7 min stop at the end

	consumption		
loading & recuperation	**total**	**acceleration resistance**	**gradient resistance**
6000 kg & with	2.251882 kWh/km	0.000000 kWh/km	0.000000 kWh/km
6000 kg & without	2.755691 kWh/km	0.584497 kWh/km	0.000000 kWh/km
3000 kg & with	2.005306 kWh/km	0.000000 kWh/km	0.000000 kWh/km
1500 kg & with	1.882105 kWh/km	0.000000 kWh/km	0.000000 kWh/km

4.2 Results route 2

diameter line with ascending slope

- 22 sequent SORT 2 cycles → ca. 20km total length
- ascending slope of 100m
- journey time over 1h, plus 7 min stop at the end

	consumption		
loading & recuperation	**total**	**acceleration resistance**	**gradient resistance**
6000 kg & with	2.554722 kWh/km	0.000000 kWh/km	0.242358 kWh/km
6000 kg & without	2.975431 kWh/km	0.531276 kWh/km	0.242358 kWh/km
3000 kg & with	2.257610 kWh/km	0.000000 kWh/km	0.201965 kWh/km
1500 kg & with	2.109150 kWh/km	0.000000 kWh/km	0.181768 kWh/km

4.3 Results route 3

diameter line with ascending- & downward slope

- 44 sequent SORT 2 cycles → ca. 40km total length
- ascending slope of 100m → slope down of 100m
- journey time over 2h, plus a 7 min stop in the middle and one at the end

	consumption		
loading & recuperation	**total**	**acceleration resistance**	**gradient resistance**
6000 kg & with	2.311915 kWh/km	0.000000 kWh/km	0.000000 kWh/km
6000 kg & without	2.925718 kWh/km	0.617324 kWh/km	0.057173 kWh/km
3000 kg & with	2.055329 kWh/km	0.000000 kWh/km	0.000000 kWh/km
1500 kg & with	1.927123 kWh/km	0.000000 kWh/km	0.000000 kWh/km

5. Conclusion

- main part of the consumption caused by the rolling resistance,
  up to 1.47 kWh/km (6 t load)
- if air conditioning is operating, it uses another big part of the energy with 0.95 kWh/km
- As a consequence of the slow acceleration and the slight gradient of the route, the power limitation of 80% of the drive power is never reached

Consumption in kWh/km	Route 1 0m	Route 2 0 – 100m	Route 3 0 – 100 – 0m
total (6t load)	2.25	2.55	2.31
without rekuperation (additional to 6t)	0.50	0.42	0.61
1t weight	0.082	0.099	0.085

- The main difference between the consumption of route 1 and route 3 is conditioned by the efficiency losses to overcome the gradient resistance and to recuperate these.

Thank you for your attention

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