SOLUTIONSplus
Summer School

Module 5: Electric Drives for Micromobiles

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Introduction
Target Groups of Micromobiles

Target Group 1: Individual or Shared Mobility

- Urban traffic (up to 50 km/h)
- One or two passengers
- Compact, lightweight
- Cheap
- Low power demand

➢ **Electric Motorcycle**

Source: NIU Technologies

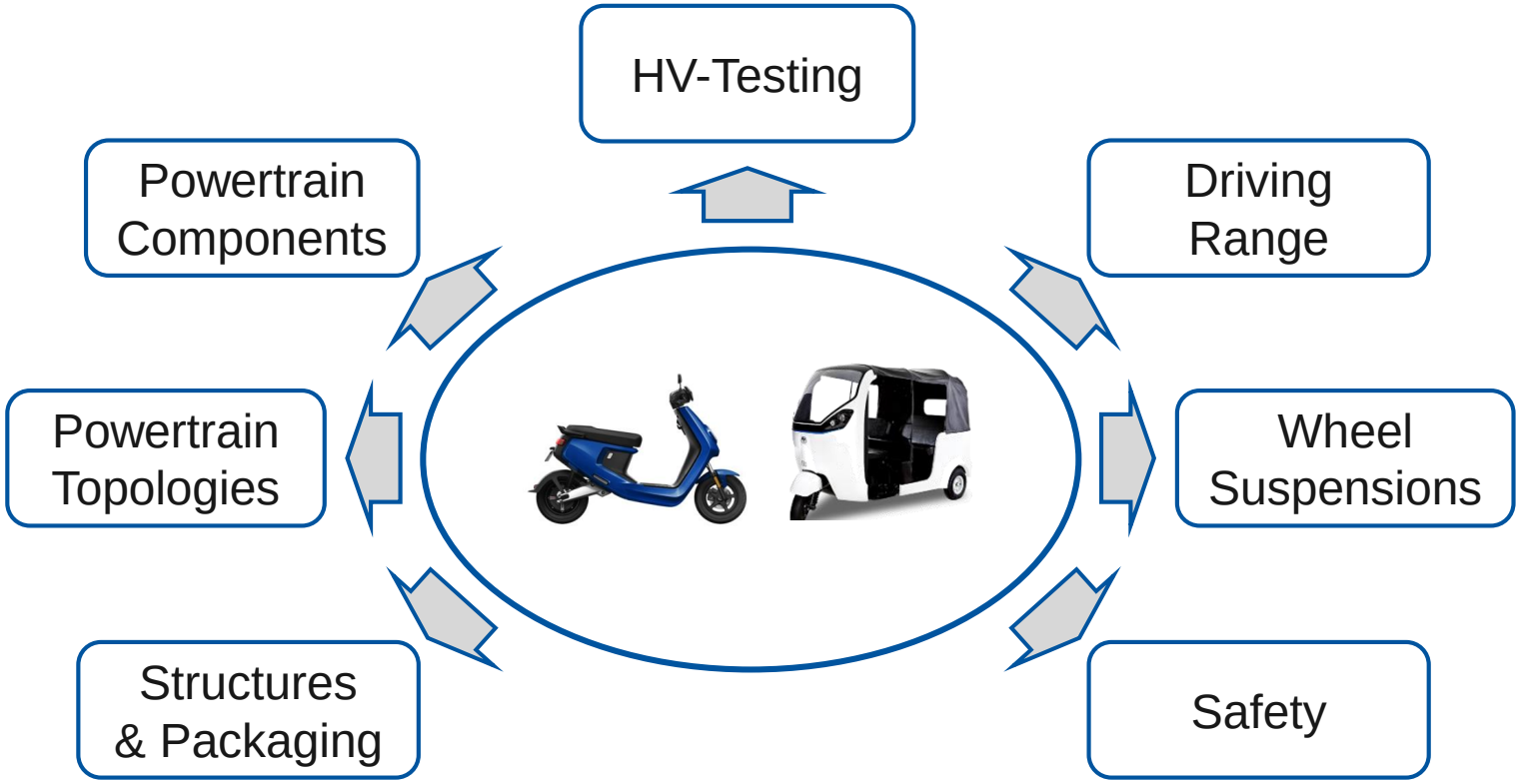
Target Group 2: Commercial or Cargo Mobility

- Urban traffic (up to 50 km/h)
- Up to four passengers
- Environmental protection
- Medium cargo capacity

➢ **Electric Rikshaw**

Source: Terra Motors

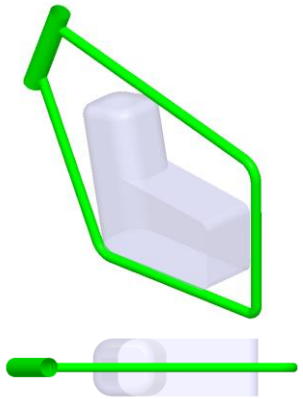
Key Aspects of Micromobiles



Micromobiles on System Level
Motorcycle Structures

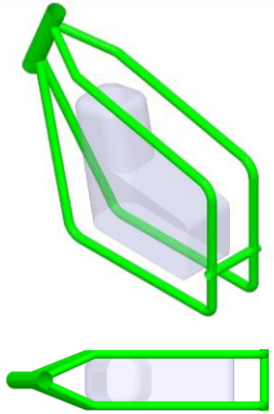
General Types of Frames

Single Cradle Frame



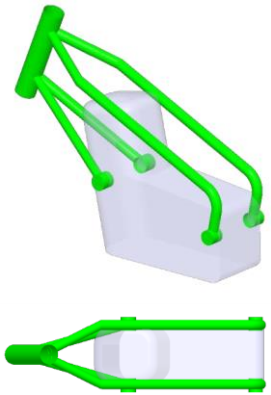
- Simple, light, compact
- Low stiffness (especially with lateral load)

Double Cradle Frame



- Three dimensional structure
- Higher stiffness

Perimeter Frame



- Engine integration as load-bearing component
- Reduced frame weight with highest stiffness

Source: ika

Typical Frame Materials

- Steel
- Aluminium

Frame Concepts for E-Drives

- Typical frame concepts are modified to fulfil the requirements for E-drives

Battery Changing
KTM Freeride E

Source: Dirtrider

Source: Adventuremotorcycle

Load-Bearing Battery Housing
BMW C evolution

Source: Motorscooterguide

Source: Bennetts

Micromobiles on System Level
Package Design

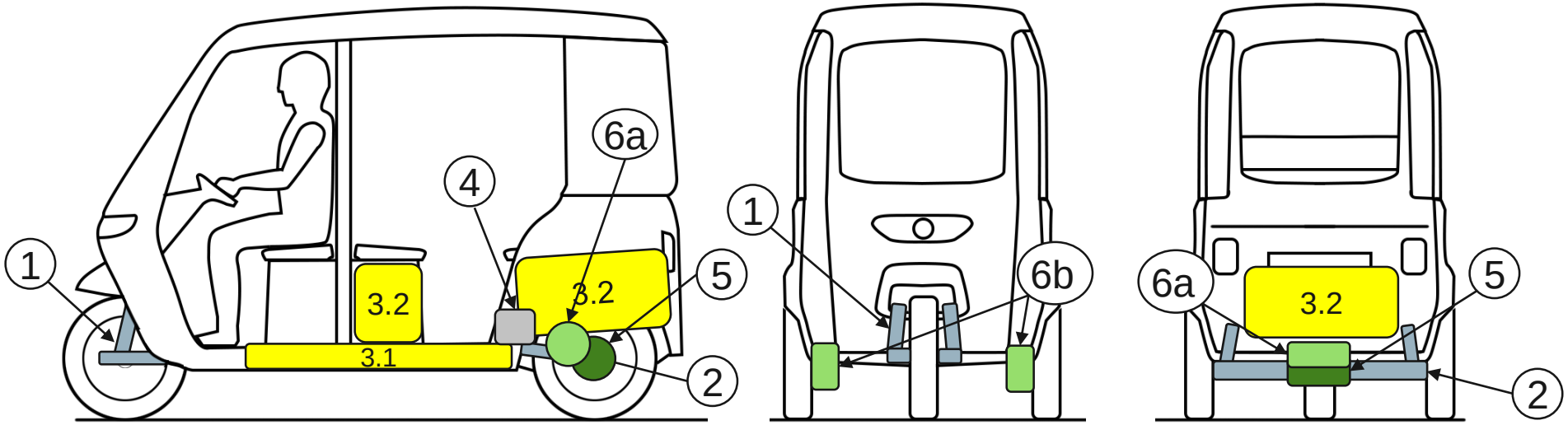
Package

Functional Units
- contour / design space of the aggregates
- engine & luggage compartment
- wheels and axles with respect necessary ground clearance
- free space to the vehicle‘s outer skin

Body Structure
- positioning and size of
  - all main beams
  - bumpers
  - points of belt anchorage

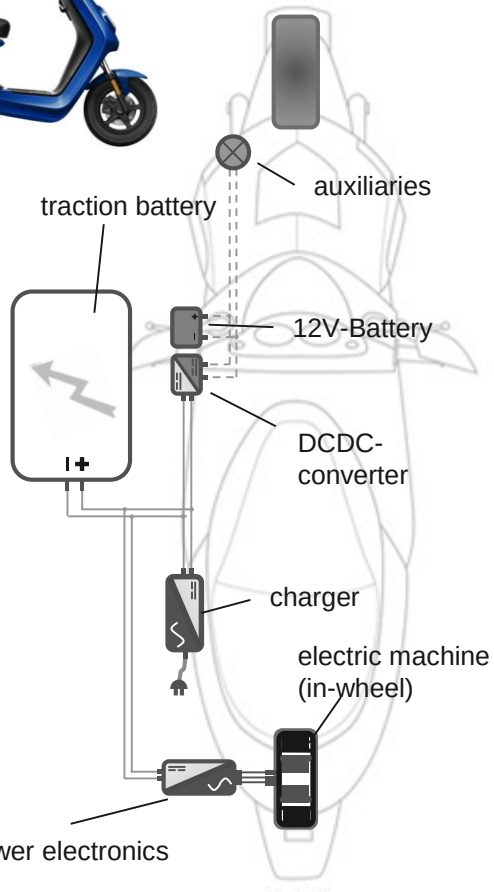
Passenger Compartment / Interior
- seating position of passengers
- minimum values for distances between occupants‘ heads and vehicle structure
- sight lines of the driver
- reach envelopes

Main Components
1. Front axle
2. Rear axle
3. Battery system
   1. Floor integrated
   2. Using luggage space / engine bay
4. Power electronics
5. (Transmission)
6. Electric motor

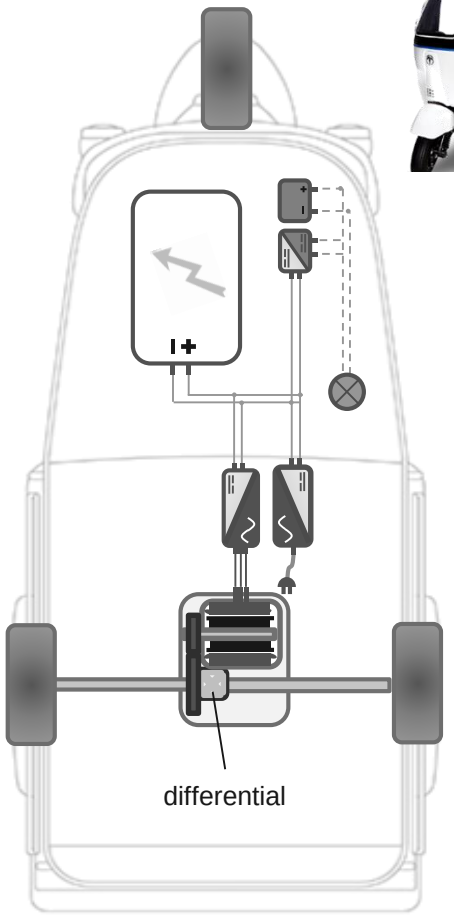


Micromobiles on System Level
Powertrain Topologies

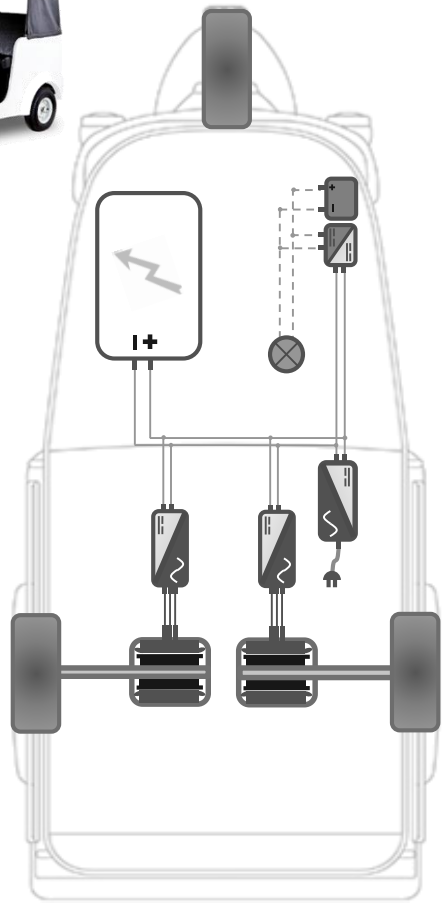
2W Single Motor

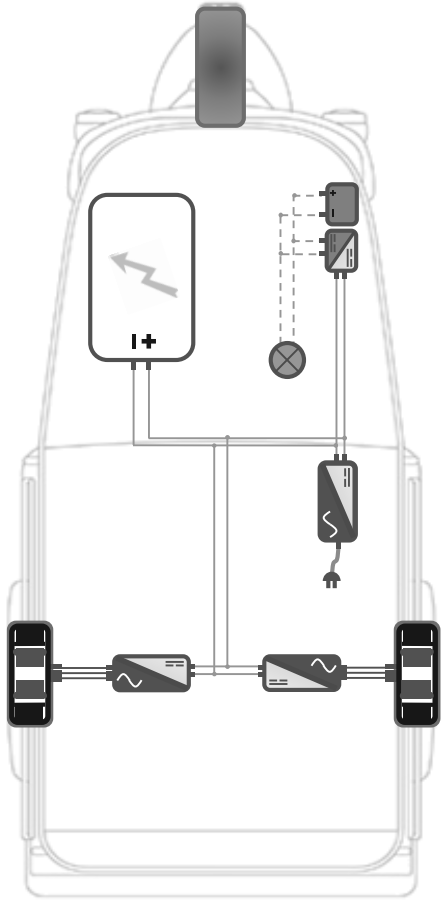


3W Single Motor



3W Two Motor





Powertrain Components
Electric Machines for Micromobiles

Types of Electric Machines

AC Machines (3 Phases)
- Permanent Magnet Synchronous Machine (PMSM)
- Asynchronous Machine (ASM)

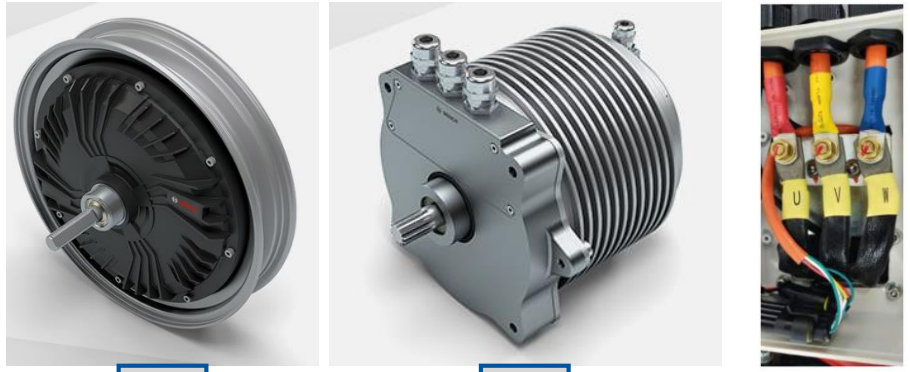
DC Machines
- Brushless DC motors (BLDC)
  - They work similar to PMSM, but run on DC
  - A controller converts DC to block-commuted voltage (not sinusoidal like in AC machines)

- In-Hub motors and Non-In-Hub motors
  - In-hub motors require less space and no transmission is needed, but performance and efficiency are lower

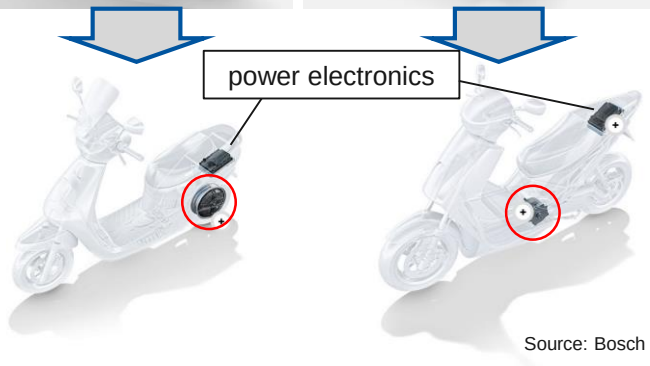
- Inverter DC voltage supply (by battery): 12 – 80 V

Examples in Micromobiles

In-Hub motor | Central motor | 3 Phases



Source: eTuk



Source: Bosch

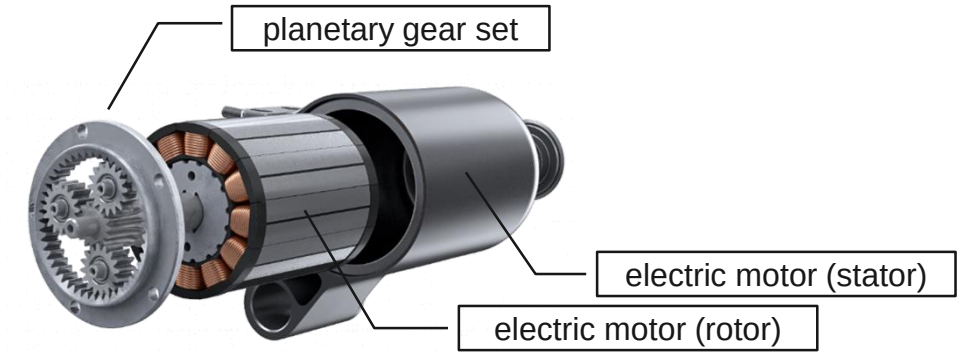
Typical Power Ranges

0.85 kW – 5 kW for vehicles with up to 3+1 seats
5 – 7 kW for vehicles with 4+1 seats or cargo

Powertrain Components
Transmissions for Micromobiles

Transmissions in Electric 2-Wheelers

- Due to limited installation space, the transmission needs to be compact
- One or two gears, depending on electric machine size
  - ➢ e.g. planetary gear set



Source: Gogoro

Transmissions in Electric 3-Wheelers

- Because two wheels are driven, a differential is needed
  - e.g. when driving corners, the outer wheel rotates faster than the inner wheel
- Usually only one gear
  - ➢ e.g. final drive with differential

Source: indiamart.com

Safety and Testing of Electrical Systems

The Five Safety Rules (Before starting the work)

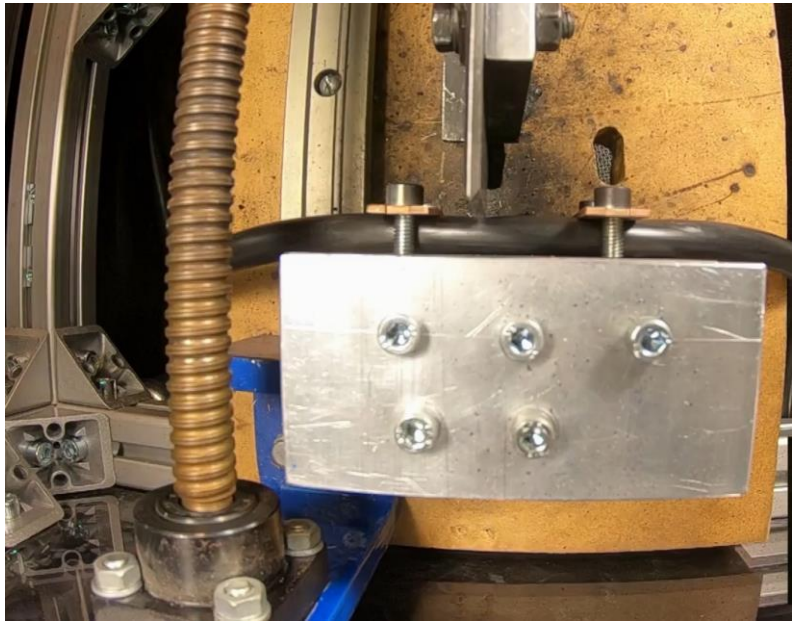
1. Unlock
   - Disconnecting an electrical system
2. Secure against restarting
3. Determine lack of voltage
4. Grounding and shorting
   - Discharge stored energy in capacitors and inductors
5. Cover adjacent live parts
   - e.g. Cover battery poles

Low Voltage and High Voltage

- Voltages < 60 V (DC) (protective low voltage)
  - Voltages below 60 V are in principle uncritical at first.
- Voltages > 60 V (DC) (High Voltage - HV)

Voltage Level Risk

- Danger of electric arcs above 20 V
- Fire hazard, temperatures up to 1000 °C
- e.g. Cutting cable under 48 V and 100 A load

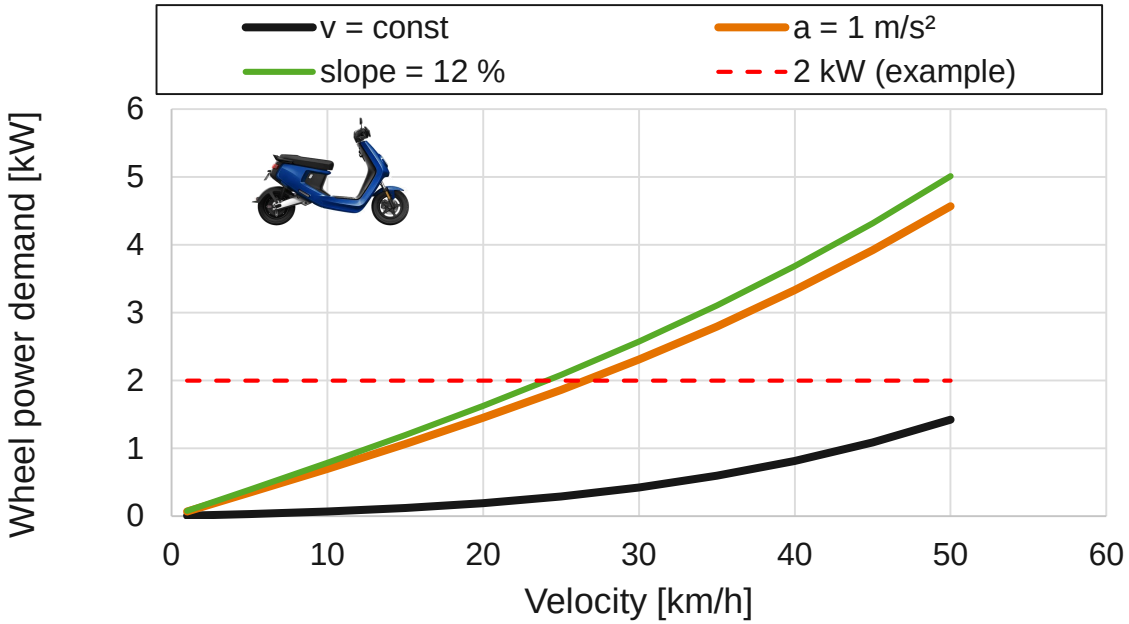


Driving Range
Power Demand of Micromobiles

Electric Motorcycle

Test mass: 130 kg (vehicle) + 90 kg (driver + luggage)

Typical power for vehicle type: ~2 kW

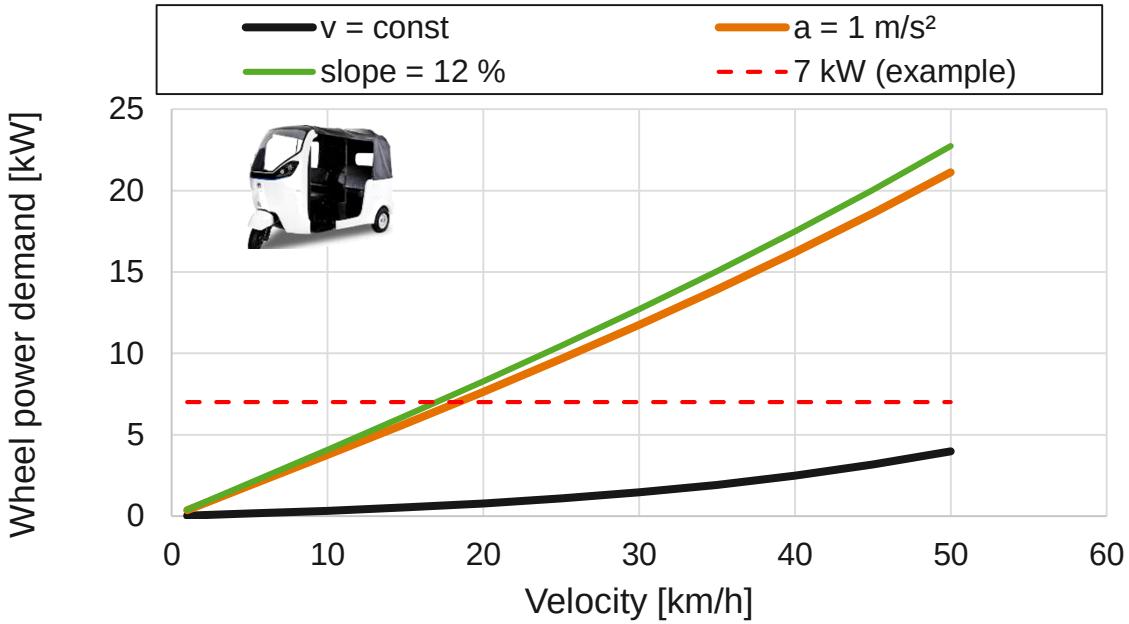


➢ To drive 50 km/h, at least 1.5 kW are needed

Electric Rikshaw

Test mass: 850 kg (vehicle) + 300 kg (driver + luggage)

Typical power for vehicle type: ~7 kW



➢ To drive 50 km/h, at least 4 kW are needed

Driving Range
Driving Resistances

The powertrain has to meet demands set by the driving resistances*:

- **Rolling Resistance (F_{Roll})**
  Friction of the rolling wheel

Source: popularmechanics

- **Air Drag (F_{Air})**
  Friction of air and the surface of the vehicle

Source: carbodydesign

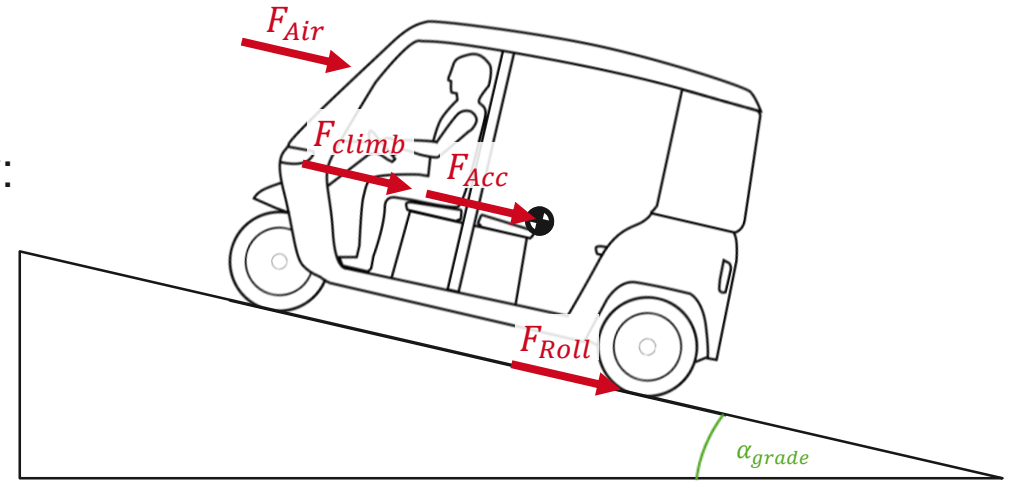
- **Climbing Resistance (F_{Climb})**
  Force to climb a grade

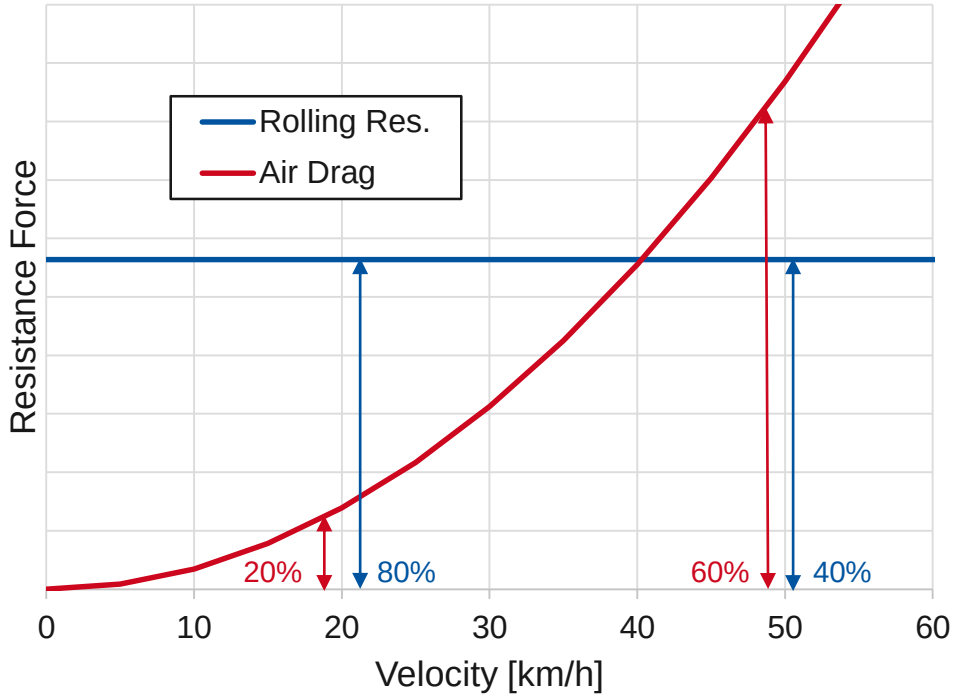
Source: civilengineering

- **Acceleration Resistance (F_{Acc})**
  Force to accelerate vehicle

Source: science4fun

** Powertrain losses also need to be taken into account*





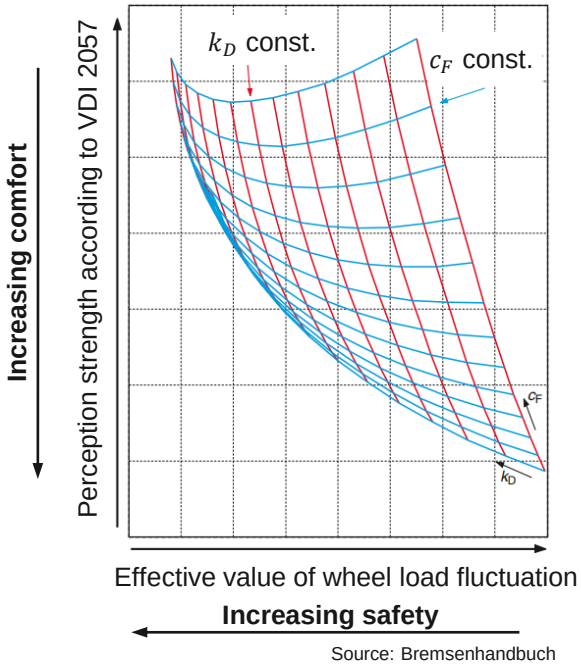
Driving Range
Range Examples for Micromobiles

Vehicle	Battery size	Range	Weight
 Source: Vespa	Vespa Elettrica 45 km/h	4.2 kWh	100 km	130 kg
 Source: Piaggio	Piaggio Ape E-City 45 km/h	4.5 kWh	68 km	389 – 689 kg
 Source: eTukFactory	eTuk Limo GT 45 km/h	10.8 kWh	80 – 100 km	1,030 – 1,553 kg

Wheel Suspensions
Comfort and Safety

Ride Comfort & Safety

- A major conflict of goals in chassis design is the conflict between ride safety and ride comfort



Source: Bremsenhandbuch

Ride comfort:
- Low vertical body accelerations
- Soft springs
- Soft dampers

Ride safety:
- Low wheel load fluctuation
- Hard springs
- Hard dampers

- Minimising vertical body accelerations while keeping wheel load fluctuations low is critical

Axle Concepts



Source: VISION mobility

Usage of MacPherson front axle
+ low production cost
+ very compact
- adjustability of vehicle dynamics lower than with double wishbone suspension

Usage of rigid axles at the rear
+ simple and robust
+ low production cost
+ constant ground clearance
- mutual influence of the wheels on one axle
- space requirement

Safety
Countermeasures against Injuries

Head Protection - Helmets

bicycle

Source: Casco

motorcycle

Source: Shoei

Abrasion & Cutting Protection

gloves

Source: ADAC

boots

Source: ADAC

Fracture Protection - Body Protectors

back protector

Source: Motorradonline

knee protector

Source: Spidi

elbow protector

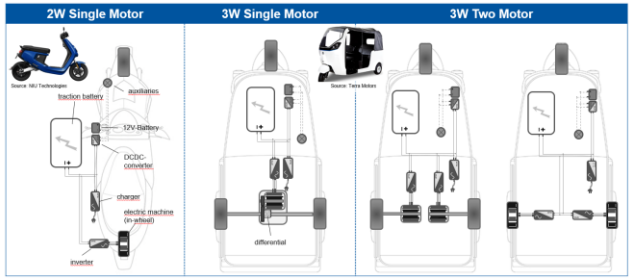
Source: alpinestars

jacket

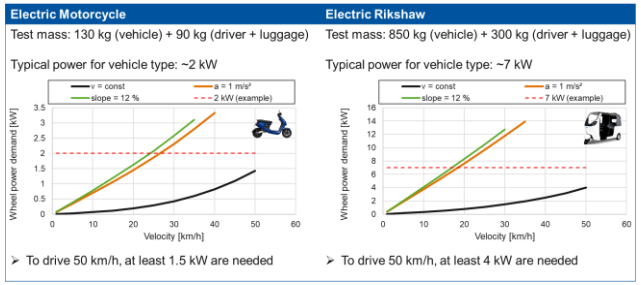
Source: alpinestars

Summary
Lessons Learned

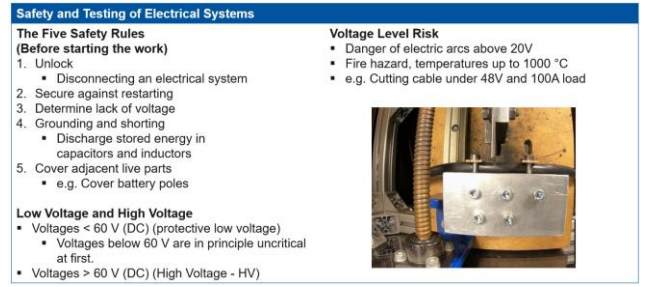
- **What are possible powertrain topologies of micro mobiles?**
  - Both two- and three-wheelers can be built with different powertrain topologies



- **How much power do micromobiles need?**
  - Power demand depends mainly on vehicle mass and desired maximum velocity



- **Which safety aspects are important for micromobiles?**
  - For high voltage safety, high mechanical stress on the cables must be avoided
  - Live wires must be insulated sufficiently
  - Motorcyclists can use protection gear



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Backup

Energy Consumption and Range
Impacts on Range and Testing

Impacts on Range

External factors impacting range
- Hills and valleys in the area of use (changes in altitudes)
- Driver behavior
- Ambient temperature
- Road condition (paved / not paved)

Larger vehicles have a higher air drag
- ➢ Keeping the air drag low increases range
- ➢ The shape of the vehicle is also important

Heavy vehicles have a high rolling resistance
- ➢ Keeping the weight low increases range

Battery size
- ➢ More energy, more range

Means to Determine the Range

Simulation
- Simulate the vehicle in a driving cycle
- Needs parameterization
- Fast, reproducible results

Testbench
- Needs a functioning prototype
- Stationary measurement
- Needs a test bench facility

Source: IEEE

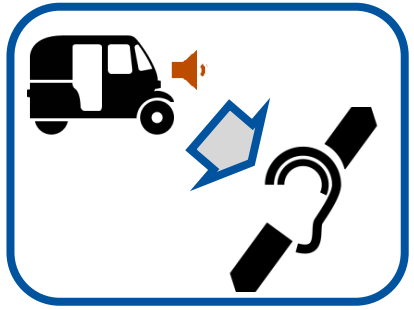
Real World Driving Test
- Needs at least a functioning prototype
- Needs mobile measurement
- Very time consuming

Source: ADAC

Micromobiles on System Level
Synthetic Driving Sound

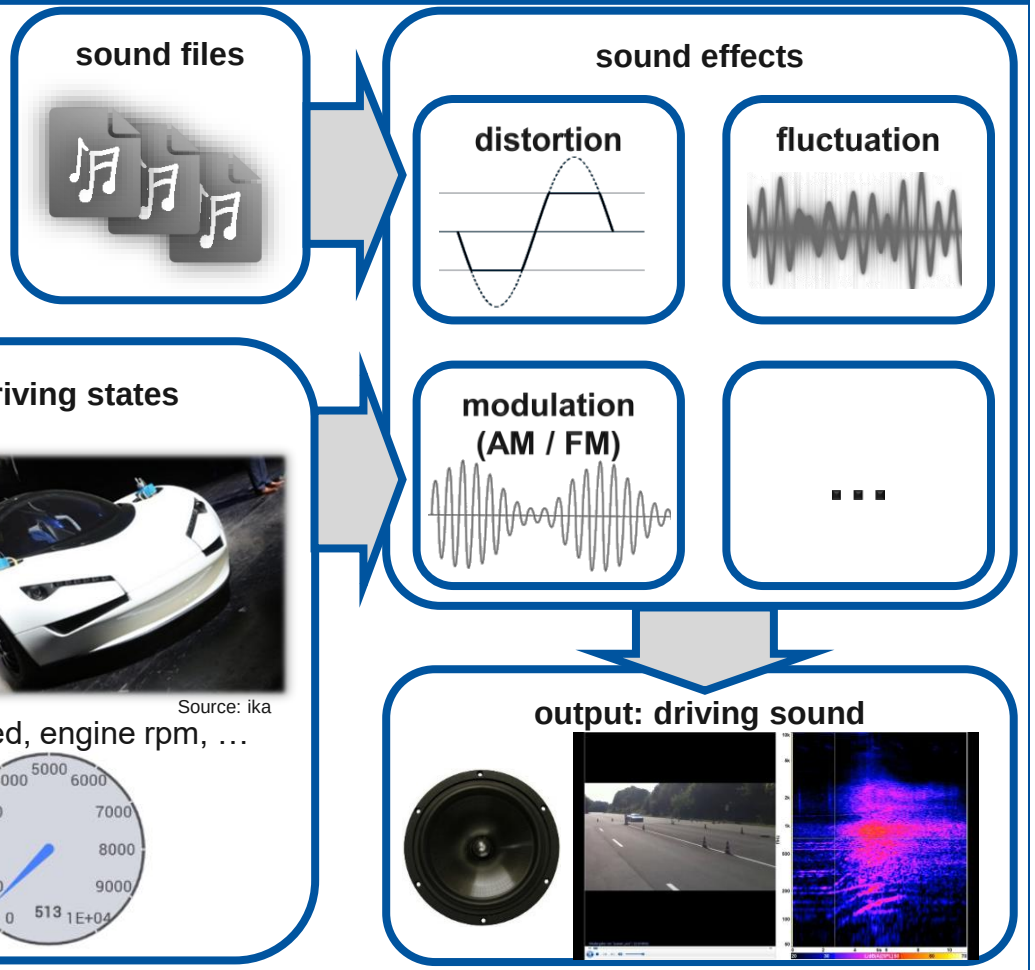
Background

- Sound of electric micromobiles compared to combustion vehicles:
  - \+ Quieter sound
  - \+ More pleasant environment
  - \- May be overheard
  - \- Resulting **higher safety risk**



- **Solution**: Acoustic Vehicle Alerting System (AVAS)
  - Creation of a synthetic driving sound
  - Legal obligation in EU, USA, China, Japan, …
- Not allowed signals:
  - Siren, horn, bell, alarm sounds
  - Music, animals, confusing sounds

Processing of Active Sound Design for AVAS



HMI
Displays & Controls

Displays

Displays are devices that give persons **information about processes**

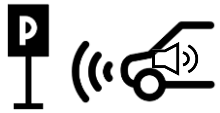
&

Controls

Control elements are all components gathering **input from the user**

Example: How to choose your Information Display:

Human Modality

		+	−
visual		▪ Can carry high information load	▪ Probably distracting ▪ Already intensively used modality ▪ Requires change of visual focus
acoustic		▪ Driver can see the road ▪ High salience possible	▪ Eventually too high salience (distracting) ▪ Usually addresses all passengers ▪ Speed of information transmission is relatively fixed
haptic – tactile		▪ Very intense and direct ▪ Attention grabbing ▪ Eyes free	▪ Needs to be interpreted ▪ Low information load ▪ Intrusive ▪ Low resolution
haptic – kinaesthetic		▪ Very intention grabbing	▪ Very Intrusive ▪ Low information load

Injury Classification

- AIS (Abbreviated Injury Scale): Indicator for evaluating the severity of an injury with regard to the probability of survival
- The classification of an injury in the AIS System is dependant on the medical state of the art

AIS	Injury	Examples
0	none	
1	minor	abrasion and cutting injuries, contusions or others
2	moderately severe	deep flesh wounds, concussion with unconsciousness under 15 min. uncomplicated bone fractures
3	severe, not life-threatening	fractures of the skull without injuries of the brain, luxations of the spine underneath the fourth cervical vertebra without damage to the spinal cord, loss of one eye, multiple rib fractures without paradox breathing
4	very severe, life-threatening, survival probable	contusion of the brain with or without fracture of the skull with unconsciousness under 12 hours, paradox breathing, bladder rupture, loss of a leg above the knee
5	very severe, survival uncertain	fractures of the spinal column underneath the fourth cervical vertebra with damage to the spinal cord, ruptures of the intestine and heart, unconsciousness for more than 12 hours including bleeding inside the skull
6	very severe or fatal, survival improbable	fractures of the cervical vertebra above the third cervical vertebra including damage to the spinal cord, most servere, open chest cavity injuries and abdominal cavity injuries
9		unknown injuries