Emerging Implications of Electric Bicycles

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Presentation Outline

- Introduction
- E-Bike fundamentals
  - The physics, the terminology and the technology
- Regulating E-bikes – an international comparison
- Market size and segments
- Emerging issues
- Conclusions

Introduction

- The bicycle has a role to play in enhancing the sustainability of urban transportation systems however its performance depends on the physical ability of the rider
  - Provision of power assistance could expand the role of the bicycle in the context of urban transportation
- This seminar examines electric bicycles (E-Bikes) and aims to
  - Characterise their technological development
  - Compare and contrast international regulations governing their use
  - Identify emerging issues of relevance to the transportation profession

E-Bike Fundamentals

- E-bike physics 101
  - Kinetic energy
  - Power required for movement

Kinetic energy

- Kinetic energy is the energy an object possesses due to its motion
  - Kinetic energy management is crucial in transportation safety

Kinetic Energy

\[ KE = \frac{1}{2} MV^2 \]

\[ M = \text{mass} \]
\[ V = \text{velocity (speed)} \]

2 x speed = 4 x KE
3 x speed = 9 x KE

200000 400000 600000 800000 1000000 1200000 1400000
0 1 0 2 0 3 0

Kinetic Energy (Joules)

Speed (mph)

R + B = 85 kg (187 lbs)
R + B = 155 kg (341 lbs)
Power required for movement

- **Power is required to overcome 3 forces**
  - Rolling resistance
  - Gravity (grade)
  - Wind resistance

\[
P = (a+g)MV + bFV^3
\]

where
- \(a\) = coefficient of rolling resistance
- \(b\) = drag factor
- \(g\) = grade of hill (\%)
- \(M\) = mass (rider + bicycle)
- \(F\) = frontal area
- \(V\) = speed

Cyclist on a regular bicycle, traveling at 20 mph on a flat road, no headwind
- Power required = 220 watts

What power output can a person sustain?
- Untrained cyclist: 80 W
- Fit cyclist, training ride: 150 to 200 W
- World one hour record holders: 300 W
- Elite athletes in a sprint (short duration): 1000 W

E-bike Fundamentals: Terminology and Technology

- **Powered bicycle (E-PB) versus Power assisted bicycle (E-PAB)**
  - Pedalelec = name used for those bicycles where the rider must be pedaling for the motor to provide power
  - Term ‘hybrid power’ being used by some manufacturers
Motor options to provide the extra power

- **Friction drive**
- **Direct (chain) drive**
- **Hub (front or rear)**
  - Some have regenerative capacity

Battery technology

- **Sealed lead acid (SLA)**
  - Well understood and cheapest
  - Heavy
  - Modest life
- **Nickel Metal Hydride (NiMh)**
  - Lighter than SLA
  - Extended life
  - Sensitive to discharge/charge pattern
- **Lithium Ion (Li-ion)**
  - Lighter than NiMh
  - Less sensitive to dis/charge pattern
  - State of the art but expensive

Battery Capacity

- **Critical factors are**
  - Voltage (like pressure)
  - Amp hour rating (rate of flow)
- **Energy content of battery = Volts x Amp hr**
  - For example, 24 Volt battery pack rated at 10 Amp hr = 24 x 10 = 240 watt hrs
- **If motor consumes 12 W hrs per mile**
  - Riding range = 240/12 = 20 miles
- **Battery packs on E-bikes typically range from 240 W hr to 650 W hr**

E-bike Fundamentals: Some designs are like a conventional bicycle

E-bike Fundamentals: other designs are like motor scooters

E-bike velomobile designs

- **Human Powered**
- **Human + Motor Powered**
Emerging designs

- Bik.e
- Yike

Are these bicycles?

Emerging designs

- Bik.e
- Yike

Are these bicycles?

It depends on the regulations

Regulating E-bikes

- In many jurisdictions, vehicles not solely human powered are classified as bicycles

US legislation from 2002 states that:

For the purpose of this section, the term ‘low-speed electric bicycle’ means a two- or three-wheeled vehicle with fully operable pedals and an electric motor of less than 750 watts (1 h.p.), whose maximum speed on a paved level surface, when powered solely by such a motor while ridden by an operator who weighs 170 pounds, is less than 20 mph (32 kph).

250W, only provides power when rider is pedaling (E-PAB)
Institute of Transport Studies

Three wheels, operable pedals, 500 W motor, max speed of 20 mph (motor only)

750 W, only provides power when rider is pedaling

Operable pedals, 500W motor, max speed of 20 mph (motor only)

Comparison of international E-bike regulations

<table>
<thead>
<tr>
<th>Country</th>
<th>Power Limit</th>
<th>E-PB allowed?</th>
<th>E-PAB allowed?</th>
<th>Maximum speed under power assistance</th>
<th>Other conditions and comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>750 W</td>
<td>✓</td>
<td>✓</td>
<td>32 kph</td>
<td>Operable pedals required</td>
</tr>
<tr>
<td>Canada</td>
<td>500 W</td>
<td></td>
<td></td>
<td>32 kph</td>
<td>Power assistance only above 32 kph</td>
</tr>
<tr>
<td>EU</td>
<td>250 W</td>
<td></td>
<td>✓</td>
<td>25 kph</td>
<td>Power assistance only when pedaling and up to 25 kph</td>
</tr>
<tr>
<td>Japan</td>
<td>250 W</td>
<td></td>
<td>✓</td>
<td>24 kph</td>
<td>Max assistance at 15 kph declining to zero above 24 kph</td>
</tr>
<tr>
<td>China</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>20 kph</td>
<td>Little evidence of enforcement</td>
</tr>
<tr>
<td>Australia</td>
<td>200 W</td>
<td>✓</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Local, Oregon Situation

- Oregon State Law (ORS 801.258) defines an electric assisted bicycle similarly to the US Federal legislation but allows up to 1,000 W
- In Oregon, a driver license is not required for electric assisted bicycles
  - but riders must be at least 16 years old and be eligible for driving privileges
- (Unsuccessful) 2009 Oregon Senate Bill sought to modify electric bicycle regulations to allow up to 3,800 W and 35 mph

What about vehicles which don’t fit the definition of an electric assisted bicycle?

- Could fit into the ‘moped’ category
- Under Oregon Law:
  - "independent power source that is capable of propelling the vehicle, unassisted, at a speed of not more than 30 miles per hour on a level road surface
  - power drive system that functions directly or automatically only and does not require clutching or shifting by the operator after the system is engaged.
  - Requires registration and license
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E-bike regulations

• **Clearly little international consistency**
  
  – Does there have to be?

• **Adverse safety and mobility impacts may arise from use of vehicles which are ‘legal’ under current regulations**
  
  – Also implications for operations (establishing speed limits) and enforcement

• **Merit in considering a performance based standard framework for regulating these and similar vehicles**

Market size

• **Global E-bike sales in 2010 reportedly estimated to be 24 million**
  
  – 21.6 million (90%) in China
  
  – 1.2 million (5%) in rest of Asia (India, Japan, Taiwan, and S.E. Asia)
  
  – About 700,000 in Europe (50% of them in Holland and Germany)
  
  – About 300,000 in USA (up from 150,000 in 2009)

Market segments

• In China, E-bikes are not a transitional mode between human-powered bikes and car use, but a more affordable, higher quality mobility option to public transport (specifically buses)

Market segments (Cont.)

• **Rider age or a health constraint may make it impossible, or uncomfortable, to bike**
  
  – E-bike can provide independent mobility where bicycle, car or transit may not be an option

• **Individuals who would not otherwise ride**
  
  – Overcome distance or hills where car might be preferred to conventional bike
  
  > may increase the frequency or range of riding
  
  – could relax end of trip facilities as a constraint
Market segments – Evidence of greater appeal to women riders

- In Japan, three quarters of purchasers are women and about two thirds of all purchasers are over 50 years of age.
- While not as extreme a distribution, more women than men also use E-Bikes in China.
- Informal market feedback in the USA suggests 50/50 male/female purchaser split.
  - E-bike as an equaliser, safety dimension appeals (easier to get going, stable more quickly, speed maintenance)

Market segments (Cont.)

- Enhanced load carrying suited to cargo bikes and city delivery vehicles.

Market potential: Limited experience reported from western countries

- Electric Bike 2000 Field trial in Quebec, Canada loaned E-bikes to 369 participants to try for commuting.
  - Nearly two-thirds (64%) said they were prepared to use E-bikes as a mode of transport to commute.
- “Early adopters” project being undertaken at PSU.
  - Confirms E-bikes are being used for commuting, replace trips that would otherwise be undertaken by car rather than conventional bike or transit.

Market niche and potential for E-bikes in the USA remains unclear

- Increased exposure through general retail, specialist E-bike stores and in regular bike shops could stimulate uptake.

Will E-bikes cross the Chasm?

- Will cycling (sub) culture support or oppose the jump?
Will E-bikes cross the Chasm?

Should the transportation profession stimulate the chasm jump for these vehicles?

Portland’s 2030 Bike Master Plan

BICYCLING IN PORTLAND HAS EVOLVED

Safety Issues

- Concerns in China where some scooter style vehicles do over 25 mph (40 kph) and there is little enforcement
- Limited experience from western countries
  - Canada: Electric Bike 2000 Field trial conducted
    > Strong support for use on bike paths (comparable speeds to conventional bicycle), enhanced perceived safety clearing intersections and increased willingness to stop at STOP signs
  - USA: not aware of reports of deteriorated safety outcomes arising from crash reports

Safety implications

- Potential to be proactive in relation safety concerns
  - Scope to reduce the kinetic energy to be dissipated in a crash
    > Ensure braking systems are adequate
    > Advanced battery technology has potential to reduce weight
    > Technology to limit maximum speed under power assistance

Enforcement Issues

- Vehicles
  - Modifications to enhance performance
- User behaviour
  - Speed appropriate for conditions
Environmental Impacts

- Manufacture and recycling/disposal of batteries
- Production of energy for recharging batteries
  - Associated issue of charging locations and need for recharging stations

Solar recharging option

- Sanyo has recently installed two solar recharging stations in Tokyo for its Eneloop E--bike

Conclusions

- Evidence suggests that E-bikes will become more prevalent
  - Unclear what their market potential is or whether the transportation profession will proactively stimulate their uptake
- Clear mobility, safety and environmental tradeoffs requiring management
  - Transportation agencies need to be aware of this emerging vehicle type and their implications for how the transportation system is regulated, designed and operated