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 = \( \frac{1}{2} M V^2 \)

M = mass
V = velocity (speed)

2 x speed = 4 x KE
3 x speed = 9 x KE
Power required for movement

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

- **Power required (P) in Watts (W) =**
  - Power for rolling resistance (aMV)
  - + Power for grade (Gravity) (gMV)
  - + Power for wind resistance (bFV^3)

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

where

- a = coefficient of rolling resistance, b = drag factor
- g = grade of hill (%)
- M = mass (rider + bicycle), F = frontal area
- V = speed
Power required for movement

- **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
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)
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)

17.5 inches

180 lbs
## 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 3 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 a 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
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?

Technology Adoption Lifecycle

Innovators
Early Adopters
Early Majority
Late Majority
Laggards

"The Chasm"

Area under the curve represents number of customers
Will E-bikes cross the Chasm?

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

"The Chasm"

Innovators

Early Adopters

Early Majority

Late Majority

Laggards

Technology Adoption Lifecycle

Area under the curve represents number of customers

Should the transportation profession stimulate the chasm jump for these vehicles?
Portland’s 2030 Bike Master Plan

Bicycling in Portland has evolved:

PRE-BMP: Fearless Cyclist

1996 BMP: Confident Cyclist

2009 BMP: All Portlanders

"Who we are planning for has changed with time."
Is there a role for E-bikes here?

60% Interested, but Concerned

10% Confident

30% No Way, No How
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