MONASH University

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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

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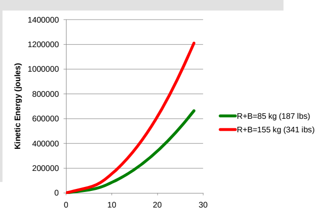
$$\text{Kinetic Energy} = \frac{1}{2}MV^2$$

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

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  - Power required = 220 watts

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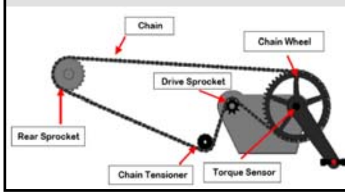
  - Power required = 220 watts
- **What power output can a person sustain?**
  - Untrained cyclist: 80 W
  - Fit cyclist, training ride: 150 to 200^+ W
  - World one hour record holders: 300 W
  - Elite athletes in a sprint (short duration): 1000 W

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**

Are these bicycles?

Yike

Emerging designs

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Are these bicycles?

It depends on the regulations

Yike

Regulating E-bikes

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

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)

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750 W, only provides power when rider is pedaling

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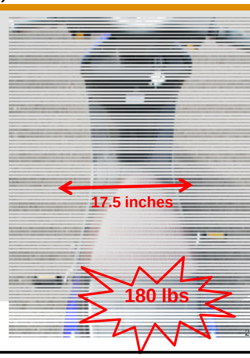
Operable pedals, 500W motor, max speed of 20 mph (motor only)



Comparison of international E-bike regulations

Country	Power Limit	E-PB allowed?	E-PAB allowed?	Maximum speed under power assistance	Other conditions and comments
USA	750 W	✓	✓	32 kph	Operable pedals required
Canada	500 W	✓	✓	32 kph	Power assistance only above 3 kph
EU	250 W	✗	✓	25 kph	Power assistance only when pedaling and up to 25 kph
Japan	250 W	✗	✓	24 kph	Max assistance at 15 kph declining to zero above 24 kph
China	-	✓	✓	20 kph	Little evidence of enforcement
Australia	200 W	✓	✓	-	

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**

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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

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

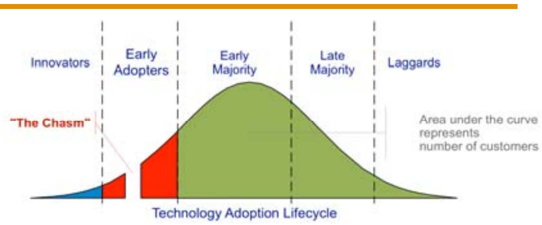
Market potential: Limited experience reported from western countries

- 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?



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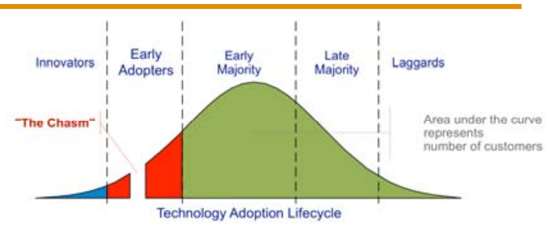
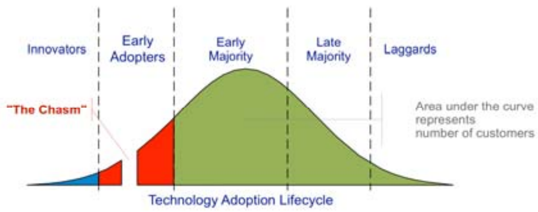


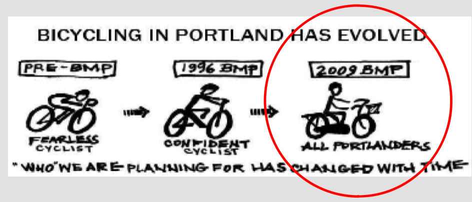
Will cycling (sub) culture support or oppose the jump?

Will E-bikes cross the Chasm?

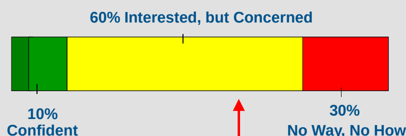


Should the transportation profession stimulate the chasm jump for these vehicles?

Portland's 2030 Bike Master Plan



Reaching everyone



Is there a role for E-bikes here?

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