ELECTRIFYING TORONTO’S TRANSPORTATION:
SOONER AND LATER

Richard Gilbert

Presentation to the
Greater Toronto Transportation Conference
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SOONER AND LATER?

‘SOONER’ REFERS TO A PROPOSED REFASHIONING OF TRANSIT CITY TO ACHIEVE MORE ELECTRIFICATION WITHIN THE SAME BUDGET.

‘LATER’ REFERS TO THE LONGER LOOK AT ELECTRIFICATION THAT CONCLUDES THIS PRESENTATION.
FIRST, SOME REMINDERS OF OUR OIL PREDICAMENT
FIRST OF TWO SIMILAR INDICATIONS THAT THE WORLD OF OIL IS ABOUT TO CHANGE:

a huge gap in anticipated supply in relation to expected demand

Source: US Energy Information Administration, April 2009
SECOND SIMILAR INDICATION THAT THE WORLD OF OIL IS ABOUT TO CHANGE: a huge gap in anticipated supply in relation to expected demand.

Shortfalls in millions of barrels per day: **43 in 2028; 45 in 2030; 52 in 2035**

Source: International Energy Agency, World Energy Outlook, 2010 (Figure 3.19)
A THIRD INDICATION THAT THE WORLD OF OIL IS ABOUT TO CHANGE: production of petroleum liquids may not have peaked yet, but exports have
A special oil challenge for Ontario

Ontario has no stockpiled oil

Every nation except Canada maintains substantial stockpiles of oil to protect against interruptions in supply

SOURCES OF ONTARIO’S OIL IN 2009

- 76% came from Western Canada, all shipped through the U.S.
- 20% came from outside North America; Algeria was the main supplier
- 4% came from sources in Eastern Canada
There is always optimism

The New York Times
Tuesday, November 16, 2010

There Will Be Fuel

By CLIFFORD KRAUSS

NEW OIL SUPPLIES Pipes await use at the Devon Jackfish oil sands drilling project, left, under construction in Alberta, Canada. The country’s oil sands supply more oil for North America than Saudi Arabia does. THREE summers ago, the world’s supertankers were racing across the oceans as fast as they could to deliver oil to markets growing increasingly thirsty for energy. Americans were grumbling about paying as much as $4 a gallon for gasoline, as the price of crude oil leapt to $147 a barrel. Natural gas prices were vaulting too, sending home electricity bills soaring.

NO SHORTAGE A Chesapeake Energy natural gas well near Burlington, Pa. Experts say the nation has gas reserves for 100-plus years.

Ralph Wilson/Associated Press
ELECTRIFYING TORONTO’S TRANSPORTATION SOONER: REFASHIONING TRANSIT CITY
CURRENT PROJECT
(west from Finch West station; 2019;
11 km at $75 [C$49] million /km)

CURRENT PROJECT
(Spadina line extension to Vaughan
City Centre; 2015
8.6 km at $306 [C$3007] million/km)

CURRENT PROJECT
(to Morningside Ave. and
maintenance/storage yard; 2014;
12 km at $86 [C$78] million/km)

CURRENT PROJECT
(Jane St. to Kennedy Ave.
tunnelled section shown; 2020;
10 km tunnelled at $458 [C$361] million/km;
9 km surface at $80 [C$64] million/km)

CURRENT PROJECT
(Kennedy Ave. to Sheppard Ave. E.
replacing Scarborough RT; 2020;
9.5 km at $219 [C$152] million/km)

Red dollar amounts
are 2010$. Others are
current dollars.
CURRENT PROJECT
(Spadina line extension to Vaughan City Centre; 2015
8.6 km at $306 [33007] million/km)

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(to Morningside Ave. and maintenance/storage yard; 2014;
12 km at $86 [578] million/km)

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replacing Scarborough RT; 2020;
9.5 km at $219 [152] million/km)

Red dollar amounts are 2010$. Others are current dollars.
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PROPOSED PROJECT
(Sheppard line extension to Downsview station; 4.5 km at about $300 million/km; stations at Bathurst and perhaps Senlac and Wilmington)

PROPOSED PROJECT
(Extension of Finch trolley to Don Mills station.)
One of Vancouver’s 228 new trolleybuses
(made in Winnipeg; 40 are articulated)
Trolleybus capital costs per two-way kilometre
(based on the system installed in Landskrona, Sweden, in 2003)

<table>
<thead>
<tr>
<th>Item</th>
<th>Actual cost/km in millions of Swedish krona in 2003</th>
<th>In 2010 Can$ (tripling bus capacity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wires and poles</td>
<td>5.6</td>
<td>1.1</td>
</tr>
<tr>
<td>Substation</td>
<td>1.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Vehicles*</td>
<td>5.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Other</td>
<td>1.7</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>13.6</strong></td>
<td><strong>4.7</strong></td>
</tr>
</tbody>
</table>

*Landskrona initially provided one single-unit (29 seated, 41 standing, low-floor) trolleybus per two-way route-km, enough for an average 8.5-minute headway. The proposal for Toronto would provide three times this capacity.*
A new plan for Transit City that stays within the current budget, adds two subway lines, and completes the whole program (rather than less than half of it) by 2020

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
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<tbody>
<tr>
<td>Sheppard LTR (Ph. 1)</td>
<td>1,030</td>
<td>Sheppard LRT</td>
<td>1,240</td>
<td>Both phases</td>
</tr>
<tr>
<td>Eglinton LTR (tunneled)</td>
<td>3,610</td>
<td>Eglinton subway</td>
<td>3,000</td>
<td>Use Spadina per-km cost</td>
</tr>
<tr>
<td>Eglinton LRT (surface, Ph. 1)</td>
<td>576</td>
<td>Eglinton trolleys (east, west)*</td>
<td>115</td>
<td>All phases</td>
</tr>
<tr>
<td>Scarborough LRT (Ph. 1)</td>
<td>1,445</td>
<td>Scarborough trolley*</td>
<td>50</td>
<td>LRT is too much per km</td>
</tr>
<tr>
<td>Finch LRT (Ph. 1)</td>
<td>535</td>
<td>Finch trolley*</td>
<td>110</td>
<td>To Don Mills station</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sheppard subway extension</td>
<td>1,410</td>
<td>Use Spadina per-km cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jane trolley*</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Don Mills trolley*</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Malvern LRT</td>
<td>720</td>
<td>Use Finch per-km cost</td>
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<td></td>
<td></td>
<td>West Waterfront LRT ?</td>
<td>376</td>
<td>Balance of funds</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>7,196</strong></td>
<td><strong>Total</strong></td>
<td><strong>7,196</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Trolleybus system costs have been estimated at $5.0 million per route-kilometre, following previous slide
How has this been done?

Unchanged: Sheppard E. LRT (Ph. 1) including yard (12 km)

Delete: Eglinton LRT, Finch LRT, Scarborough LRT (40 km)...-$6,166 mill.

Add: Sheppard E. LRT (Ph. 2), Malvern LRT, and West Waterfront LRT (27 km)...+$1,306 mill.

Add: Sheppard West subway, Eglinton subway (14 km)...+$4,410 mill.

Add: Eglinton (E. and W.) trolleys, Scarborough trolley, Finch trolley (to Don Mills), Jane trolley, Don Mills trolley (83 km)...+$450 mill.

TOTAL CHANGE...$0

Note: Cost of trolleybus maintenance and storage yards is not included. (Existing bus yards can be converted at relatively little cost.)
Issues in refashioning Transit City

Too many LRT vehicles are on order.  
*Negotiate with Bombardier to replace some of these with subway cars.*

Tunnelling machines ordered for Eglinton.  
*To be bored to subway specifications anyway.*

Tunnelling machines needed for the Sheppard extension.  
*Use the machines being used for the Spadina extension.*

Trolleybuses take up roadway.  
*But perhaps less roadway than LRT, even on own rights-of-way.*

Parts of Eglinton and Sheppard must be massively redeveloped to justify a subway.  
*True. Start now; be very generous to neighbourhoods and property owners. (Some redevelopment should in any case be planned to justify LRT.)*

The provincial government won’t agree to a change in plan.  
*The province will likely agree with what Toronto wants unless it costs more, is less cost-effective or results in undue delay.*
Capital costs can be huge

Current estimated cost of Eglinton LRT is $4.186 billion in 2010$.

Annual ridership along Eglinton is projected to be 52 million/year.

Annual cost of $4.186 billion over 35 years at 4% is about $222.2 million.

Thus, capital cost per Eglinton LRT ride is about $4.25. (Plus an operating cost of perhaps $2.00/ride.)

With installation of a subway, and appropriate development, the capital cost per ride could perhaps be reduced to about $1.00 per ride (presumes about four times the ridership).
Development must be subway-related

There is much recent and ongoing development along Sheppard Avenue East.

Relative ridership on the Sheppard line is not increasing.

It was 4.0% of the ridership on the YUS and BD lines in 2007-2008.

It was 3.9% of the ridership on these lines in 2009-2010.

For the most part, the new development is not subway-related.
Along the Spadina extension
Vaughan Corporate Centre station location

click here to return to slide show
Development at Vaughan Corporate Centre ignores the subway

The above is from the City of Vaughan Web site, November 2010

click here to read shaded paragraph
At 1,500 acres, the Vaughan Corporate Centre is the largest and most ambitious project in the city’s history. Designed as an urban gateway to the City of Vaughan, the area is easily accessible from two major highway systems which provide direct travel corridors west to Pearson International Airport and south to downtown Toronto.
Metrolinx has estimated residents or jobs at three Spadina extension stations in 2031 (adjusted to within 600-metre radius of station)

<table>
<thead>
<tr>
<th>Station</th>
<th>Residents or jobs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaughan Corporate Centre</td>
<td>15,000</td>
</tr>
<tr>
<td>Steeles West</td>
<td>12,000</td>
</tr>
<tr>
<td>Finch West</td>
<td>12,000</td>
</tr>
</tbody>
</table>

My rough estimate of residents/jobs needed within 600 metres of each station for a subway line to pay its way \( \approx 40,000 \) (per km\(^2\)).

(See 2006 *Toronto Star* article in next slide.)

Also see Lo et al (2008, p46): “Our rough estimate was that a minimum population density of 31,500/km\(^2\) was essential to achieve breakeven operations.”
Building subways without subsidies
Aug. 28, 2006. 01:00 AM
RICHARD GILBERT

Transit subsidies are relatively new. The TTC functioned without capital subsidies until the 1960s, and without regular operating subsidies until the 1970s. The initial section of the Yonge line, opened in 1954, was funded almost entirely from the fare box, as were much of the University line and the initial section of the Bloor-Danforth line, opened in 1966.

Now, operating subsidies are expected, and so are even larger capital subsidies, especially for new subway lines.

Several things have changed. The most important is that, compared with the 1950s, the TTC now provides twice as much service for every 100 passengers it carries (about 47 vehicle-kilometres of service in 2004, compared with 23 in 1954).

In the 1950s, service was mostly in the denser, inner parts of Toronto. Since then, it has
Hong Kong shows that subways can be built and operated without subsidy (if densities are high enough).
Familiar image of Hong Kong
But, much of it is like this (no subway here)
Or like this

click here to return to slide show
Opportunities for development along an Eglinton subway line

Eglinton and Keele
Opportunities for development along an Eglinton subway line

Eglinton and Caledonia
Opportunities for development along an Eglinton subway line

Eglinton and Dufferin
Opportunities for development along an Eglinton subway line

Eglinton and Oakwood
Opportunities for development along an Eglinton subway line

Eglinton and Oakwood (looking south)
Opportunities for development along an Eglinton subway line

Eglinton and Oakwood (looking east)
Opportunities for development along an Eglinton subway line

Eglinton and Oakwood (looking west)
Opportunities for development along an Eglinton subway line

Eglinton West station
Opportunities for development along a Sheppard W. subway line

Sheppard W. and Bathurst
Opportunities for development along a Sheppard W. subway line

Sheppard W. and Wilmington
Why build Sheppard W. subway (4.5 km) when another 270 km of trolleybus route could be added with the same funds?

Main reason could be to provide test of proposition that subways can be built without subsidies (if built in conjunction with appropriate development).

Also, could another 270 km be accommodated?
Encouraging news from GO TRANSIT

Preliminary findings from GO’s Electrification Study:

1. Electric locomotives – at right – are the most cost effective (vs. diesel, dual mode, electric multiple, maglev, etc., etc.)

2. Six options remain under consideration, include electrifying entire system (at right)
Encouraging news from Quebec

Un monorail Montréal-Québec?

Une capsule de 80 places, suspendue dans les airs au-dessus de l’autoroute 20, qui filerait à 250 km/h vers la capitale nationale.

PHOTO FOURNIE PAR L’IREC

Gabriel Bélard
Cyberpresse

Imaginez-vous un instant assis dans une capsule d’un peu moins de 80 places, suspendue dans les airs au-dessus de l’autoroute 20, et qui file à 250 km/h vers la capitale nationale.

Ce projet n’a rien d’un scénario de science-fiction. Il est plutôt le fruit d’une étude de l’Institut de recherche en économie contemporaine (IREC) sur la

Disney World monorail
(since 1971; trains by Bombardier)

Wuppertal Schwebebahn
(since 1898)
ELECTRIFYING TORONTO’S TRANSPORTATION LATER: BUBBLES AND BEAMS?
Most trips by Toronto residents are made by car, even residents of the core during rush periods.

Core
(roughly former Toronto, E. York, York – PDs 1-6)

During rush hours
- Transit: 11%
- Cycle/walk: 35%
- Automobile: 54%

During other hours
- Transit: 13%
- Cycle/walk: 62%
- Automobile: 25%

Inner suburbs
(roughly former Etobicoke, N. York, Scarborough – PDs 7-16)

During rush hours
- Transit: 4%
- Cycle/walk: 24%
- Automobile: 73%

During other hours
- Transit: 7%
- Cycle/walk: 77%
- Automobile: 17%
There is frequent overstatement of how bad things are for drivers. For example, *Globe and Mail* reports on IBM’s May 2010 international survey of “commuter pain” included the following:

- “Five North American cities were polled and Toronto (surprise) topped the list of most unhappy commuters”
- “Torontonians are more aggravated by their daily commute than residents of New York, Los Angeles or Montreal.”

The survey actually showed that respondents in the Toronto region:
- mostly (67%) have a commute time of less than 30 minutes, with only 4% over 45 minutes;
- are able to leave for work later on average than in other North American regions;
- are less inclined than in other regions to switch to transit when fuel prices rise; and
- are less inclined to report travel stress than residents of Los Angeles and Montreal.
What surveys show depends on the questions you ask.

If you ask “Is congestion a problem in your city (area, community, neighbourhood, etc.)?” up to 90% respond “Yes.”

If you ask “Is congestion a problem for you?”, up to 90% respond “No.”

Similar differences in results occur when you ask about crime.
Only bright feature of car use

Driving by the Toronto region’s 16- to 20-year-olds fell by more than a third per capita between 1986 and 2006.

Possible causes: (1) graduated permit; (2) high insurance rates; (3) greater interest in electronics.

How can this be used to change a culture of automobile dependence?
Need to reduce dependence on oil

- Continue using internal combustion engines (ICEs)
- Switch to electric motors
- Switch to grid-connected vehicles

CURRENT PREDICAMENT

BASIC CHOICES

FOUR SCENARIONS

FURTHER ALTERNATIVES

CHALLENGES

- Raise ICE efficiency enough to offset oil depletion, or lower transport activity
- Produce sufficient fuel without adding pollution or reducing food production
- Improve batteries and lower their cost enough to provide acceptable vehicles
- Achieve settlements dense enough to make public transit feasible
- Develop and deliver acceptable and affordable PRT systems
Need to reduce dependence on oil

Continue using internal combustion engines (ICEs)

Switch to grid-connected vehicles

Focus on personal rapid transit (PRT)

Focus on public transit

Switch to alternative ICE fuel

Continue using automobiles (and trucks)

Continue using oil

Switch to electric motors

Raise ICE efficiency enough to offset oil depletion, or lower transport activity

Produce sufficient fuel without adding pollution or reducing food production

Improve batteries and lower their cost enough to provide acceptable vehicles

Achieve settlements dense enough to make public transit feasible

Develop and deliver acceptable and affordable PRT systems
New-LDV fuel economy (CAFE) standards are set to rise by 2025

- Will fall from 9.2 to 6.6 L/100km, 2010-2016 (25.5 to 35.5 mpg)
- *May* fall from 6.6 to 3.7 L/100km, 2017-2025 (35.5 to 62.0 mpg)
- Result *if activity level and fleet turnover rates are unchanged* would reduce oil consumption for LDV vehicle use by about 40% by 2025
- This is consistent with possible oil depletion by 2025: about 40%
- But may not allow for maintenance of more essential uses (aviation, pharmaceuticals, plastics, fertilizers, pesticides)
- And fuel economy often has perverse effects (Jevons Paradox)
Need to reduce dependence on oil

Continue using internal combustion engines (ICEs)

Switch to alternative ICE fuel

Switch to grid-connected vehicles

Continue using oil

Continue using automobiles (and trucks)

Focus on public transit

Focus on personal rapid transit (PRT)

Current Predicament

Basic Choices

Four Scenarios

Further Alternatives

Challenges

Raise ICE efficiency enough to offset oil depletion, or lower transport activity

Produce sufficient fuel without adding pollution or reducing food production

Improve batteries and lower their cost enough to provide acceptable vehicles

Achieve settlements dense enough to make public transit feasible

Develop and deliver acceptable and affordable PRT systems
Need to reduce dependence on oil

Switch to electric motors

Continue using internal combustion engines (ICEs)

Continue using oil

Switch to alternative ICE fuel

Continue using automobiles (and trucks)

Switch to grid-connected vehicles

Focus on public transit

Focus on personal rapid transit (PRT)

Raise ICE efficiency enough to offset oil depletion, or lower transport activity

Produce sufficient fuel without adding pollution or reducing food production

Improve batteries and lower their cost enough to provide acceptable vehicles

Achieve settlements dense enough to make public transit feasible

Develop and deliver acceptable and affordable PRT systems
Lithium is not good enough; what about barium titanate (EEStor), zinc air? — there is little evidence of feasibility.

The specific energy of both gasoline and diesel fuel is about 12,500 Wh/kg, more than 60 TIMES the maximum value shown here. Thus, even if electric motors are five times as efficient, and batteries improve by a factor of three, there will still be more than a 4:1 difference in effective energy storage.
A fuel-cell solution is **impracticable** because of reliability, cost and, above all, high energy losses.
Need to reduce dependence on oil

Switch to electric motors

Continue using internal combustion engines (ICEs)

Continue using oil

Switch to alternative ICE fuel

Continue using automobiles (and trucks)

Switch to grid-connected vehicles

Focus on public transit

Focus on personal rapid transit (PRT)

Raise ICE efficiency enough to offset oil depletion, or lower transport activity

Produce sufficient fuel without adding pollution or reducing food production

Improve batteries and lower their cost enough to provide acceptable vehicles

Achieve settlements dense enough to make public transit feasible

Develop and deliver acceptable and affordable PRT systems
Need to reduce dependence on oil

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Switch to alternative ICE fuel

Continue using oil

Switch to grid-connected vehicles

Focus on public transit

Focus on personal rapid transit (PRT)

Challenges:

- Raise ICE efficiency enough to offset oil depletion, or lower transport activity
- Produce sufficient fuel without adding pollution or reducing food production
- Improve batteries and lower their cost enough to provide acceptable vehicles
- Achieve settlements dense enough to make public transit feasible
- Develop and deliver acceptable and affordable PRT systems
Trolley trucks are already in frequent use
(Siemens-made, Barrick’s Goldstrike Mine, Nevada)
Grid-connected automobile in 1882 (Siemens, near Berlin)
Another suggestion for grid-connection
But PRT pods captive to guideways may be the best way to go.
This is an artist’s impression of what is being installed at Heathrow Airport, London UK.
Here’s a PRT station at Heathrow’s Terminal 5 car park.
Such a system is being considered for the airport at St. Louis, Missouri.
Similar too is the Vectus PRT system, undergoing trials at the test track in Uppsala, Sweden.
A system in which dedicated pods are hung from the rail could be better, such as this proposal for Seattle, Washington.
And this proposal for Götgatan, Stockholm, Sweden.
There are PRT proposals for San Jose airport, Santa Cruz, and Alameda, all in California.
Proposals for Edina (a suburb of Minneapolis), Ithaca, New York, and Perimeter Center, Atlanta.
Virginia is interested.

Interest and development of PRT appears to be growing around the world. With the inevitable construction of at least two systems and the testing underway of several others … it can be argued that PRT is proving to be a feasible technology.

December 2008 report from the Virginia Department of Rail and Public Transportation to the Governor and General Assembly (State Legislature)
From a comparative analysis done for the State of New Jersey

<table>
<thead>
<tr>
<th></th>
<th>Time for a 6.4-km direct trip, in minutes</th>
<th>Time for a 12.8-km trip, one transfer, in minutes</th>
<th>Average capacity persons/hour/direction</th>
<th>Yearly millions of person-kilometres for each two-way km of service</th>
<th>Capital cost per person-kilometre in dollars</th>
<th>Operating cost per person-kilometre in dollars</th>
<th>Total cost per person-kilometre in dollars</th>
<th>Total cost compared with PRT</th>
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<tbody>
<tr>
<td>Subway</td>
<td>15.0</td>
<td>35.0</td>
<td>14,400</td>
<td>189.2</td>
<td>0.10</td>
<td>0.25</td>
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</tr>
<tr>
<td>LRT subway</td>
<td>19.0</td>
<td>43.0</td>
<td>3,300</td>
<td>43.4</td>
<td>0.45</td>
<td>0.42</td>
<td>0.87</td>
<td>2.59</td>
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<tr>
<td>LRT surface</td>
<td>19.0</td>
<td>43.0</td>
<td>3,300</td>
<td>43.4</td>
<td>0.10</td>
<td>0.42</td>
<td>0.52</td>
<td>1.56</td>
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<tr>
<td>PRT (two-way)</td>
<td>11.4</td>
<td>21.9</td>
<td>4,100</td>
<td>53.9</td>
<td>0.04</td>
<td>0.30</td>
<td>0.34</td>
<td>1.00</td>
</tr>
</tbody>
</table>

We might have had PRT instead of Google

When I was here at Michigan ... I wanted to build a personal rapid transit system on campus to replace the buses. It was a futuristic way of solving our transportation problem. I still think a lot about transportation -- you never loose a dream, it just incubates as a hobby. ...

I think it is often easier to make progress on mega-ambitious dreams. I know that sounds completely nuts. But, since no one else is crazy enough to do it, you have little competition.
Objections to PRT (and streetcars and trolleybuses) include visual pollution, addressed by the ground-level powering of the Tramway de Bordeaux.
The trams of my London childhood, withdrawn in 1952, had optional underground powering (and double-ended operation).
Trams with underground powering had been in operation for decades. Here is a shot from 1919. Note the exposed operator.
At this point, a brief video is shown ‘Bubbles and Beams: A Convenient Future’

To view the video, click here
Signs that a TRANSPORT REVOLUTION is under way
Per-capita vehicle movement and sales in the US, 2000–2010
Monthly vehicle production in China, 2005–2010, seasonally adjusted (≥ 4 wheels) (now mostly ICE-based; EM-based coming see next slide)
China 'to focus on promoting electric cars'

Agence France-Press, Thu Oct 28, 6:48 am ET

BEIJING (AFP) – Chinese authorities have agreed to promote electric cars to address the country's intensifying energy and pollution concerns, as auto sales surge, an official said Thursday.

The Ministry of Industry and Information Technology and other government agencies have studied the future of China's auto industry, Zhu Hongren, the ministry's spokesman, told reporters.

"The basic consensus is to take electric cars as the main strategic direction for the transformation of China's auto industry," Zhu said.

Efforts will be made to develop better batteries, engines and electric control technology with the aim of mass producing electric vehicles and plug-in hybrid cars, he said.

China overtook the United States last year to become the world's largest auto market in terms of units sold. ....
High-speed (200+ km/h) and very high speed (300+ km/h) routes under construction in China

When the Beijing to Ürümqi line is completed in 2015, the travel time for the 3,450 km will be 12 hours (average including stops of 288 km/h)

Beijing to Tianjin: first 300+ km/h line

Shanghai to Nanjing: world’s busiest line

Wuhan to Guangzhou: 350 km/h, world’s fastest
Bombardier 380-km/h, 16-car train for the Beijing-Shanghai route (2014)
For more information about *Transport Revolutions*, visit www.transportrevolutions.info
Monorail using sails proposed by Henry Palmer in 1828


THANKS FOR YOUR INTEREST!

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