RAILROAD MAGLEVICATION
AS AN OPTION FOR ULTRA HIGH SPEED RAIL

Outline

1. The Technology of Maglevication
2. Why Maglevify?
3. Cost-Effectiveness Analysis
4. What About Ridership?
5. Conclusions
What is the Railroad?

- Steel wheels guided by steel rails
- Propulsion and braking limited by wheel-rail adhesion
- Curvature limited by wheel climb, wheel lift, rail roll
- Superelevation (cant) provides a gravitational component of lateral force
  - Causes problems with freight operations
  - Maximum is six inches (FRA standard)
- Imbalance (cant deficiency) = higher speeds
  - Rail wear, passenger comfort, subgrade issues
  - Maximum is three inches (FRA)

What is Magnetic Levitation?

- Linear induction motor provides propulsion
- Vehicle is “floating” – magnetic repulsion
- Lateral magnets provide guidance
**What is Maglevication?**

“The process of retro-fitting magnetic guidance infrastructure to existing railroad network in a backwards-compatible fashion.”

**Design Issues**

- Just like electrification in 1920
  - Steam trains ran ‘under the wires’
- Passenger comfort – tilting trainsets
- Stabilization – low center of gravity, other magnetic features
- Cost – expensive intelligent vehicles, cheaper infrastructure
- Compatibility – freight trains without magnetic assistance run at low speeds
Why Maglevify?

- Leverage value of existing infrastructure
  - High proportion of costs in high-speed rail schemes often ROW related
  - Most rail lines are not capacity constrained, physically speaking
  - Allows sharing of common and joint costs
- Reduce costs of new alignments
  - Higher grades avoids tunnels
  - Sharper curves avoids urban areas
  - Use of highway medians possible
- Incremental design
  - Allows pay-as-you-go financing approach
- Enhance access through penetration
  - Reaches downtown on classic infrastructure
  - Enables areas of lower demand to receive direct high-speed service
- Eliminates transfers

Operating Constraints

<table>
<thead>
<tr>
<th>Type of Infrastructure</th>
<th>Type of Train</th>
<th>C.D.</th>
<th>Curvature Limited</th>
<th>Super-elevation Limited</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ordinary Passenger</strong></td>
<td>X</td>
<td>Ordinary speed</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tilting Passenger</strong></td>
<td>X</td>
<td>Ordinary speed</td>
<td>C.D. restrict</td>
<td></td>
</tr>
<tr>
<td><strong>Maglevified Trainset</strong></td>
<td>Full speed</td>
<td>Enhanced speed</td>
<td>Full speed</td>
<td></td>
</tr>
<tr>
<td><strong>General Freight</strong></td>
<td>X</td>
<td>Ordinary speed</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Maglev Loco plus Freight</strong></td>
<td>T.E. restrict</td>
<td>Ordinary speed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

X = Not permitted
C.D. = Cant deficiency
T.E. = Tractive effort
Cost Effectiveness Analysis

- Performance metrics
  - Cost per mile, cost per minute saved
  - Infrastructure cost per passenger trip
- Geographic assumptions

Cost

- Rail
- Infrastructure
- Rail

Traction performance modelling

Modelling Costs & Benefits

- Journey time savings (benefits)
  - Same geography, different technologies

<table>
<thead>
<tr>
<th>Minute Saving by Improvement Category</th>
<th>Hybrid</th>
<th>Conventional</th>
<th>Maglev</th>
</tr>
</thead>
<tbody>
<tr>
<td>SeaBrd</td>
<td>19</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Mountain (cost)</td>
<td>11</td>
<td>9</td>
<td>54</td>
</tr>
<tr>
<td>Mountain (midway)</td>
<td>83</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Praya</td>
<td>14</td>
<td>14</td>
<td>14.6</td>
</tr>
<tr>
<td>City</td>
<td>6</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Metropolitan</td>
<td>6</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>50.5</td>
<td>28</td>
<td>10</td>
</tr>
</tbody>
</table>

Route improvement costs

- Separates the cost of realignment, maglevification, and constructing rights-of-way

Rail Route Improvement Cost Model

<table>
<thead>
<tr>
<th>Subsidies</th>
<th>City</th>
<th>Prairie</th>
<th>Mountain</th>
<th>SeaBrd</th>
<th>Maglev</th>
</tr>
</thead>
<tbody>
<tr>
<td>% new right of way</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
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<tr>
<td>% maglevation impact</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>% realignment cost reported</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

- Cost per mile ($ million/mile)
  - Average for Maglev: 4.8
  - Average for SeaBrd: 2.8
  - Average for Maglev and SeaBrd: 3.8

- Total Cost ($ million)
  - Maglev: 848
  - SeaBrd: 500

Cost savings for Maglev: $2.642 million
Cost savings for SeaBrd: $1.39 million per mile
The Correct Performance Measure?

- Cost/mile does not measure speed
- Low-cost methods = low performance
  - Price/performance ratio (e.g. $/min-saved)
- What about ridership?
  - Anyone developed an accurate model lately?

The Correct Performance Measure?

- Subject to competitive pricing by airlines
  - Cross-subsidy between corridors
- Assume ridership (from curve), look at infrastructure cost per pax or pax-mile

Ridership is Anyone’s Guess

- 210-mile corridor looks like it’s not going to generate enough traffic

### Cost-Effectiveness Analysis for Maglevication

<table>
<thead>
<tr>
<th>Investment Alternative</th>
<th>Distance (mi)</th>
<th>Cost/mile ($/mile)</th>
<th>Capacity (pax/hr)</th>
<th>Time Saved (min)</th>
<th>Cost/mile ($/mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate Maglevication</td>
<td>200</td>
<td>2.43</td>
<td>30,000</td>
<td>15</td>
<td>60,000</td>
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<tr>
<td>Conventional Maglev</td>
<td>200</td>
<td>1.68</td>
<td>20,000</td>
<td>18</td>
<td>40,000</td>
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<tr>
<td>Conventional Rail</td>
<td>210</td>
<td>0.55</td>
<td>15,000</td>
<td>20</td>
<td>30,000</td>
</tr>
<tr>
<td>Maglev New York, City</td>
<td>200</td>
<td>1.17</td>
<td>15,000</td>
<td>20</td>
<td>30,000</td>
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<tr>
<td>Maglev New York, Region-Maglev</td>
<td>100</td>
<td>0.70</td>
<td>10,000</td>
<td>25</td>
<td>15,000</td>
</tr>
</tbody>
</table>

### Ridership Analysis for Maglevication

<table>
<thead>
<tr>
<th>Investment Alternative</th>
<th>Annual Demand (pax)</th>
<th>Annual Revenue (pax/mile)</th>
<th>Annual Cost (pax/mile)</th>
<th>Ridership Cost per pax (pax/mile)</th>
<th>Ridership Cost per mile (pax/mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate Maglevication</td>
<td>120,000</td>
<td>20,000</td>
<td>10,000</td>
<td>$10,000</td>
<td>$0.08</td>
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<tr>
<td>Conventional Maglev</td>
<td>110,000</td>
<td>18,000</td>
<td>9,000</td>
<td>$9,000</td>
<td>$0.08</td>
</tr>
<tr>
<td>Conventional Rail</td>
<td>100,000</td>
<td>16,000</td>
<td>8,000</td>
<td>$8,000</td>
<td>$0.08</td>
</tr>
<tr>
<td>Maglev New York, City</td>
<td>100,000</td>
<td>14,000</td>
<td>7,000</td>
<td>$7,000</td>
<td>$0.08</td>
</tr>
<tr>
<td>Maglev New York, Region-Maglev</td>
<td>60,000</td>
<td>12,000</td>
<td>6,000</td>
<td>$6,000</td>
<td>$0.08</td>
</tr>
</tbody>
</table>
- Three cities, 2m pop., 50-miles apart
  - Two strong and one medium markets
  - Columbus-Dayton-Cincinnati?
  - Cleveland- Akron-Youngstown-Pittsburgh?

  This is a screening analysis
  - You do it for your favourite local corridor!
  - $0.32 per paxmile is likely lower than the fully-allocated costs of interstate highways serving 100-mile corridors with 3 cities
  - Still better than pie-in-the-sky proposals

- High speed rail and maglev are not cheap
  - But still not cheap!

- Intercity rail research ought to focus on the ‘mode’ with best price/performance ratio; not the mode with best perf.
- Performance is defined in terms of pax utility, not station-to-station ‘flight’ time
- Incremental maglevification has many advantages
  - No need for new ROW, or cheaper ROW
  - Pay-as-you-go financing
  - Backwards-compatibility and penetration
- Intercity rail research ought to focus on ways to maglevify existing infrastructure
Acknowledgements

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Sources: http://www.bwmaglev.com/, The Shanghai Maglev Project, Railroad: What it is and What it does, If there were no Shinkansen.