Economic and Social Benefits of HSR in China and Advanced Train Control Technologies

Prof. Tao Tang
Director of State Key Lab of Rail Traffic Control and Safety
Beijing Jiaotong University
Beijing, China
E-mail: ttang@bjtu.edu.cn
October 30, 2015

International Workshop on High-Speed Rail Planning and Operations, Washington D.C.
OUTLINE

1. Motivation of Developing HSR
2. Current HSR Network
3. Performances of HSR
4. Contribution of HSR to Economy and Society
The busiest railway system with the highest efficiency in the world

In China, the length of railway per capita is only 5.7 cm in 2005

- Traffic density: 35.51 million converted tk/km
- Passenger: 606.2 billion p/km
- Freight (t/k): 2.072 trillion

- In the world: 6% (route length), 25% (converted turnover)
The Six rounds of Existing Line Speed-up Campaigns

First Round
In 1997

- To launch the 40 direct express and 64 passenger train, sunset-departure and sunrise-arrival trains with top speed of 140 km/h

Second Round
In 1998

- Extending the speed-up railway network to nearly 10,000 km long
- Reducing the Beijing-to-Urumqi travel time from 67 to 47 hours

Third Round
In 2000

- Extending the speed-up railway network to 13000 km long, covering most of the provinces throughout the country
- The average travel speed of passenger train up to 65.2 Km/h
- The average travel speed of express train up to 119.2Km/h

Fourth Round
In 2001

- Extending The speed-up railway network to 22000, increasing 6000 km again
- Extending the speed above 160 km/h network up to 14000 km

Fifth Round
In 2004

- Extending the speed-up network up to 22000, increasing 6000 km again
- Extending the speed above 160 km/h network up to 14000 km
- Extending the speed above 200 km/h network up to 6003 km

Sixth Round
In 2007

- Extending the speed-up network up to 22000, increasing 6000 km again
- Extending the speed above 160 km/h network up to 14000 km
- Extending the speed above 200 km/h network up to 6003 km
The Six round of Existing Line Speed-up Campaigns

The Travel Time Improvement During Existing Line Speed-up Campaigns in the ten years.

<table>
<thead>
<tr>
<th>Route</th>
<th>Sixth Speed-up in 2007</th>
<th>Reduced Time compared to Fifth Speed-up in 2004</th>
<th>Reduced Time compared to First Speed-up in 1997</th>
<th>Reduced time compared to 1996</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing~Shanghai</td>
<td>9:59</td>
<td>1:59</td>
<td>5:10</td>
<td>7:27</td>
</tr>
<tr>
<td>Beijing~Harbin</td>
<td>7:50</td>
<td>3:40</td>
<td>7:02</td>
<td>9:12</td>
</tr>
<tr>
<td>Beijing~Xian</td>
<td>11:01</td>
<td>0:29</td>
<td>4:40</td>
<td>5:53</td>
</tr>
<tr>
<td>Beijing~Wuhan</td>
<td>9:55</td>
<td>0:30</td>
<td>3:35</td>
<td>7:02</td>
</tr>
<tr>
<td>Beijing~Guangzhou</td>
<td>20:25</td>
<td>1:41</td>
<td>7:45</td>
<td>13:15</td>
</tr>
<tr>
<td>Shanghai~Nanjing</td>
<td>1:58</td>
<td>0:44</td>
<td>0:51</td>
<td>2:56</td>
</tr>
<tr>
<td>Shanghai~Hangzhou</td>
<td>1:24</td>
<td>0:32</td>
<td>0:50</td>
<td>1:48</td>
</tr>
<tr>
<td>Shanghai~Nanchang</td>
<td>5:08</td>
<td>5:53</td>
<td>10:13</td>
<td>10:41</td>
</tr>
<tr>
<td>Shanghai~Changsha</td>
<td>7:30</td>
<td>7:30</td>
<td>11:50</td>
<td>18:20</td>
</tr>
<tr>
<td>Shanghai~Xian</td>
<td>16:01</td>
<td>0:17</td>
<td>7:37</td>
<td>9:19</td>
</tr>
</tbody>
</table>
Insufficient railway capacity

- In 2008, each day: **Supply**: 2.76 million seats
  **Requirement**: 3.72 million persons
- About 35% of freight transport requirement can be satisfied

Railway Station during the Spring Festival
4 vertical and 4 horizontal High speed Railway (2003)

- Total length of the 8 long distance high speed railway is about 12,000 km

- Qingdao-Taiyuan 770km
- Xuzhou-Lanzhou 1400km
- Shanghai-Chengdu 1900km
- Beijing-Hong Kong 2230km
- Beijing-Shanghai 1318km
- Shanghai-Shenzhen 1600km
- Hangzhou-Changsha 880km
- Beijing-Haerbin 1860km
Long term plan of Chinese Railway (2008)

- 16,000 km of high-speed railway by 2020
- Eight long distance lines and more than 10 Intercity passenger railway lines
- The high speed network will cover 70% of the country’s key cities and 90% of the population nationwide

Legend

- Conventional line
- HSR or Passenger dedicated line
- Planed conventional

Click to add Text
OUTLINE

1. Motivation of Developing HSR
2. Current HSR Network
3. Performances of HSR
4. Contribution of HSR to Economy and Society
First Project——Jinjing Intercity

- 116.6 Km long, 3 min headway (design);
- 87% line in elevated, saving 2000 mu land;
- Aug.1,2008, business operation in 350 Km/h;
• 2014, over **16,000 km** high-speed railway in operation

• **14.3%** in total length

• 2014, **880 million** passengers carried by EMU trains, amount to **37.5%** in total
Investment of Chinese HSR

- Beijing-Shanghai: 1318km, 350km/h, 217.6 billion RMB

Top ten shareholder

- China Railway Investment Corp: 54%
- Ping An Asset: 13%
- social insurance funds: 8%
- 6%
- 4%
- 4%
- 2%
- 2%
- 1%
- 3%
- 3%

China Railway Investment Corp

Ping An Asset

social insurance funds;

Map of China highlighting major cities and rail routes.
Chinese High Speed Railway Technology System

Integrated ballast

GSM-R Communication System

CRH Series High Speed Train

CTCS Train Control system

The high speed Comprehensive detection train
Infrastructure
Rolling Stocks
Traffic Management

Distributed Autonomous Central Traffic Control (CTC)
CTCS-L2
- Used in 250 Km/h High speed railway line.
- The specification of CTCS-L2 is developed.
Train Control System

- Used in 350 Km/h high speed railway line.
- The specification of CTCS-L3 is made refer to ETCS-L2.
- The CTCS-2 is used as back-up mode.

**CTCS-L3**

- **Radio**
  - OBC
  - speed
  - Balise
- **GSM-R Network**
- **TIU**
- **TCR**
- **Balise**

**Onboard:** CTCS-L2 module + Control module based on GSM-R, including Cab signal.

**Wayside:** RBC based on CTCS-L2

CTCS-L2 is used as a backup system.

**Autonomous CTC**

**Track Circuit**

- **Train Control Center**
- **Interlock**
- **Radio Block Center**
OUTLINE

1. Motivation of Developing HSR

2. Current HSR Network

3. Performances of HSR

4. Contribution of HSR to Economy and Society
Passenger flow volume (1)

- In 2014, 2600 EMU trains per day
- Sharp increase of passengers carried by EMU trains
  - 2013, 670 million passengers by EMU train,
  - 2014, 880 million passengers by EMU train, amount to 37.5% in total
  - Each year increased by 30%
Passenger flow volume (2)

Number of Passenger

<table>
<thead>
<tr>
<th>Year</th>
<th>Million people</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>167609</td>
</tr>
<tr>
<td>2011</td>
<td>186226</td>
</tr>
<tr>
<td>2012</td>
<td>189337</td>
</tr>
<tr>
<td>2013</td>
<td>210597</td>
</tr>
<tr>
<td>2014</td>
<td>235704</td>
</tr>
</tbody>
</table>

Passenger kilometers

<table>
<thead>
<tr>
<th>Year</th>
<th>Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>8762.18</td>
</tr>
<tr>
<td>2011</td>
<td>9612.29</td>
</tr>
<tr>
<td>2012</td>
<td>9812.33</td>
</tr>
<tr>
<td>2013</td>
<td>10595.62</td>
</tr>
<tr>
<td>2014</td>
<td>11604.75</td>
</tr>
</tbody>
</table>
Revenue of HSR

- **Beijing-Shanghai High Speed Railway:**
  - First year: 11 billion RMB
  - Second year: 17 billion RMB
  - Third year: 25 billion RMB

- Without considering depreciation, four HSR lines revenue and expenditure had been balanced
  - **Beijing-Tianjing:** 120 km, Aug-1-2008
  - **Shanghai-Nanjing:** 301 km, July-1-2010
  - **Beijing-Shanghai:** 1318 km, June-30-2011
  - **Shanghai-Hangzhou:** 202 km, Oct-26-2010

From: Huaxia Times
From: Internet
## Land occupancy

### Indicators of HSR and Freeway on land occupancy

<table>
<thead>
<tr>
<th></th>
<th>Length /km</th>
<th>Acreage /hm²</th>
<th>Capacity /bn per•km</th>
<th>Acreage hm²/100 mn per•km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing-Shanghai Highway</td>
<td>1262</td>
<td>About 10000</td>
<td>About 120</td>
<td>About 8.3</td>
</tr>
<tr>
<td>Beijing-Shanghai HSR</td>
<td>1318</td>
<td>About 4208</td>
<td>2101 (designed)</td>
<td>About 2</td>
</tr>
</tbody>
</table>

**Viaduct**
Energy cost

Total energy consumption of revenue

Beijing-Tianjin HSR: 0.24 ton of standard coal /10000 yuan (RMB)

Equal to 43% of conventional railway

Energy consumption/100 person km

EMU: <16 Kwh electricity  30% of car  20% of plane

From Lele Li, Guohua Zhou- Revenue indices of Chinese HSR social effects
**Influence on environment: Noise**

**HSR:** Many measures to reduce vibration and noise, e.g. sound barrier, integrated ballast track

- **CRH380A 300km/h**  
  about **65 db**

- **Boeing747-300 take off**  
  about **87.7 db**

- **Car 120km/h Freeway**  
  about **76 db**
Influence on environment: $\text{CO}_2$

$\text{CO}_2$ emission

0.06 g/person km

9.30 g/person km

From: http://www.xzbu.com/2/view-453973.htm
OUTLINE

1. Motivation of Developing HSR
2. Current HSR Network
3. Performances of HSR
4. Contribution of HSR to Economy and Society
Time value saved by HSR

In 2013, Beijing-Shanghai HSR Time Value

- Saving Time \times Annual passengers \times Time value per person
- \approx 11.5 \text{ (billion RMB)}

\[ \Delta C(h) = \frac{(14.7-5.9)(h/\text{person}) \times [83.9 \text{ (million persons)} \times \frac{553(\text{km})}{1318(\text{km})]} \times \{74200(\text{RMB/year})/[251(\text{day/year}) \times 8(\text{h/day})]\}}{1318(\text{km})} \]

Time value saved by Beijing-Shijiazhuang HSR (218km)

<table>
<thead>
<tr>
<th>Speed (km/h)</th>
<th>T1(min)</th>
<th>T2(min)</th>
<th>\Delta C(h)</th>
<th>R(bil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>156</td>
<td>85</td>
<td>1.183</td>
<td>2.27</td>
</tr>
<tr>
<td>250</td>
<td>156</td>
<td>68</td>
<td>1.467</td>
<td>2.82</td>
</tr>
</tbody>
</table>

From Lele Li, Guohua Zhou- Revenue indices of Chinese HSR social effects
## Travel Circle from Beijing

<table>
<thead>
<tr>
<th>Route</th>
<th>Travel Time in 2015</th>
<th>Travel Time in 2007</th>
<th>Travel Time in 1997</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing~Shanghai</td>
<td>4:50</td>
<td>9:59</td>
<td>15:09</td>
</tr>
<tr>
<td>Beijing~Harbin</td>
<td>7:08</td>
<td>7:50</td>
<td>14:52</td>
</tr>
<tr>
<td>Beijing~Xian</td>
<td>5:26</td>
<td>11:01</td>
<td>15:41</td>
</tr>
<tr>
<td>Beijing~Wuhan</td>
<td>5:20</td>
<td>9:55</td>
<td>13:30</td>
</tr>
<tr>
<td>Beijing~Guangzhou</td>
<td>8:03</td>
<td>20:25</td>
<td>28:10</td>
</tr>
<tr>
<td>Shanghai~Nanjing</td>
<td>1:14</td>
<td>1:58</td>
<td>2:49</td>
</tr>
<tr>
<td>Shanghai~Hangzhou</td>
<td>0:59</td>
<td>1:24</td>
<td>2:10</td>
</tr>
<tr>
<td>Shanghai~Nanchang</td>
<td>3:02</td>
<td>5:08</td>
<td>15:21</td>
</tr>
<tr>
<td>Shanghai~Changsha</td>
<td>4:24</td>
<td>7:30</td>
<td>19:20</td>
</tr>
<tr>
<td>Shanghai~Xian</td>
<td>10:26</td>
<td>16:01</td>
<td>23:38</td>
</tr>
</tbody>
</table>
Tianjin: economy promoted by Beijing-Tianjin HSR

- Economy was increased by **16.5%** in both 2008 and 2009, much more higher than the average growth rate of GDP in China
- Retail sales of social consumer goods up **25.2%** in 2008, **21.5%** in 2009
- The revenue of theater grow **20%** after the opening of Beijing-Tianjin HSR
- The sales volume of traditional art ware such as Clay figurine Zhang, Folk painting grow **50%**

Data source: People's Railway Network
<table>
<thead>
<tr>
<th>Rank</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non metal mining</td>
<td>Nonmetal mineral Products</td>
<td>Metal mining</td>
<td>Metal smelting and rolling processing</td>
<td>Petroleum and natural gas mining</td>
</tr>
<tr>
<td>pull coefficient</td>
<td>0.622</td>
<td>0.597</td>
<td>0.558</td>
<td>0.486</td>
<td>0.407</td>
</tr>
<tr>
<td>Pull economic amount/RMB billion)</td>
<td>1214</td>
<td>1165</td>
<td>1088</td>
<td>948</td>
<td>793</td>
</tr>
<tr>
<td>Rank</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Waste material</td>
<td>Metal products</td>
<td>Petroleum, coking and nuclear fuel processing</td>
<td>Wood processing and furniture manufacturing</td>
<td>Instrumentation and culture, office machinery manufacturing</td>
</tr>
<tr>
<td>pull coefficient</td>
<td>0.397</td>
<td>0.377</td>
<td>0.341</td>
<td>0.332</td>
<td>0.324</td>
</tr>
<tr>
<td>Pull economic amount/RMB billion)</td>
<td>774</td>
<td>734</td>
<td>665</td>
<td>648</td>
<td>632</td>
</tr>
</tbody>
</table>
## HSR Drives the economy growth of related industries (2/3)

<table>
<thead>
<tr>
<th>Rank</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>Information Transmission, Computer Service and Software</td>
<td>Electricity, heat production and supply</td>
<td>Electrical, machinery and equipment manufacturing</td>
<td>Transportation and warehousing</td>
<td>Coal Mining and Processing</td>
</tr>
<tr>
<td>Pull coefficient</td>
<td>0.292</td>
<td>0.262</td>
<td>0.24</td>
<td>0.231</td>
<td>0.227</td>
</tr>
<tr>
<td>Pull economic amount/RMB billion)</td>
<td>570</td>
<td>512</td>
<td>469</td>
<td>451</td>
<td>443</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rank</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>General, special equipment manufacturing</td>
<td>Chemical</td>
<td>Tenancy and Business Services</td>
<td>Water production and distribution</td>
<td>Polytechnical Services</td>
</tr>
<tr>
<td>Pull coefficient</td>
<td>0.225</td>
<td>0.22</td>
<td>0.208</td>
<td>0.202</td>
<td>0.184</td>
</tr>
<tr>
<td>Pull economic amount/RMB billion)</td>
<td>439</td>
<td>429</td>
<td>405</td>
<td>393</td>
<td>359</td>
</tr>
</tbody>
</table>

From: Zhengze Yang, Qingyun Wang, To evaluate effects of HSR from city development
## HSR Drives the economy growth of related industries (3/3)

<table>
<thead>
<tr>
<th>Rank</th>
<th>21</th>
<th>22</th>
<th>23</th>
<th>24</th>
<th>25</th>
<th>26</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>Finance and Insurance</td>
<td>Whole sale and retail trade</td>
<td>Miscellaneous manufacturing</td>
<td>Paper printing and stationery manufacturing</td>
<td>Transportation equipment manufacturing</td>
<td>Communications, computers and other electronic equipment manufacturing</td>
</tr>
<tr>
<td>Pull coefficient</td>
<td>0.181</td>
<td>0.175</td>
<td>0.147</td>
<td>0.128</td>
<td>0.128</td>
<td>0.127</td>
</tr>
<tr>
<td>Pull economic amount/RMB billion</td>
<td>354</td>
<td>342</td>
<td>287</td>
<td>250</td>
<td>250</td>
<td>247</td>
</tr>
</tbody>
</table>

- Update Secondary industry, Third industry
- Support New type urbanization
- Adjust the industry distribution in less developed regions

From: Zhengze Yang, Qingyun Wang, To evaluate effects of HSR from city development
HSR boosts tourism

<table>
<thead>
<tr>
<th>City</th>
<th>Annual growth rate (%)</th>
<th>City</th>
<th>Annual growth rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guangzhou</td>
<td>6.3</td>
<td>7.1</td>
<td>4.7</td>
</tr>
<tr>
<td>Qinyuan</td>
<td>26.4</td>
<td>15.3</td>
<td>20</td>
</tr>
<tr>
<td>Shaoguan</td>
<td>17.4</td>
<td>29</td>
<td>16.4</td>
</tr>
<tr>
<td>Chenzhou</td>
<td>17</td>
<td>24.6</td>
<td>40.8</td>
</tr>
<tr>
<td>Hengyang</td>
<td>31.8</td>
<td>30.2</td>
<td>25.9</td>
</tr>
<tr>
<td>Zhuzhou</td>
<td>14.5</td>
<td>30.3</td>
<td>33.2</td>
</tr>
<tr>
<td>Changsha</td>
<td>18.2</td>
<td>24.7</td>
<td>25.6</td>
</tr>
<tr>
<td>Yueyang</td>
<td>15.6</td>
<td>5.9</td>
<td>8</td>
</tr>
<tr>
<td>Chibi</td>
<td>13.8</td>
<td>30.4</td>
<td>30.9</td>
</tr>
<tr>
<td>Xianning</td>
<td>27.8</td>
<td>61.4</td>
<td>29.8</td>
</tr>
<tr>
<td>Wuhan</td>
<td>37.7</td>
<td>39.2</td>
<td>31.4</td>
</tr>
</tbody>
</table>

From Chenglin Tan, Haiyan Zheng, Impacts of Wuhan-Guangzhou HSR on tourism
HSR boosts tourism

- **Example 1**
  Beijing-Shanghai HSR: Temple and Cemetery of Confucius and the Kong Family Mansion in Qufu.
  In the first 3 days of May, 2014, visitors grow 6.2% and ticket income grow 17.2% compared to last year.

- **Example 2**
  Beijing-Guangzhou HSR: Hubei Province
  In 2013, visitors grow 18.5% and tourism income grow 17.2% compared to last year.
Huge Traffic Demand in Future

- **Year 2014**
  - Passenger trips: 2.35 billion trips in total
  - Travel frequency: 1.7 trip/person on average

- **Year 2020 (simple forecast)**
  - Travel frequency: 4 trip/person
  - Demand: $1.45 \text{ billion persons} \times 4 \text{ trip/person}$
    - $= 5.8 \text{ billion trips}$
Thanks!

Question?

Prof. Tao Tang
Director of State Key Lab of Rail Traffic Control and Safety
Beijing Jiaotong University
Beijing, China
E-mail: ttang@bjtu.edu.cn
October 30, 2015