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Medium Capacity Guided Transit Systems

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Medium Capacity Guided Transit Systems

Abstract
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Disciplines
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MEDIUM CAPACITY GUIDED TRANSIT SYSTEMS

April 25th, 2002

Prof. Vukan R. Vuchic
University of Pennsylvania

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1. Increasing Need for Medium Capacity Transit Systems

- Large gap between Bus and Metro Systems
- Services which Buses or Metros can not provide
- Need for higher performance systems than Buses at lower cost than Metros

- Medium-capacity transit modes
  - Bus Semirapid Transit - BST
  - Light Rail Transit - LRT
  - Automated Guided Transit - AGT, rubber-tired or rail

- Human factor in cities: transit is needed that has a strong distinctive image, but can penetrate inner city and pedestrian areas
• Importance of Right-of-Way (ROW) Separation for System Performance

- Definitions of ROW Categories:
- Streets, mixed traffic - C;
- Longitudinally separated - B; and
- Fully grade-separated - A.

- Separated ROW, B and A, provide high performance and competitiveness with auto travel
- Comparison between ROW B and A:
  - ROW B requires lower investment, has greater diversity in alignment geometry and locations
  - ROW A allows higher performance and full automation
• Light Rail Transit - the Dominant Medium Capacity System

- Comparison of LRT with buses

  • LRT is easier to separate and thus provide faster and more reliable service
  • LRT has better performance, higher capacity and lower operating cost

• With electric propulsion, LRT produces no air pollution and much lower noise
  • LRT has a stronger image, it is popular and attracts more riders
  • LRT contributes to livability of the city
  • Buses require lower investment and need fewer transfers
- Comparison of LRT with Metro systems
  - LRT requires substantially lower investment
  - LRT can penetrate high-density and pedestrian areas
  - LRT can be built incrementally
  - Metro has a higher capacity, speed and reliability
  - Metro has a strong positive impact on shaping the city

- Planning, technology and operational innovations in LRT since the 1950s
  - Diversity of LRT: from Tramways to High-Performance Light Metro

- Light Rail Rapid Transit – LRRT
- Automated LRRT
4. Review of LRT Applications
   - Developments of LRT by region:
     - Europe: Germany, Belgium, Switzerland, Austria, France
     - North America: USA, Canada, Mexico
     - Developing countries: Tunis, Egypt, Philippines, Hong Kong
     - Japan working on catching up in LRT development
     - Korea: any progress so far? Inadequate understanding, failure to use LRT
   - Nine types of applications of LRT

• Automated Guided Transit – AGT (or APM)
  - The beginnings: theoretical concepts: AGT, including GRT and PRT
  - Theoreticians and idealistic inventors introduced many incorrect concepts: from monorails to PRT “systems”
  - Real world experience eliminated PRT, modified GRT into practical AGT systems
  - Development of Westinghouse, Airtrans, VAL and other AGT systems
- Two categories of AGT: airport and other shuttles, and transit systems
- AGT as transit:
  - North America: Miami and Detroit
  - VAL in France: Lille, Toulouse, Orly, Rennes, and in Taipei
  - Japanese AGT’s: Kobe, Osaka, Yokohama
  - ALRT systems - AGT on rails: Vancouver, London Docklands
- Automated metros: Lyon, Paris, Berlin

6. Comparison of LRT and AGT

- Experiences in mode selection in USA, French and Italian cities, Taipei
  - Reasons for much wider use of LRT than AGT:
  - Diversity in alignment capability, vehicle types and performance
  - Ability to fit into urban environment
  - Much lower investment and somewhat lower operating costs
  - Rail systems are not proprietary - multiple suppliers prevent excessive supply costs

These advantages usually greatly outweigh the advantages of automated systems
- Technical Evaluation of Transit System Concepts

- Transit system planning should be based on functional definition, then proceed to selection of mode technology

- Major components that should be planned for guided modes are:
  - Right-of-way categories: ability to use not only A, but also B or C, may be a great advantage, resulting in much lower investment costs
  - Which vehicle and train sizes should be used?
  - Rail or rubber-tired systems?

- What role should the system have in human-oriented city and urban design

- Advantages and disadvantages of fully automated transit systems:

  Would the advantages of automated systems be worth their much higher cost, inability to be integrated in urban areas and other problems?
• **Comments on Transit Developments in Korea**

- Present conditions and needed improvements:
  *Seoul, Busan*
  *and medium-size cities*
- Medium capacity systems neglected:
  *they are not used*
- Importance of economic efficiency:
  *need for networks, not only single lines*

- Expanded diversity and roles of rail transit should be utilized
- Automation is a secondary aspect:
  *it is method of operation, not a determinant of modes*
- Generic systems should be favored over proprietary systems with single suppliers which carry considerable risks
- "Family of rail transit modes" should be introduced.
Figure 19. Bipolarized transit

Figure 20. Intermediate systems "filling the gap" between street transit and metros
Compared to fully-separated ROW, Category A, partially separated ROW, Category B, gives transit systems the following advantages (+) and disadvantages (-):

+ Much lower investment cost
+ Much more diversified alignment - boulevard and street medians can be used
+ It can penetrate into pedestrian zones and enhance their livability
+ Stations are smaller, simpler and more pedestrian-friendly

- System performance - speed, reliability, capacity - is lower
- Operational safety is lower (no positive fail-safe signal control)
- May involve complex traffic regulation

Figure 21. Investment cost / performance characteristics of different generic classes of transit modes

Figure 22. Investment cost / performance characteristics of different generic classes of transit modes
Advantages and disadvantages of LRT as compared to BST are:

- LRT has a stronger image, it is popular and attracts more riders
- Greater capacity, vehicle performance and quality of ride
- Vehicles are more spacious and comfortable, have better image
- Much easier provision and protection of separate ROW (B or A)
- LRT can use tunnels, BST can not
- More acceptable in pedestrian streets and zones
- Due to electric propulsion, LRT has no exhaust, much less noise
- Has a much stronger positive impact on urban development
  - Higher investment costs
  - More construction required, longer implementation
  - Introduces new technology, requires special facilities
  - Limited to track network, involves more transfers

Figure 23. Comparison of Light Rail Transit with Bus Semirapid Transit

Major innovations in LRT in recent decades include:

- Consolidation of networks into fewer, but higher quality lines (tramways to Light Rail Transit)
- Systematic replacement of ROW C by ROW B and A
- High-quality tracks and switches prevent any noise production
- Articulated vehicles, 1-4 car trains
- Low-floor vehicles
- Self-service fare collection
- 1-4 car trains have 8 to 32 door channels for simultaneous boarding/alighting
- Integration of tunnel, surface and aerial alignments on the same line
- Intermodal integration with buses and metros
- Operation of LRT in central cities in pedestrian zones
- Integration (track sharing) of LRT with Regional Rail lines for services to suburbs

Figure 24. Major innovations in LRT since the 1950’s
Main Categories of Light Rail Transit Systems Are:

- Conventional Tramways: Toronto, Moscow, St. Petersburg
- Upgraded Conventional Tramways: Zürich, Melbourne, Amsterdam, Oslo
- LRT Networks Developed from Tramways: Köln, Stuttgart, Berlin
- New LRT Systems: Calgary, San Diego, Birmingham, Nantes
- LRT - Regional Rail Integrated Systems: Manchester, Karlsruhe, Saarbrücken
- Light Rail Rapid Transit, LRT - Philadelphia-Norristown, Essen-Mülheim, Manila
- Automated Light Rail Transit, ALRT - Vancouver, London-Docklands, Kuala Lumpur

Figure 25. Nine categories of LRT/Tramway systems and their applications

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A Airtrans – Dallas/FW</td>
<td>LTV/Vought ?USA</td>
<td>6.48</td>
<td>2.24</td>
<td>14.52</td>
<td>16/40</td>
<td>8,150</td>
<td>56</td>
<td>4,075</td>
<td>10.47</td>
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<tr>
<td>B ALRT – Vancouver</td>
<td>UTDC ? Canada</td>
<td>12.70</td>
<td>2.50</td>
<td>31.75</td>
<td>40/100</td>
<td>20,600</td>
<td>(LIM)</td>
<td>5,150</td>
<td>(LIM)</td>
</tr>
<tr>
<td>C KCV - Kobe</td>
<td>Kawasaki ? Japan</td>
<td>8.00</td>
<td>2.39</td>
<td>19.12</td>
<td>20/62</td>
<td>14,840</td>
<td>90</td>
<td>7,420</td>
<td>8.57</td>
</tr>
<tr>
<td>D M – Bahn</td>
<td>Siemens -Germany</td>
<td>11.80</td>
<td>2.30</td>
<td>27.14</td>
<td>7/70</td>
<td>12,700</td>
<td>(LIM)</td>
<td>n.a.</td>
<td>(LIM)</td>
</tr>
<tr>
<td>E Morgatown</td>
<td>Alden/Boeing ?USA</td>
<td>4.73</td>
<td>1.83</td>
<td>8.66</td>
<td>8/21</td>
<td>5,370</td>
<td>45</td>
<td>2,683</td>
<td>11.54</td>
</tr>
<tr>
<td>F New Tram – Osaka</td>
<td>Niigata/LTV ? Japan</td>
<td>8.00</td>
<td>2.29</td>
<td>18.32</td>
<td>20/62</td>
<td>14,340</td>
<td>90</td>
<td>7,170</td>
<td>9.00</td>
</tr>
<tr>
<td>G Skybus – Miami</td>
<td>Westinghouse Elec. ? USA</td>
<td>9.30</td>
<td>2.59</td>
<td>24.09</td>
<td>28/70</td>
<td>13,500</td>
<td>90</td>
<td>6,750</td>
<td>10.47</td>
</tr>
<tr>
<td>H VAL – Lille</td>
<td>Matra ? France</td>
<td>12.50</td>
<td>2.06</td>
<td>25.75</td>
<td>34/86</td>
<td>19,870</td>
<td>240</td>
<td>9,935</td>
<td>17.33</td>
</tr>
</tbody>
</table>

| a. Standard size per person: 0.36 m². Capacity may vary due to different seating arrangements. |
| b. Assumed weight per person: 70 kg. |
| c. Propulsion by linear induction motor (LIM) which has different power characteristics than conventional electric motors. |

Figure 26. Vehicle characteristics for selected AGT systems
<table>
<thead>
<tr>
<th>System – City</th>
<th>Types of Service</th>
<th>Headway (min/TU)</th>
<th>Frequency (TU/h)</th>
<th>Cars/TU</th>
<th>Car capacity (prs/car)</th>
<th>Offered capacity (sps/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• ALRT – Vancouver</td>
<td>Min 2.5</td>
<td>24</td>
<td>1</td>
<td>20</td>
<td>480</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Max 1.25</td>
<td>28</td>
<td>6</td>
<td>100</td>
<td>28,800</td>
<td></td>
</tr>
<tr>
<td>2. KCV ? Kobe</td>
<td>Min 2.5</td>
<td>24</td>
<td>6</td>
<td>10</td>
<td>1,440</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Max 2.0</td>
<td>30</td>
<td>6</td>
<td>62</td>
<td>11,160</td>
<td></td>
</tr>
<tr>
<td>3. New Tram – Osaka</td>
<td>Min 2.5</td>
<td>24</td>
<td>4</td>
<td>10</td>
<td>960</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Max 2.0</td>
<td>30</td>
<td>4</td>
<td>62</td>
<td>7,440</td>
<td></td>
</tr>
<tr>
<td>4. Skybus – Miami</td>
<td>Min 2.5</td>
<td>24</td>
<td>1</td>
<td>14</td>
<td>336</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Max 1.5</td>
<td>40</td>
<td>6</td>
<td>70</td>
<td>16,800</td>
<td></td>
</tr>
<tr>
<td>5. VAL – Lille</td>
<td>Min 2.5</td>
<td>24</td>
<td>2</td>
<td>17</td>
<td>816</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Max 1.25</td>
<td>48</td>
<td>4</td>
<td>86</td>
<td>16,512</td>
<td></td>
</tr>
</tbody>
</table>

Figure 27. Data for service / capacity computations of different AGT systems

Compared to AGT, LRT has the following characteristics:

+ LRT requires much lower investment cost
+ It has lower operating cost
+ LRT is not limited to ROW A only; it can utilize streets
+ LRT can fit into urban and pedestrian zones and enhance their attraction
+ Vehicles offer considerably better riding comfort
+ LRT has a good image and it is very popular as a symbol of the city
- LRT can not be operated automatically, unless it has only ROW A
- It has lower speed and frequency of service than AGT
- LRT has somewhat lower safety than AGT
- Its schedule can not be quickly adjusted to unexpected changes, as AGT

Figure 28. Comparison of Light Rail Transit and Automated Guided Transit
Rubber-tired guided as compared to rail transit systems have the following differences:

+ Rubber-tired vehicles allow more flexible alignment: sharper curves and steeper gradients than rail vehicles
+ For small and medium-size vehicles design with rubber tires is simpler
+ Rubber-tired vehicles produce less noise in curves than rail vehicles
- They are less stable and provide a considerably less comfortable ride than rail vehicles because of rail stability, larger size of rail vehicles and use of bogies
- Average vehicle weight is similar, but rubber-tired vehicles have greater rolling resistance and therefore use more energy
- Rubber tires produce more heat in tunnels and represent certain fire hazard
- Rubber-tired systems can be used on ROW A only; they can not cross any streets
- Their switching is slower, more complicated and takes more space; guideways can not cross each other
- Rubber-tired systems are more vulnerable to snow and ice

Figure 11. Comparison of rail with rubber-tired guided transit

Fully automated operation of transit vehicles and trains as compared to driver operated ones has these advantages and disadvantages:

+ Very frequent operation of short trains is feasible even during off-peak periods
+ Quick adjustments of schedules to any changing conditions are possible
+ Driving regime can be optimized for all conditions
  - Investment cost is much higher
  - Lines can not go through streets, pedestrian or green areas
  - Presence of a crew member has certain advantages for security, informing passengers, etc. For this reason some fully automated systems still place a crew member on the train
  - Handling of emergencies is more difficult
  - Mechanical and control systems are much more complex, require high-cost maintenance
  - Operating cost is usually higher on automated systems

Figure 12. Evaluation of fully automatic transit systems
### Figure 31. Historic development of automation of guided transit systems

<table>
<thead>
<tr>
<th>City / Line</th>
<th>Year</th>
<th>Cars</th>
<th>Meters</th>
<th>Spaces</th>
<th>Crew Size</th>
<th>Operation – Event</th>
<th>Innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York Subway</td>
<td>1904</td>
<td>6</td>
<td>108</td>
<td>1100</td>
<td>7</td>
<td>Driver + 6 Guards</td>
<td>2-Person Crew</td>
</tr>
<tr>
<td>Paris Metro</td>
<td>1930?</td>
<td>5</td>
<td>71</td>
<td>750</td>
<td>2</td>
<td>1 Guard / Car --- 1 Guard / Train</td>
<td>1-Person Crew + Platform Attendant</td>
</tr>
<tr>
<td>Hamburg U-Bahn</td>
<td>1957</td>
<td>8</td>
<td>112</td>
<td>1100</td>
<td>1</td>
<td>Eliminate Guard</td>
<td></td>
</tr>
<tr>
<td>New York / Times Square Shuttle</td>
<td>1964</td>
<td>3</td>
<td>54</td>
<td>540</td>
<td>(1)</td>
<td>Driver Sitting</td>
<td>(1), ATO</td>
</tr>
<tr>
<td>London / Victoria Line</td>
<td>1968</td>
<td>8</td>
<td>128</td>
<td>1480</td>
<td>1</td>
<td>Driver Door Control</td>
<td>1 Person, ATO</td>
</tr>
<tr>
<td>Philadelphia / PATCO</td>
<td>1969</td>
<td>6</td>
<td>124</td>
<td>1200</td>
<td>1</td>
<td>Central Station Supervision</td>
<td>Unattended Stations</td>
</tr>
<tr>
<td>San Francisco / BART</td>
<td>1972</td>
<td>10</td>
<td>220</td>
<td>2160</td>
<td>1</td>
<td>Driver Door Control</td>
<td>1-Person, 10-Car Train</td>
</tr>
</tbody>
</table>

### Figure 13 (cont). Historical development of automation of guided transit systems

<table>
<thead>
<tr>
<th>City / Line</th>
<th>Year</th>
<th>Cars</th>
<th>Meters</th>
<th>Spaces</th>
<th>Crew Size</th>
<th>Operation – Event</th>
<th>Innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dallas - Fort Worth / Airtrans</td>
<td>1974</td>
<td>2</td>
<td>13</td>
<td>80</td>
<td>0</td>
<td>ATO, ATS; Low Capacity</td>
<td>Automated Network in Airport</td>
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<tr>
<td>Morgantown</td>
<td>1975</td>
<td>1</td>
<td>5</td>
<td>21</td>
<td>0</td>
<td>ATO, ATS; Very Low Capacity</td>
<td>Automated Low-Capacity Transit</td>
</tr>
<tr>
<td>Atlanta Airport / Westinghouse</td>
<td>1980</td>
<td>3</td>
<td>36</td>
<td>420</td>
<td>0</td>
<td>ATO, ATS; Medium Capacity</td>
<td>Med. Capacity Automated Shuttle</td>
</tr>
<tr>
<td>Lille / VAL</td>
<td>1983</td>
<td>2</td>
<td>28</td>
<td>172</td>
<td>0</td>
<td>ATO, ATS</td>
<td>Automated Regular Transit</td>
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<tr>
<td>Vancouver / Skytrain</td>
<td>1986</td>
<td>4</td>
<td>51</td>
<td>440</td>
<td>0</td>
<td>ATO, ATS</td>
<td>Roving Driver-Attendant</td>
</tr>
<tr>
<td>London / Docklands LRT</td>
<td>1988</td>
<td>2</td>
<td>56</td>
<td>524</td>
<td>(1)</td>
<td>ATO, ATS</td>
<td>Driver-Attendant on Each Train</td>
</tr>
<tr>
<td>Lyon Metro Line D</td>
<td>1993</td>
<td>3</td>
<td>50</td>
<td>450</td>
<td>0</td>
<td>ATO, ATS</td>
<td>Fully Automated Metro</td>
</tr>
<tr>
<td>Paris Metro Line 14</td>
<td>1998</td>
<td>5</td>
<td>75</td>
<td>750</td>
<td>0</td>
<td>ATO, ATS</td>
<td>Fully Automated Metro</td>
</tr>
</tbody>
</table>
도시철도 국제 세미나 및 Workshop

Ⅰ. 국제세미나 및 Workshop 중점

Ⅱ. 국제세미나 발표자료

1. 한국의 도시철도 경영방향
   1.1 도시철도 건설과 운영 현황
   1.2 도시철도의 경영활용과 방향

2. 해외의 경영전략
   2.1 미국의 도시철도 경영전략 및 운영경험
   2.2 독일의 경영전략 건설 및 운영경험

3. 국내 경영전략연구개발 현황 및 향후 방향
   3.1 체계 경영전략시스템 구축을 위한 시스템인프라기술
   3.2 교통증상시 시스템 AGT 시장시스템
   3.3 AC 750V 전력분급시스템
   3.4 무선통신을 이용한 무인운전시스템
   3.5 환경원과의 인프라구조의 선도구축

주관: 한국철도기술연구원 (KRRRI)
후원: 건설교통부

● 일시: 2002년 4월 25일 ~ 4월 26일
● 장소: 조치원 홍익대학교 국제경영연구원