TTC Presentation to the Sheppard Transit Expert Advisory Panel

Date: February 24, 2012
Part 1
LRT in Major Cities
Paris, France

Line T3 – 8 km, 110,000 psgrs/day
Paris, France

Line T3 – 8 km, 110,000 psgrs/day
Paris, France

Line T1 – Opened 1992, 30-million riders/year
Grenoble, France

Four lines, 1987-2007
Cologne, Germany

40 km of centre roadway operation
Berlin, Germany

Rebuilt, upgraded post-reunification
Dresden, Germany

Rebuilt, upgraded post-reunification
Barcelona, Spain

Six lines, 20-million psgrs/yr
San Francisco, USA

T-Third – 8 km – opened 2007
Nice, France

Opened 2007, 90,000 psgrs/day in 2011
St Petersburg, Russia

60 km in centre of road

2/24/2012
Kayseri, Turkey

Opened 2009, 18 km, all in centre of road
Part 2
Underground Construction
International Comparisons
The Madrid Experience
UNDERGROUND CONSTRUCTION
INTERNATIONAL COMPARISONS
COMPARING SUBWAY COSTS AND SCHEDULE

• Meaningful cost and schedule comparison of subway projects in different countries constructed at different times is complex
• Requires normalization for political/governmental differences, technical/operational differences and economic/business differences, e.g.:
  – Extent of program and reliability of funding/cash flow
  – Length of line in tunnel vs. surface or elevated
  – Local construction safety regulations
• Study by US Federal Transit Administration used to determined cost per kilometre for design and construction of recent subway projects, worldwide
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FTA STUDY OF SUBWAY COSTS – WORLDWIDE

- TTC costs slightly higher than average

<table>
<thead>
<tr>
<th>Cost/km 2010$ millions</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.0</td>
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<tr>
<td>$100.0</td>
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<tr>
<td>$200.0</td>
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<tr>
<td>$300.0</td>
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<tr>
<td>$400.0</td>
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<tr>
<td>$500.0</td>
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<tr>
<td>$600.0</td>
</tr>
<tr>
<td>$700.0</td>
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<tr>
<td>$800.0</td>
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</tbody>
</table>

International
(Mostly Underground)

US

Average Toronto Cost
($290)

TTC

Transit City

Average Global Cost
($275 million/km)
TORONTO PROJECT COST COMPARISON

- Average Toronto Cost ($290 million/km)
- Average Global Cost ($275 million/km)

<table>
<thead>
<tr>
<th>Project</th>
<th>Cost/km 2010$ millions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheppard Subway</td>
<td>$200.0</td>
</tr>
<tr>
<td>TYSSE (EFC)</td>
<td>$250.0</td>
</tr>
<tr>
<td>YSNE (OME)</td>
<td>$300.0</td>
</tr>
<tr>
<td>Sheppard West Extension</td>
<td>$220.0</td>
</tr>
<tr>
<td>SRT - Kennedy to Sheppard</td>
<td>$200.0</td>
</tr>
<tr>
<td>ECLRT - Jane to Kennedy</td>
<td>$180.0</td>
</tr>
<tr>
<td>Finch LRT - Keele to Humber College</td>
<td>$200.0</td>
</tr>
<tr>
<td>Sheppard East Extension</td>
<td>$300.0</td>
</tr>
</tbody>
</table>

2/24/2012
MAJOR SUBWAY COST VARIATION DRIVERS - 1

• Station length, spacing and type
  – Underground stations are most expensive component of a subway
  – More stations per km = higher overall cost per km
  – Longer stations = higher overall cost per km
  – More terminal/interchange stations = higher overall cost per km

• Proportion of project in tunnel
  – Construction of transit underground is typically 4 times the cost/km of surface and 2 times the cost/km of elevated
  – Higher proportion of project in tunnel = higher overall cost per km
  – Direct comparison of overall project cost/km between projects with significantly different proportions in tunnel is not valid
MAJOR SUBWAY COST VARIATION DRIVERS – 2

• Geotechnical conditions
  – Tunnel advance rate – typical average can vary from .25m/hour to 2m/hour (an 8x factor), depending upon geology and tunnel diameter
  – Mitigation of existing structure settlement, especially with high water table

• Extent of existing underground infrastructure
  – Impacted utilities must be relocated and existing structures may have to be underpinned to prevent settlement

• Market conditions and competition for resources
  – Tunnel construction is highly specialized and the number of experienced contractors/personnel is limited
  – Simultaneous construction of multiple subway projects, worldwide, can raise bid prices
TTC – Transit Building Expertise

SUBWAY DESIGN AND CONSTRUCTION TIMES

TTC Construction time is faster than International Average

<table>
<thead>
<tr>
<th>Subway System</th>
<th>Time (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTC</td>
<td>(6.5)</td>
</tr>
<tr>
<td>Average Global Time</td>
<td>(9 years)</td>
</tr>
</tbody>
</table>
WHY DO SUBWAYS TAKE SO LONG TO BUILD?

- Planning and Environmental Assessment – typically 2 years
- Design and property acquisition – typically 2 years
- TBM launch area construction – typically 1 year
- Tunnel boring – typically 2 years
- Station construction and fit-out – typically 3 years
- Systems testing and commissioning – typically 1 year
- Actual durations depend upon specific project scope
- Above durations take advantage of typical opportunities for overlapping design and construction activities

- **Typical duration, planning and EA**: 2 years
- **Typical duration, design and construction**: 9 years
- **Typical duration, total**: 11 years
TBM LAUNCH AREA CONSTRUCTION

• Launch Area includes launch shaft and tunnel construction support site
• Construction support facilities include tunnel liner storage and handling, muck handling and drying, concrete making and delivery, TBM power substation etc.
TUNNEL BORING

- Duration depends on length of tunnel, average advance rate and number of TBMs
- Number of TBMs increases for longer tunnels and to offset slow advance
- Hence, typical 2-year duration
STATION CONSTRUCTION AND FIT-OUT

• Cut-and-cover construction includes:
  – Traffic management
  – Utility relocation
  – Headwalls and sidewalls
  – General excavation and shoring
  – Base, mezzanine and roof slabs
  – Entrances
  – Platforms and stairs
  – Tunnel ventilation facilities
  – Escalators and elevators
  – Plumbing and electrical
  – Architectural finishes
CUT-AND-COVER CONSTRUCTION WITH DECKING - 1
CUT-AND-COVER CONSTRUCTION WITH DECKING - 2
CUT-AND-COVER CONSTRUCTION WITH DECKING - 3
CUT-AND-COVER CONSTRUCTION WITH DECKING - 4
CUT-AND-COVER CONSTRUCTION WITH DECKING - 5
CUT-AND-COVER CONSTRUCTION WITH DECKING - 6
CUT-AND-COVER CONSTRUCTION WITH DECKING - 7
CUT-AND-COVER CONSTRUCTION WITH DECKING - 8
CUT-AND-COVER CONSTRUCTION WITH DECKING - 9
CUT-AND-COVER CONSTRUCTION WITH DECKING - 10
APTA PEER REVIEW OF TTC PROJECT DELIVERY – 2007

• Estimating of budgets and schedules for capital delivery “in line with customary practice”
• Panel “impressed with the discipline and detail”
APTA PEER REVIEW OF TC SYSTEM CONCEPT – 2010

• Program is “ambitious ... yet decidedly well conceived”
• Panel “impressed with the extent of planning and thought given to the alignment, the vehicle choice and the detailed analyses of optional designs and operating strategies”
• “Evidence of a well developed plan was ... the sophisticated project office organization and governance structure”
• Scope “paralleled similar advanced projects in Paris, France” as well as similar to North American projects, including Denver, Sacramento, Pittsburgh and Ottawa
CONCLUSION

• “Subway” is not a defined term
• Comparison between cost and schedule of specific projects requires normalization
• Average TTC transit project cost/km of $290 million is within 6% of international average of $275 million
• TTC project times are in-line with international experience
MADRID EXPERIENCE
METROSUR VS. SHEPPARD SUBWAY
POLITICAL/GOVERNMENTAL COST DIFFERENTIATORS

- Madrid MetroSur part of continuous system expansion program
  - Continuity of staff, standards and contractors
- Approvals/Permits
  - No environmental assessment or public participation
  - No permits (Site Plan, Building etc.)
- Property acquisition
  - Compulsory property purchase - City owns property below 10m depth
- Construction change decision making
  - High change approval limits for project staff
  - Major changes approved by Mayor within 24 hours

2/24/2012
METROSUR VS. SHEPPARD SUBWAY
TECHNICAL COST DIFFERENTIATORS - 1

• Construction conditions
  – 90m wide construction corridor with significant green field component – limited utilities and traffic impacts
  – 30% of line cut-and-cover
  – Work done 24/7/365

• Ground conditions – self-supporting compacted sands
  – Rapid TBM advance rate – 35m/day vs. 15m/day on Sheppard
  – Tolerate high levels of structural settlement to eliminate temporary excavation support systems

• Industry standard fire and life safety code (NFPA 130) not applied
  – Single double-track tunnel – no egress walkway, crossover structures and cross-passages
  – Jet fans in tunnel vs. station fan shafts on Sheppard
METROSUR VS. SHEPPARD SUBWAY
TECHNICAL COST DIFFERENTIATORS - 2

• Station requirements
  – Station boxes 130m long vs. 200m on Sheppard
  – Interchange stations 8km apart vs. 5km on Sheppard and no terminal stations (continuous loop)

• Track requirements
  – Conventional direct fixation track vs. noise and vibration isolation on Sheppard
## METROSUR VS. SHEPPARD SUBWAY
### NORMALIZED COST COMPARISON

<table>
<thead>
<tr>
<th></th>
<th>Original Cost ($ million per km)</th>
<th>2010 Cost ($ million per km)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sheppard Subway Cost</strong></td>
<td>142.5</td>
<td>212.3</td>
</tr>
<tr>
<td><strong>Equating Adjustments:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accelerated Construction</td>
<td>2.5</td>
<td>3.7</td>
</tr>
<tr>
<td>Code Requirements</td>
<td>3.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Ground Conditions</td>
<td>4.8</td>
<td>7.1</td>
</tr>
<tr>
<td>Cross Over Structures</td>
<td>4.3</td>
<td>6.4</td>
</tr>
<tr>
<td>Tail Tracks not required</td>
<td>5.6</td>
<td>8.3</td>
</tr>
<tr>
<td>Trackwork Installation</td>
<td>2.5</td>
<td>3.7</td>
</tr>
<tr>
<td>Use of Open Cut Construction</td>
<td>5.9</td>
<td>8.7</td>
</tr>
<tr>
<td>Proportion of Terminal/Interchange Stations</td>
<td>18.9</td>
<td>28.1</td>
</tr>
<tr>
<td>Station Box Size</td>
<td>4.8</td>
<td>7.1</td>
</tr>
<tr>
<td><strong>Total Adjustment</strong></td>
<td><strong>52.1</strong></td>
<td><strong>77.6</strong></td>
</tr>
<tr>
<td><strong>Adjusted Sheppard Subway Cost</strong></td>
<td><strong>90.4</strong></td>
<td><strong>134.7</strong></td>
</tr>
<tr>
<td>Madrid MetroSur Cost</td>
<td>87.1</td>
<td>115.0</td>
</tr>
</tbody>
</table>
CONCLUSION

• Political/governmental cost differentiators are significant, but difficult to evaluate
  – Tend to directly influence schedule more than cost
  – Schedule reduction leads to cost savings
• Major technical differences between MetroSur and Sheppard Subway require normalization for meaningful cost comparison
  – Needs highly detailed analysis
• Preliminary normalized comparison shows Sheppard Subway costing 17% more per kilometre than MetroSur
Part 3
Sheppard Transit
- What Has Changed Since 1986
What Has Changed Since 1986?

1986 Subway Planning
Development Forecasts and OP
  – High density development at nodes (subway stations)

Aggressive forecast targets for employment
  – NY and Scarborough centres

2011
New OP – focus on Avenues not nodes (subway stations)
  – Lower development forecasts
  – Protects stable residential areas

Development industry has moved away from high density nodes
Actual Employment is much lower than forecast
### 1986 Forecast to 2011 Actual

<table>
<thead>
<tr>
<th>Category</th>
<th>1986 Forecast to 2011 (^{(1)})</th>
<th>2011 Actual (^{(2)})</th>
</tr>
</thead>
<tbody>
<tr>
<td>City Population</td>
<td>2.1 Million in 1986&lt;br&gt;2.5 Million in 2011 forecasted</td>
<td>2.5 Million - met</td>
</tr>
<tr>
<td>City Employment</td>
<td>1.23 Million in 1986&lt;br&gt;1.7 million in 2011 forecasted</td>
<td>High employment growth around Toronto&lt;br&gt;1.30 million</td>
</tr>
<tr>
<td>Transit Technology</td>
<td>Subway was the predominant form of transit investment</td>
<td>LRT is the predominant form serving areas that do not justify subway investment</td>
</tr>
<tr>
<td>Development Trend</td>
<td>Will proceed in nodes</td>
<td>“Avenue” concept v.s. “Nodes”&lt;br&gt;Community opposition to major developments</td>
</tr>
</tbody>
</table>

Sources
2. City Planning
3. TTC
## 1986 to 2011

<table>
<thead>
<tr>
<th></th>
<th>1986 Forecast for 2011 (^{(1)})</th>
<th>2011 Actual (^{(2)})</th>
</tr>
</thead>
<tbody>
<tr>
<td>North York Centre Employment</td>
<td>29,400 in 1986&lt;br&gt;93,400 in 2011 forecasted</td>
<td>30,200 jobs in 2011&lt;br&gt;Mainly residential development</td>
</tr>
<tr>
<td>Transit Share - NYC</td>
<td>60% target for 2011</td>
<td>34% actual</td>
</tr>
<tr>
<td>Scarborough City Centre</td>
<td>14,400 in 1986&lt;br&gt;65,000 in 2011 forecasted</td>
<td>13,700 in 2011&lt;br&gt;Mainly residential development</td>
</tr>
<tr>
<td>Employment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transit Share – SCC</td>
<td>55% target for 2011</td>
<td>21% actual</td>
</tr>
<tr>
<td>Kennedy and Sheppard</td>
<td>10,000 employment in forecasted for 2011</td>
<td>Limited employment</td>
</tr>
</tbody>
</table>

Sources
2. City Planning
3. TTC
## 1986 To 2011

<table>
<thead>
<tr>
<th></th>
<th>1986 Forecast to 2011</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheppard Subway Ridership</td>
<td>15,400 person per hour (pph) forecasted for 2011&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>4,500 pph actual&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7,300 pph east of Don Mills&lt;sup&gt;(3)&lt;/sup&gt; forecast (2031)</td>
</tr>
<tr>
<td>Eglinton Subway Ridership</td>
<td>17,600 person per hour&lt;sup&gt;(3)&lt;/sup&gt; forecasted for 2011</td>
<td>6,000 – 10,000 pph&lt;sup&gt;(3)&lt;/sup&gt; forecast (2031)</td>
</tr>
<tr>
<td>Let’s Move Transit Plan</td>
<td>6 lines totalling 58 km by 2011 - $10.8 B ($2011)</td>
<td>5.4 KM Sheppard Subway 1.3 KM Wilson to Downsview Total by 2011 $6.7 KM</td>
</tr>
</tbody>
</table>

**Sources**
2. City Planning
3. TTC
## 1986 to 2011

<table>
<thead>
<tr>
<th></th>
<th>1986 Forecast to 2011</th>
<th>2011</th>
</tr>
</thead>
</table>
| Life-cycle costs – subway and LRT | Capital and 30-year (3) operating cost used to determine breakeven point:  
>15,000 pphpd - subway  
<15,000 pphpd – LRT | Projected demand for 2031 (3)  
Sheppard Subway east of Don Mills = 7,300 |
| Long-term Subway Maintenance  | Subways relatively new (3)  
- limited TTC experience with long-term ownership costs | Aging subways now cost TTC (3)  
$270M/year capital and $230M/year operating for maintenance alone |

Sources
2. City Planning
3. TTC
What has been learned?

Subways don’t guarantee development

Not all subways have achieved higher development
Many station areas still have large undeveloped property
If you build it – they don’t always come

High capital and operating cost of subways

Need high probability of success
High risk - long delays in approvals and securing funding