A SYSTEMS APPROACH TO TRANSPORT PLANNING FOR REVITALIZING CONGESTED CITIES: A CASE STUDY FROM SRI LANKA

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Systems Approach to Urban Transport Planning
Overall costs induced by all transport operations impacting all users of the network as well as the non-users among its stakeholder society.

System Cost can be classified as follows:

- **Internal Cost**: Costs directly borne by the user; (vehicle use cost + user time cost)
- **External Cost**: Cost induced by the users but are passed on to third parties and the general public
- **Infrastructure Cost**: Cost of restoration, operation and maintenance of road, railway terminals, stations etc.

Simple aggregation of these three cost components will not yield an accurate total system cost since they are mutually inclusive.
Total system cost can be represented as \( A \cup B \cup C \) and further be simplified as

\[
A \cup B \cup C = A + B + C - \{ A \cap B + A \cap C + B \cap C - 2.(A \cap B \cap C) \}
\]

However, if cost components are mutually exclusive, then

\[
A \cup B \cup C = A + B + C
\]
Formulation of mathematical equations to evaluate cost components in a transport network

- **User Cost (Time Cost + Vehicle Use Cost)**

\[
TUC_t = \sum_{k=1}^{l} \sum_{j=1}^{m} \sum_{i=1}^{n} (P_{i,j,k,t} \cdot C_{i} \cdot T_{i,j,k,t} + L_{i,j,k,t} \cdot C'_{i} \cdot T_{i,j,k,t}) + \sum_{k=1}^{l} \sum_{j=1}^{m} (V_{j,k,t} \cdot O_{j,k,t} \cdot D_{j,k})
\]

- **Congestion Cost**

\[
TDC_t = \sum_{k=1}^{l} (UTC^0_{k,t} - UTC^d_{k,t}) + (VUC^0_{k,t} - VUC^d_{k,t})
\]

- **Emission Cost**

\[
VEC_t = \sum_{k=1}^{l} \sum_{j=1}^{m} (V_{j,k,t} \cdot F_{j,k} \cdot E_{j,k} \cdot D_{j,k})
\]

- **Accident Cost**

\[
TAC_t = \sum_{k=1}^{l} \sum_{j=1}^{m} (V_{j,k,t} \cdot D_{j,k} \cdot A_{j})
\]

Transport Improvement Study for Kandy
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වි ලා වැටී
(විදුම් හා ආශ්වාසයේ පවුල් 300 පසුවීමේ)

Key Facts

- Population: 130,000
- Land: approx 12 sq km
- Vehicles: 20,000
- School Children: 60,000
- Employees: 90,000
- Other Arrivals: 200,000
- Vehicle Arrivals: 56,000
- A World Heritage City
Sacred Area
Historic Quarter
Urban Quarter

Legend
- Hotels
- Other Buildings
- Schools
- Transport
- Admin. & Services Zone
- Commercial Zone
- Recreational/Sacred Zone
- Educational Zone
- Play Grounds/Parks
- Railway Stations
- Bus Terminals

Kandy City Transport Study
Map 5-1: Conflicting Land Use in Kandy CBD
University of Moratuwa in association with University of Peradeniya
July 2011
Map 3

Survey Locations
Study Area Cordon
SA01 - Gatambe Jc - Siriawayo Bandaranayaka Mw. (A001)
SA02 - Gatambe Jc - William Goppalawa Mw. (AB42)
SA03 - Ampitiya - Ampitiya Road (B195)
SA04 - Tennekumbura Bridge - Heward Road (A026)
SA05 - Lewella Bridge - Sirimalwatta Road (B069)
SA06 - Polgolla Dam - Polgolla Road
SA07 - Katugastota Bridge - Katugastota Road (A009)

CBD Cordon
CBD01 - Highscool - Siriawayo Bandaranayaka Mw. (A001)
CBD02 - Mosque Jc - Sri Sangara Mawatha (B318)
CBD03 - DS Senanayaka Mw. (A009)
CBD04 - Ahadanahamawa Road (B070)

Bypass Roads
BR01 - Haloluwa - Gugagoda Road (B365)
BR02 - Amiwatta - Amiwatta Road
BR03 - Dhamasoka Mawatha (B550)

Average Daily Vehicle & Passenger Flow

| Study Area (DSD) Cordon | 112,170 | 636,485 |
| CBD Cordon (including Minor Roads) | 149,918 | 762,502 |

Legend
- Survey Locations
- CBD Cordon
- Study Area Boundary
- Primary Roads
- Secondary Roads
- Streams/Tanks/Lakes
- Railway Stations
- Bus Terminals
- Schools

Kandy City Transport Study
Map 3-1: Survey Stations for SA Cordon, CBD cordon & Bypass Roads

University of Moratuwa in association with University of Peradeniya
July 2011
Trip Purpose Analysis

**DSD Cordon (On a Weekday)**

- Work: 31%
- Education: 14%
- NHBO: 20%
- HBO: 32%
- NHBE: 3%

**CBD Cordon (On a Weekday)**

- Work: 31%
- Education: 12%
- NHBO: 17%
- HBO: 38%
- NHBE: 2%

**CBD Cordon (On a Saturday)**

- Work: 20%
- Education: 8%
- NHBO: 21%
- HBO: 50%
- NHBE: 1%
Issue #1: Conflicting Land Use in a Heritage City
Congested City Core conflicts with Sacred Area

Road Speeds

Main Roads – 25.7 km/hr
Peak – 16.7 km/hr
Link Speed – from 4 km/hr
High Impact of School Transport on City

Modal Split

<table>
<thead>
<tr>
<th>Mode</th>
<th>Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk</td>
<td>8.0</td>
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<tr>
<td>Bicycle</td>
<td>0.0</td>
</tr>
<tr>
<td>3 Wheeler</td>
<td>10.5</td>
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<tr>
<td>Private vehicles</td>
<td>15.7</td>
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<td>Public bus</td>
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<tr>
<td>School van</td>
<td>33.9</td>
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<tr>
<td>Motor Cycles</td>
<td>4.5</td>
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<tr>
<td>Train</td>
<td>0.5</td>
</tr>
<tr>
<td>School bus</td>
<td>3.1</td>
</tr>
</tbody>
</table>

1,000 school vans carry 20,000 students
10,000 private vehs carry 20,000 students
300 buses carry 15,000 students

Profile

<table>
<thead>
<tr>
<th>Schools in SA (Nos.)</th>
<th>Students (Nos.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major</td>
<td>23</td>
</tr>
<tr>
<td>Minor &amp; International</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
</tr>
</tbody>
</table>

Profile

1,000 school vans carry 20,000 students
10,000 private vehs carry 20,000 students
300 buses carry 15,000 students

Map 4-2: Location of Schools in Study Area
University of Moratuwa in association University of Peradeniya
July 2011
Issue #2: Inadequate Road Space for Demand

- Traffic and Passenger Counts at DSD Cordon
  - 1998 → 30,000 vehicles (with 4,800 buses) carry 320,000 passengers.
  - 2011 → 56,000 vehicles (with 4,800 buses) carry 320,000 passengers.

- This reflects a growth rate of 5% per annum or a doubling of road space required every 14 years.

- Public transport has fallen from 67% (1998) to 64% (2011)

- If Public Transport Share falls to 50%, the vehicle inflow will increase to 100,000 vehicles OR

- If maximum vehicle inflow is 75,000, buses must carry 55% share.
Issue #3: Inefficient Bus Transport

- 3 Terminals - 600 m apart
- 4,800 carry 200,000 people a day

- Only 100 buses ply through the city
- 80,000 access bus stands by walking
- 120,000 access by bus
- 50,000 have both trip ends outside the DSD

- Buses provide the bulk of the transport requirement carrying 64% of passengers.
- Three Bus Terminals with over 2x80,000 pedestrian movements plus 2x50,000 bus to bus transfers daily.
- Around 96% of services terminate in city centre very few through services.
- Terminating buses cause parking problems.
- No proper Terminal – handles 400,000 passengers
Issue #4: Excessive Pedestrian Activity in CBD
Issue #5: Underutilization of Railway

- Distance: 11 km from Peradeniya to Katugastota
- Stations: 9 stations
- Trains: 20 trains/day
- Speeds: Comparable to road
- Traffic: Carried 1% of traffic, Kandy traffic 3,000, Only 300 school children

Map 2-5: Railway Network, Stations & Halts in Study Area

Kandy City Transport Study

University of Moratuwa in association
University of Peradeniya
July 2011
Recommendation #1: Land Use Readjustment
Recommendation #2: Re-routing Bus Services
Recommendation #3: New Commuter Railway Service

Proposed Stations for Commuter Rail:
1. Peradeniya
2. Sarasavi Uyana
3. Rajawatta
4. Galleme
5. Kandle Hills
6. Mulgampola
7. Kandy
8. Asgiriya
9. Mahiyawwa
10. Katugastota Road
11. Mavilmada Halt
12. Katugastota

Legend:
- Railway Stations
- Proposed Stations
- 500 m Wide Corridor
- Primary Roads
- Secondary Roads
- Streams/Tanks/Lakes
- Bus Terminals
- Schools

Map 6-1: Proposed Rail Commuter Service

Kandy City Transport Study

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July 2011
Recommendation #4: Integrated Multimodal Terminal

Legend:
- Proposed Bus Stop
- Route for North Entries
- Route for West Entries
- Route for East Entries
- Other Buildings
- Hotels
- Rail Bus Integration
- Primary Roads
- Secondary Roads
- Other Roads
- Railway Stations
- Bus Terminals

Map 6-2: Bus Routing & Functional Arrangement for Bus Terminal at Good Shed

Kandy City Transport Study

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July 2011
Recommendation #5: Strategy for School Transport

- Pedestrian Walkways
- Parking
- Regulating School Transport
- Traffic Restraints
Recommendation #6: Improve Mobility of Main Corridors

Survey Locations

Study Area Cordon

SA01 - Gatebe Jc - Sirimavo Bandaranayake Mw. (A001)
SA02 - Gatebe Jc - William Goopalawa Mw. (AB42)
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CBD03 - DS Senanayaka Mw. (A009)
CBD04 - Adahanamahalawa Road (B307)

Bypass Roads

BR01 - Haloluwa - Guhagoda Road (B365)
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BR03 - Dharmasoka Mawatha (B550)

Legend

Survey Locations

CBD Cordon

Study Area Boundary

Primary Roads

Secondary Roads

Streams/Tanks/Lakes

Railway Stations

Bus Terminals

Schools

Kandy City Transport Study

Map 3-1: Survey Stations for SA Cordon, CBD cordon & Bypass Roads

University of Moratuwa in association
University of Peradeniya
July 2011
Recommendation #7: Development of Inner Bypass
## Performance of Transport System for Current Economy

<table>
<thead>
<tr>
<th>Mode Used</th>
<th>Passengers/Day</th>
<th>VOC Mn Rs/Year</th>
<th>VOTS Mn Rs/Year</th>
<th>Total Savings Rs Mn/Yr</th>
<th>Max Transport Infra Cost Rs Mn/Yr</th>
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<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
<td>Before</td>
</tr>
<tr>
<td>Bus</td>
<td>400,000</td>
<td>420,000</td>
<td>1,168</td>
<td>1,226</td>
<td>3,139</td>
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<tr>
<td>Railway</td>
<td>6,000</td>
<td>20,000</td>
<td>35</td>
<td>117</td>
<td>44</td>
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<td>Private</td>
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<td>210,000</td>
<td>7,300</td>
<td>5,825</td>
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<td>NMT</td>
<td>14,000</td>
<td>20,000</td>
<td>-</td>
<td>-</td>
<td>17</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>670,000</strong></td>
<td><strong>670,000</strong></td>
<td><strong>8,503</strong></td>
<td><strong>7,169</strong></td>
<td><strong>6,242</strong></td>
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### Additional Metrics

- **GDP**
  - Before: 200,000
  - After: 200,000

- **Transport % of GDP**
  - Before: 7.37
  - After: 5.61

- **New GDP Potential**
  - 262,653

- **New Pax Flow**
  - 879,887

- **% increase**
  - 31.3
# Performance of Transport System in an Improved Economy

<table>
<thead>
<tr>
<th>Mode Used</th>
<th>Passengers/Day Before</th>
<th>Passengers/Day After</th>
<th>VOC Mn Rs/Year Before</th>
<th>VOC Mn Rs/Year After</th>
<th>VOTS Mn Rs/Year Before</th>
<th>VOTS Mn Rs/Year After</th>
<th>Total Savings Rs Mn/Yr Before</th>
<th>Total Savings Rs Mn/Yr After</th>
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<tbody>
<tr>
<td>Bus</td>
<td>400,000</td>
<td>480,000</td>
<td>1,168</td>
<td>1,402</td>
<td>3,139</td>
<td>1,860</td>
<td>4,307</td>
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<td>Railway</td>
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<td>175</td>
<td>44</td>
<td>164</td>
<td>79</td>
<td>339</td>
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<tr>
<td>Private</td>
<td>250,000</td>
<td>250,000</td>
<td>7,300</td>
<td>6,935</td>
<td>3,042</td>
<td>2,738</td>
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<td>-</td>
<td>17</td>
<td>22</td>
<td>17</td>
<td>22</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>670,000</strong></td>
<td><strong>780,000</strong></td>
<td><strong>8,503</strong></td>
<td><strong>8,512</strong></td>
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<td><strong>4,784</strong></td>
<td><strong>14,745</strong></td>
<td><strong>13,296</strong></td>
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## Additional Data

- **GDP**: 200,000
- **Transport**: 262,653
- **% of GDP**: 7.37
- **% of GDP**: 7.35
WASHINGTON, May 5, 2014 — The World Bank approved a credit of $147 million to help rehabilitate basic urban services and improve livability in two major cities beyond Colombo; Kandy and Galle city regions. The project seeks to produce a more spatially balanced distribution of economic opportunities, while at the same time reducing congestion in the capital and improving overall livability.
Thank You
Ex 1. BRT System on Galle Road, Colombo
Design Objective

3 Lanes Mixed Traffic
High Bus Flows Speed 18 km/hr carrying 16,000 pax.hr

2 Lanes Non Bus Traffic
Speed > 18 km/h where pax in private vehs should decrease from 8,000 to 6,000

1 Lane BRT Speed > 25 km/h which should carry 10,000

Implement Traffic Restraint Measures such as Electronic Road Pricing to cap traffic flow

Priority, Articulated Vehicles, long platforms, Off Board Ticketing, Overpasses

Current System Cost
Feasible System Cost
Maximum Improvement Cost
Ex 2. Demand Based Bus Dispatching

Route # 177

Demand/Supply Vs Time Period from Kaduwela to Kollupitiya

- Observed Curve for the Passenger Demand
- Estimated Curve for the Passenger Demand
The economically optimum headway based on Newell’s policy, should also be $h_0$.

Then the revenue to operator should be based on the cost of providing a headway of $h_0$.

The FRO is based on the total revenue to operator for a given operating cycle.

If FRO’ is less then the FRO”’, then an operating subsidy ($\Delta f$) is justifiable to minimize the total social cost.

However if FRO”’ is more than FRO’, then also it means that fare levels are higher than what is required to provide a socially optimum service and it is likely that the operator will make surplus profits.
3. Big Data (Correlation between Mobile and Transport Data)
Thank You