Freight Planning For Municipal Solid Waste

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Outline

- Motivation
- Municipal Solid Waste Management
- Freight Planning for Solid Waste
- Solid Waste/Freight Program in Tainan
- Conclusions
Motivations

- The solid waste counts 10.3% of urban freight transportation tonnage in Tainan.
- The waste collection generates local traffic congestion during the evening traffic hours daily.
- The freight planning for municipality waste management was neglect in either freight planning or waste management studies.
- To construct a freight planning process for municipal waste management.
Municipal Solid Waste

- A waste type consisting of everyday items residents consume and discard
  - Categories of kitchen/food, yard, recyclables, bulky (appliances/furniture), and garbage
- From residential, commercial, institutional, and industrial sources
Solid Waste Management

- To systematic control of waste generation, waste handling and separation at the source, collection, separation and processing of solid waste, energy generation, and disposal.

- Waste reduction is the most preferred management technique, followed by reuse and recycling, then incineration with energy recovery, and least preferred landfilling.
Solid Waste Management

- Waste generation
  - Residential
  - Institution
  - Commercial
  - Industrial

- Waste storage/separation at the source

- Waste collection

- Separation/recovery/treatment of solid wastes
  - Reuse
  - fodder
  - Composting
  - Recycling

- Energy generation

- Disposal

- Transportation
  - Municipal Contractor

- Infrastructure
  - Municipal Contractor
Freight Planning

Functions
- waste generation, collection at sources and trucking to transit sites for consolidation/to processing facilities for separation/to treatment facilities for recycling, biological or thermal treatment, and destined to landfills for final disposal.

Goal
- to promote the most cost effective operation with timely pickup service to municipal institutions and residents.
Freight Planning

- Waste generation
  - Residential
  - Institution
  - Commercial
  - Industrial

- Waste storage and collection

- Infrastructure network design

- Service level

- Route and Schedule

- Fleet size

- Routes/time table
Primary Steps

- Waste generation
  - To forecast the demand.
  - Variables include: population, income, gross domestic product, household size, age structure, etc.

- Infrastructure design
  - To design a cost-effective network of transit, processing and incineration facilities and disposal sites while meeting the waste demand
  - A strategic level decision which is an outcome of socio-economic and political compromise.
Primary Steps

- Collection methods
  - Are means to gather waste and recyclable materials and transport of these materials
  - Collection may be made by municipality, private firm under contract to municipal or with institutions and industrial premiers, *public/private partnership*.
  - The decision is a trade-off between city-wide system cost minimization and the cost incurred solely by the municipality.
Primary Steps

- Service level and Fleet size/composition
  - To determine the frequency of pickups, number of days in a week, service level.
  - A *tactical* decision.
  - Key decision factors are the heterogeneous collection trucks’ fixed and operating costs, crews and the spoiling time that waste creates odor smells.
Primary Steps

- Use the maximal walking distance to determine the least number of stops and their service areas.
- The pickup volume at each stop can be determined.
- Stops are located in suitable streets that may result in a least traffic conflicts.
- With the distance/cost from all stops to all other stops, mathematically, the service level planning can be formulated as an integrated set clustering and set partitioning integer programming problem with capacity constraint.
Primary Steps

Route and schedule operations plan

- To determine the collection truck routes for all waste types with pickup time tables to minimize cost while meeting the fleet size and carrying capacity limitations.

- An operational level decision.

- The collection of various waste types, general, kitchen/food and recyclables all in the same time with different types of collection vehicles.

- A multi-layer vehicle routing problem with drivers’ working hours
Primary Steps

- Infrastructure design, service and routing and scheduling are mutually interrelated.
  - A dense network requires a fewer collection trucks with a small collection crew.
  - The service level determines the amount of waste per stop, an input to routes plan.
  - The routes plan has a cost implication of infrastructure network design.
  - The *hierarchical computation* is an effective method.
Tainan City
Tainan City

- The oldest is now the *cultural and tourist city*.
- Economy relies on traditional manufacturing industry, agriculture, fishery
- Retail and services is the largest employment sector, margined at 52% in 2010.
- Automobiles and motorcycles are predominant transportation modes.
In 2006, DEA passed the legislation requiring all municipalities implementing the waste separation, recycling and reuse (3-in-1 collection program).

In 2003, Tainan city passed the legislation required waste separation into garbage, kitchen/food waste and recyclables.

The waste per person per year continuously declined, to 414.5 and 397.6 kg in 2009 and 2010, respectively.
# Wastes in Tainan City

<table>
<thead>
<tr>
<th></th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incineration</td>
<td>208,780</td>
<td>192,662</td>
<td>197,498</td>
<td>170,550</td>
<td>151,805</td>
<td>147,711</td>
<td>143,306</td>
<td>132,464</td>
<td>117,309</td>
</tr>
<tr>
<td>Landfill</td>
<td>31,755</td>
<td>33,045</td>
<td>18,916</td>
<td>17,502</td>
<td>13,574</td>
<td>13,669</td>
<td>5,009</td>
<td>2,703</td>
<td>10,268</td>
</tr>
<tr>
<td>Recyclable Waste</td>
<td>100%</td>
<td>79.64%</td>
<td>66.5%</td>
<td>53%</td>
<td>46%</td>
<td>41.2%</td>
<td>41.6%</td>
<td>42.3%</td>
<td>41.5%</td>
</tr>
<tr>
<td>Recyclable Waste</td>
<td>48,982</td>
<td>87,145</td>
<td>126,811</td>
<td>167,770</td>
<td>173,230</td>
<td>156,244</td>
<td>141,508</td>
<td>137,243</td>
<td></td>
</tr>
<tr>
<td>Food/Kitchen</td>
<td>8,708</td>
<td>21,826</td>
<td>24,458</td>
<td>24,734</td>
<td>52,609</td>
<td>47,540</td>
<td>39,124</td>
<td>38,404</td>
<td></td>
</tr>
<tr>
<td>Compost</td>
<td>1,615</td>
<td>1,748</td>
<td>479</td>
<td>3,814</td>
<td>16,132</td>
<td>18,679</td>
<td>17,609</td>
<td>17,174</td>
<td></td>
</tr>
<tr>
<td>Fodder</td>
<td>7,093</td>
<td>20,078</td>
<td>23,979</td>
<td>20,920</td>
<td>36,477</td>
<td>28,861</td>
<td>21,515</td>
<td>21,230</td>
<td></td>
</tr>
<tr>
<td>Bulky (Furniture/Appliances)</td>
<td>3.07%</td>
<td>6.7%</td>
<td>6.8%</td>
<td>6.6%</td>
<td>13.4%</td>
<td>13.3%</td>
<td>12.2%</td>
<td>12.5%</td>
<td></td>
</tr>
<tr>
<td>Reuse</td>
<td>1,221</td>
<td>710</td>
<td>231</td>
<td>672</td>
<td>1,461</td>
<td>2,067</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incineration</td>
<td>13,302</td>
<td>13,978</td>
<td>3,073</td>
<td>3,103</td>
<td>2,233</td>
<td>1,644</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landfill</td>
<td>1,112</td>
<td>3,022</td>
<td>1,111</td>
<td>232</td>
<td>105</td>
<td>37</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reuse</td>
<td>4.4%</td>
<td>4.7%</td>
<td>1.1%</td>
<td>1.1%</td>
<td>1.2%</td>
<td>1.2%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>240,535</td>
<td>283,397</td>
<td>325,385</td>
<td>354,956</td>
<td>375,593</td>
<td>391,634</td>
<td>356,106</td>
<td>319,598</td>
<td>306,972</td>
</tr>
</tbody>
</table>
Wastes in Tainan City
**Recyclables**

- Paper, metal and plastics products and glass containers are accounted for 50.95%, 36.46%, 5.71% and 3.09%, with a total of 96.21%.

<table>
<thead>
<tr>
<th></th>
<th>Garbage collectors</th>
<th>Community</th>
<th>Education Institutes</th>
<th>Governments</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper</td>
<td>22.42</td>
<td></td>
<td></td>
<td></td>
<td>50.95</td>
</tr>
<tr>
<td>Paper containers</td>
<td>1.64</td>
<td>0.17</td>
<td>0.17</td>
<td>0.1</td>
<td>0.22</td>
</tr>
<tr>
<td>Metal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cans</td>
<td>0.92</td>
<td>1.55</td>
<td>0.9</td>
<td>1.03</td>
<td>1.41</td>
</tr>
<tr>
<td>Other products</td>
<td>2.76</td>
<td>38.32</td>
<td>23.68</td>
<td>31.24</td>
<td>35.05</td>
</tr>
<tr>
<td>Plastics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastic containers</td>
<td>2.97</td>
<td>3.09</td>
<td>11.38</td>
<td>16.69</td>
<td>5.66</td>
</tr>
<tr>
<td>Plastic foam packaging</td>
<td>0.19</td>
<td>0.03</td>
<td>0</td>
<td>0.13</td>
<td>0.05</td>
</tr>
<tr>
<td>Glass</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glass container</td>
<td><strong>57.73</strong></td>
<td>0.26</td>
<td>6.79</td>
<td>0.7</td>
<td>3.09</td>
</tr>
</tbody>
</table>
Waste Flows

- Recyclers
- Separation
  - Bulky waste
  - Trash
  - Kitchen waste
  - Recyclables
- Incineration
- Land-filling
- Composit
- Fodder

- Processing Organization
- Recycled Goods
- On demand
- Daily
- Contractor
Collections

- Don’t leave on the ground policy.
- Residential source is served by curbside (with no more than 300 meters walking) on scheduled day/time pickup.
- City granted each of all 6 jurisdiction districts authorities to separate plan and implement respective waste collection.
- Bulky items must be requested a day ahead of pickup.
# Service and Fleet size

<table>
<thead>
<tr>
<th>Routes by truck size</th>
<th>General/Kitchen</th>
<th>Recyclables</th>
<th>Pickup schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large size</td>
<td>Mid size</td>
<td>Small size</td>
</tr>
<tr>
<td>East</td>
<td>7</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>South</td>
<td>10</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Central West</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>North</td>
<td>4</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>An-Ping</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>An-Nan</td>
<td>14</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

- The curbside garbage pickup is carried out by rear loading packers, while the recyclables are picked up by flat trucks.
Service and Fleet size

- The service level is same for all pickup areas, the days of the week could be different with a higher utilization of pickup trucks resulted in a smaller fleet size.
  - We may reduce a crew roster, if two areas of pickup days are alternated form the current M/T/Th/Sat to M/W/Th/Sat and T/W/F/Sun.
  - Such an alternation does not violate the storage time of two days constraint.
## Route and Schedule Plan

<table>
<thead>
<tr>
<th>Route #</th>
<th>Vehicle (tons)</th>
<th>Stops</th>
<th>Segments</th>
<th>Start time</th>
<th>Finish time</th>
<th>Estimated 2-day waste (T)</th>
<th>Estimated Truck loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.03</td>
<td>94</td>
<td>3</td>
<td>14:30</td>
<td>20:40</td>
<td>6.45</td>
<td>1.60</td>
</tr>
<tr>
<td>2</td>
<td>3.46</td>
<td>63</td>
<td>2</td>
<td>13:15</td>
<td>19:33</td>
<td>1.82</td>
<td>0.53</td>
</tr>
<tr>
<td>3</td>
<td>3.25</td>
<td>133</td>
<td>2</td>
<td>14:30</td>
<td>20:39</td>
<td>11.22</td>
<td>3.45</td>
</tr>
<tr>
<td>4</td>
<td>3.25</td>
<td>133</td>
<td>2</td>
<td>14:30</td>
<td>20:38</td>
<td>14.41</td>
<td>4.43</td>
</tr>
<tr>
<td>5</td>
<td>3.46</td>
<td>117</td>
<td>2</td>
<td>14:30</td>
<td>20:36</td>
<td>8.95</td>
<td>2.59</td>
</tr>
<tr>
<td>6</td>
<td>2.32</td>
<td>83</td>
<td>3</td>
<td>14:30</td>
<td>20:40</td>
<td>4.47</td>
<td>1.93</td>
</tr>
</tbody>
</table>
Route and Schedule Plan

- Routes 3-5 do not have sufficient carrying capacities for the demand that causes delays.
- Crew on route 1 has to wait in between segments.
- The policy allows jurisdiction districts authorities *separately* plan and implement requires reevaluation so that the workload can be more balanced.
Conclusions

- We construct a freight planning process for municipal waste management to promote the most cost effective operation with timely pickup service to municipal institutions and residents.

  - The primary steps include waste generation, collection methods, an infrastructure design, the service level, and route and schedule operations plan.
  
  - It involves institutional cooperation of government, commercial, institutional and industrial sources.
  
  - We discuss the methodology for service level and collection routing and scheduling operational plan.
Conclusions

- Implemented various recyclables programs, but may consider further waste reduction.
  - To change a flat fee by household embedded in the water bill to purchase garbage bags.
- Better data collection for public/private partnership.
- Increase the utilization of fleet/crews with a smaller fleet size if days of the week alternated.
- Balance workload over routes for on-time pickups, if jurisdictions can cooperatively plan routes and schedules.