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.

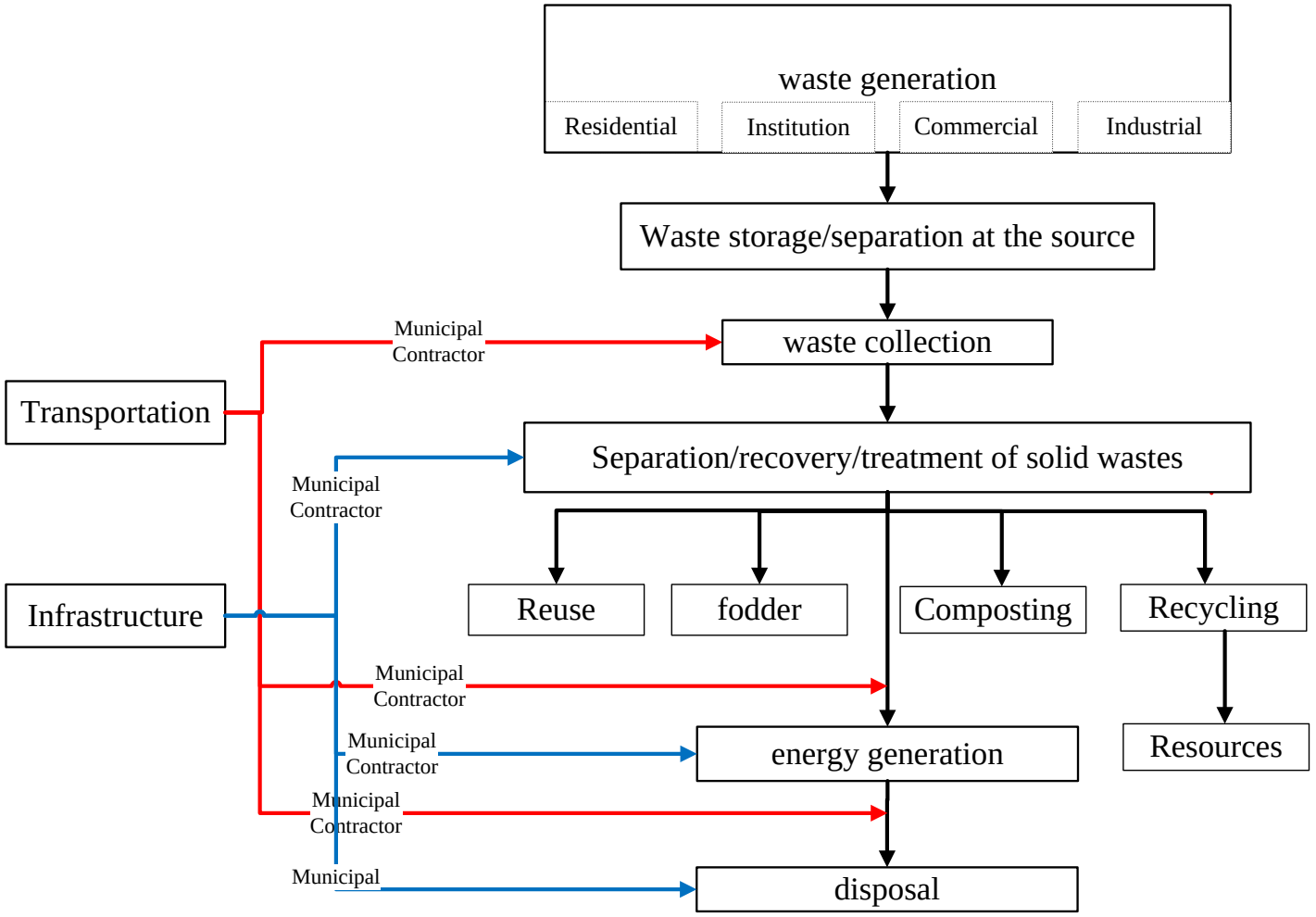
Municipal Solid Waste

- 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.

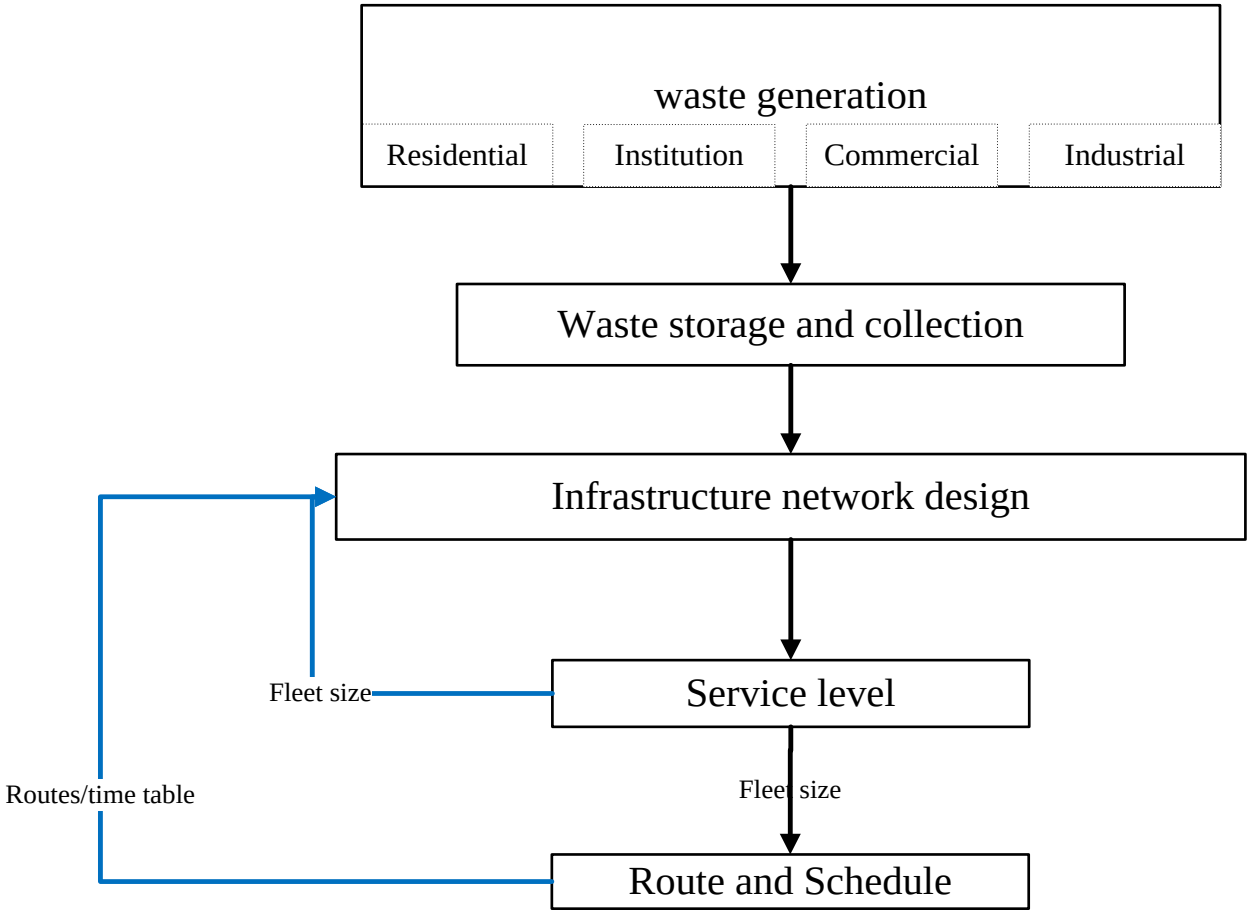
Solid Waste Management



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



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

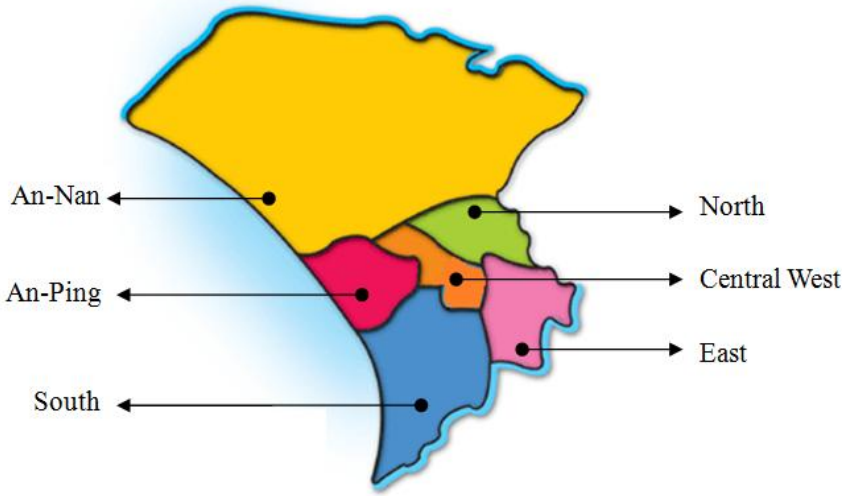
- Route and schedule operations plan
  - To determine the collection truck routes for all waste types with pickup time tables to minimize cost while meeting the fleet size and carrying capacity limitations.
  - An operational level decision.
  - The collection of various waste types, general, kitchen/food 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


Taipei
Hsinchu
Taiwan
Hualien
Tainan
Kaohsiung


An-Nan
An-Ping
South
North
Central West
East

Tainan City

- The oldest is now the *cultural and tourist city*.
- The fifth largest city after Taipei, New Taipei, Kaohsiung and Taichung cities.
- 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.

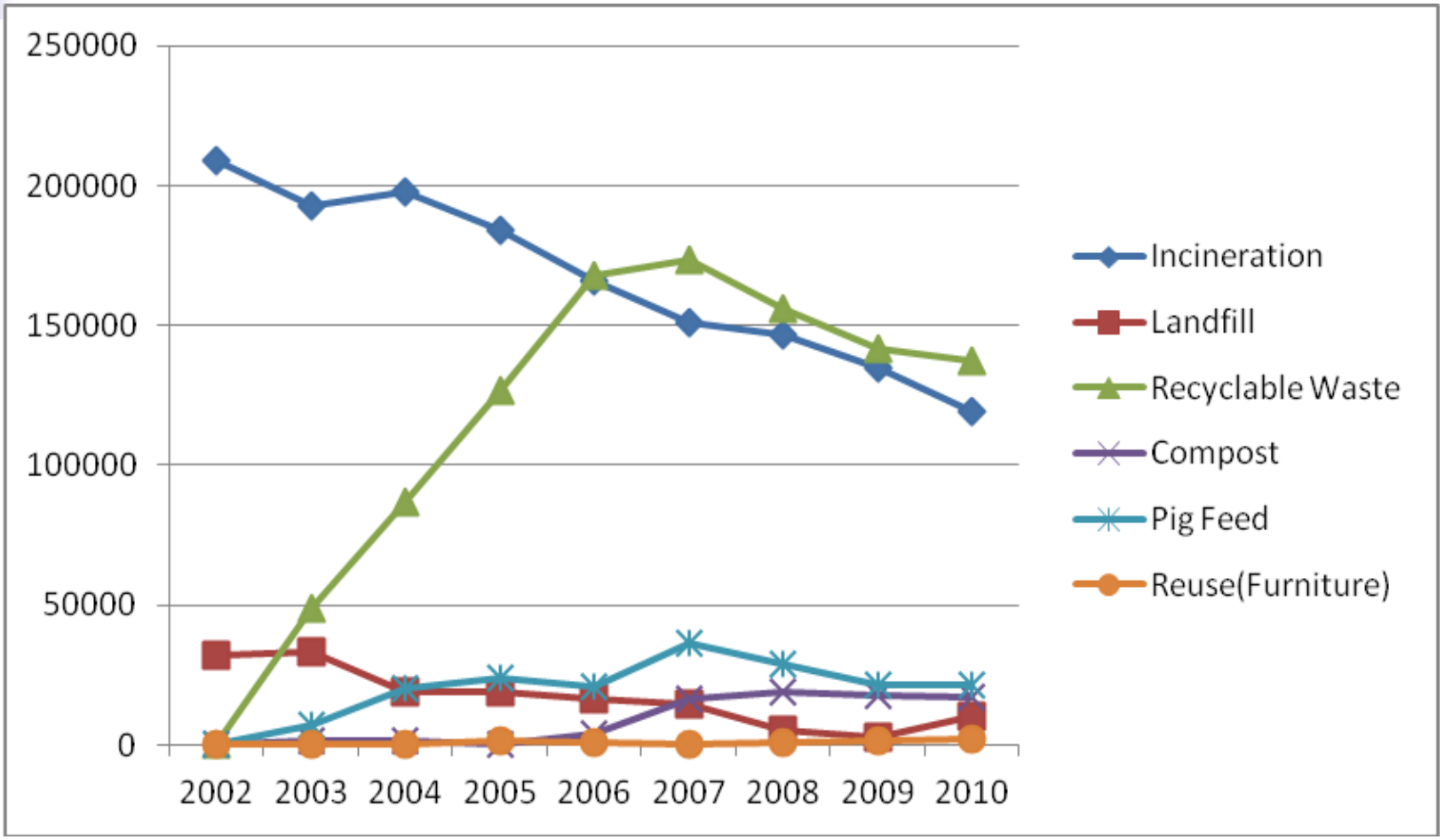
Solid Waste Program

- 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

	2002	2003	2004	2005	2006	2007	2008	2009	2010
General Waste	**240,535**	225,707	216,414	188,052	**165,379**	161,380	148,315	135,167	**127,577**
Incineration	208,780	192,662	197,498	170,550	151,805	147,711	143,306	132,464	117,309
Landfill	31,755	33,045	18,916	17,502	13,574	13,669	5,009	2,703	10,268
	100%	79.64%	66.5%	53%	46%	41.2%	41.6%	42.3%	41.5%
Recyclable Waste		48,982	87,145	126,811	**167,770**	173,230	156,244	141,508	137,243
		17.28%	26.8%	35.7%	44.7%	44.2%	43.9%	44.3%	44.7%
Food/Kitchen		8,708	21,826	24,458	24,734	52,609	47,540	39,124	38,404
Compost		1,615	1,748	479	3,814	16,132	18,679	17,609	17,174
Fodder		7,093	20,078	23,979	20,920	36,477	28,861	21,515	21,230
		3.07%	6.7%	6.8%	6.6%	13.4%	13.3%	12.2%	12.5%
Bulky (Furniture/ Appliances)			--	15,635	17,710	4,415	4,007	3,799	3,748
Reuse				1,221	710	231	672	1,461	2,067
Incineration				13,302	13,978	3,073	3,103	2,233	1,644
Landfill				1,112	3,022	1,111	232	105	37
				4.4%	4.7%	1.1%	1.1%	1.2%	1.2%
Total	240,535	283,397	325,385	354,956	375,593	391,634	356,106	319,598	306,972

Wastes in Tainan City

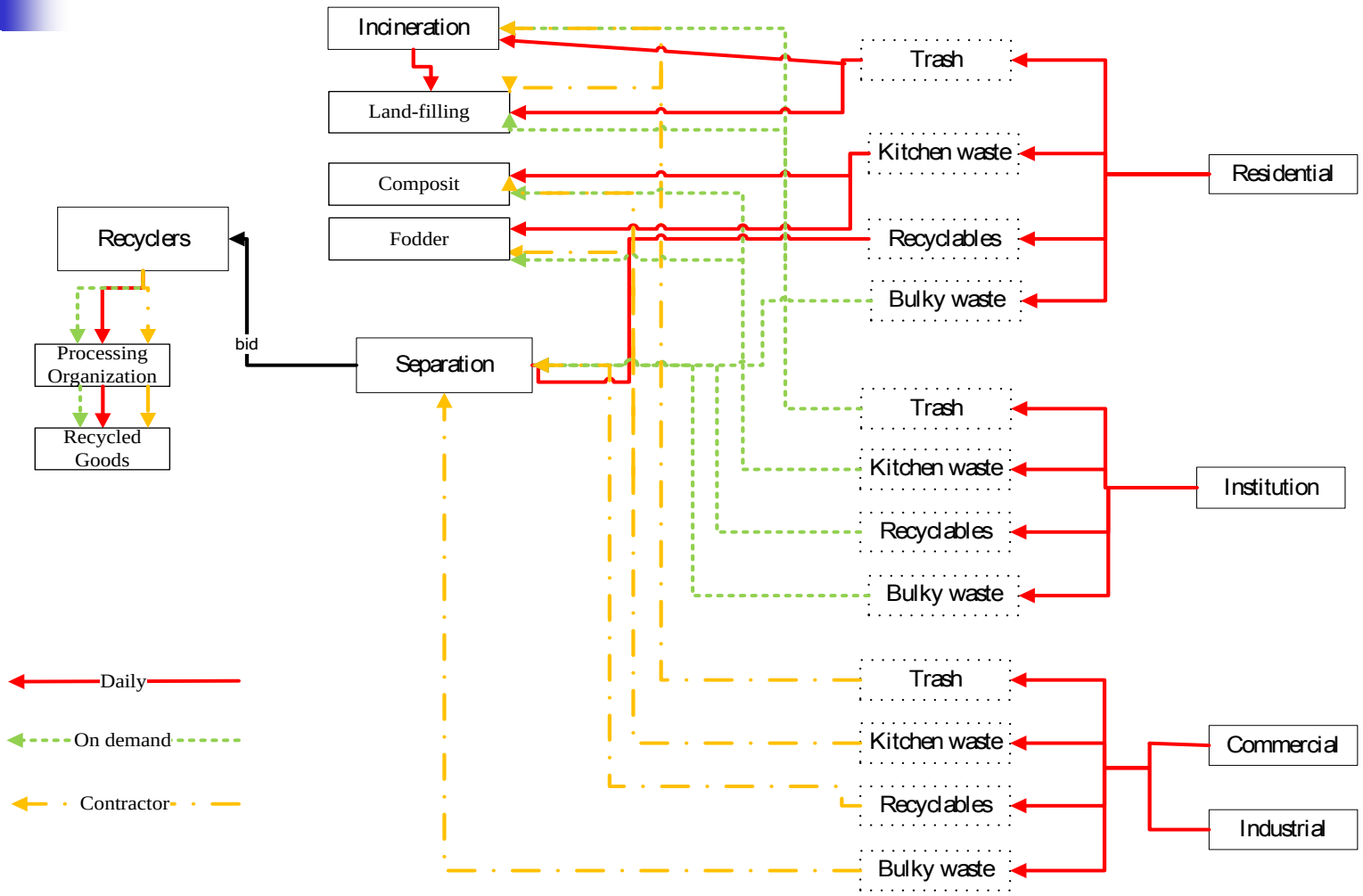


Recyclables

- 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%.

		Garbage collectors	Community	Education Institutes	Governments	Total
Paper	Paper	22.42	**54.8**	**47.42**	**41.92**	50.95
	Paper containers	1.64	0.17	0.17	0.1	0.22
Metal	Cans	0.92	1.55	0.9	1.03	1.41
	Other products	2.76	38.32	23.68	31.24	35.05
Plastics	Plastic containers	2.97	3.09	11.38	16.69	5.66
	Plastic foam packaging	0.19	0.03	0	0.13	0.05
Glass	Glass container	**57.73**	0.26	6.79	0.7	3.09

Waste Flows


Incineration
Land-filling
Composit
Fodder
Recyclers
Processing Organization
Recycled Goods
bid
Separation
Trash
Kitchen waste
Recyclables
Bulky waste
Residential
Trash
Kitchen waste
Recyclables
Bulky waste
Institution
Trash
Kitchen waste
Recyclables
Bulky waste
Commercial
Industrial
Daily
On demand
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

	General/Kitchen					Recyclables
	Routes by truck size			Total	Pickup schedule	
	Large size	Mid size	Small size			
East	7	14	1	22	M/T/Th/Sat	T/S or M/Th
South	10	6	1	17	M/T/Th/Sat	T/S or M/Th
Central West	5	4	3	12	M/T/Th/Sat	T/S or M/Th
North	4	9	3	16	M/T/Th/Sat	T/S or M/Th
An-Ping	6			6	M/T/Th/Sat	M/Th
An-Nan	14	5		19	M/T/Th/Sat	T/S or M/Th

- 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 roaster, 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

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

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.