

Assessment of fuel consumption and GHG emissions for the solid waste collection activities by using GPS data

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Outline

- **Introduction**
- **Fuel consumption estimates for each collection stage**
- **GHG emissions**
- **Effect of optimal routes**
- **Conclusions**

Part 1: Introduction

Waste separation & recycling



MORE collection
& transportation



Main goal

Examine waste collection activities in terms of:

- 1) Fuel consumption**
- 2) GHG emissions**

for each collection stage

Location: **City of Hamilton**

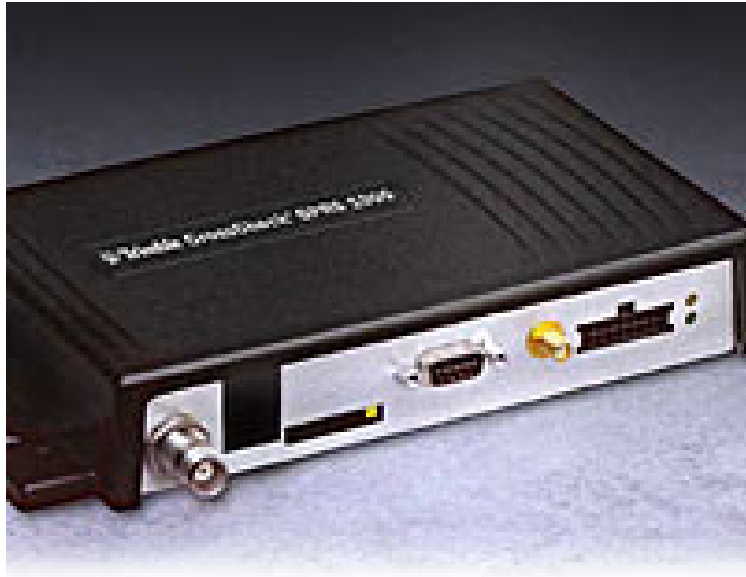


Collection trucks

- **1 co-collection truck: 900076**
- **2 normal garbage trucks**
- **Mounted Global Positioning System (GPS) units to record:**
 - trucks' positions, speeds and heading angles - 1 minute intervals
 - mileage and the times : ignitions turned on or off

Co-collection truck

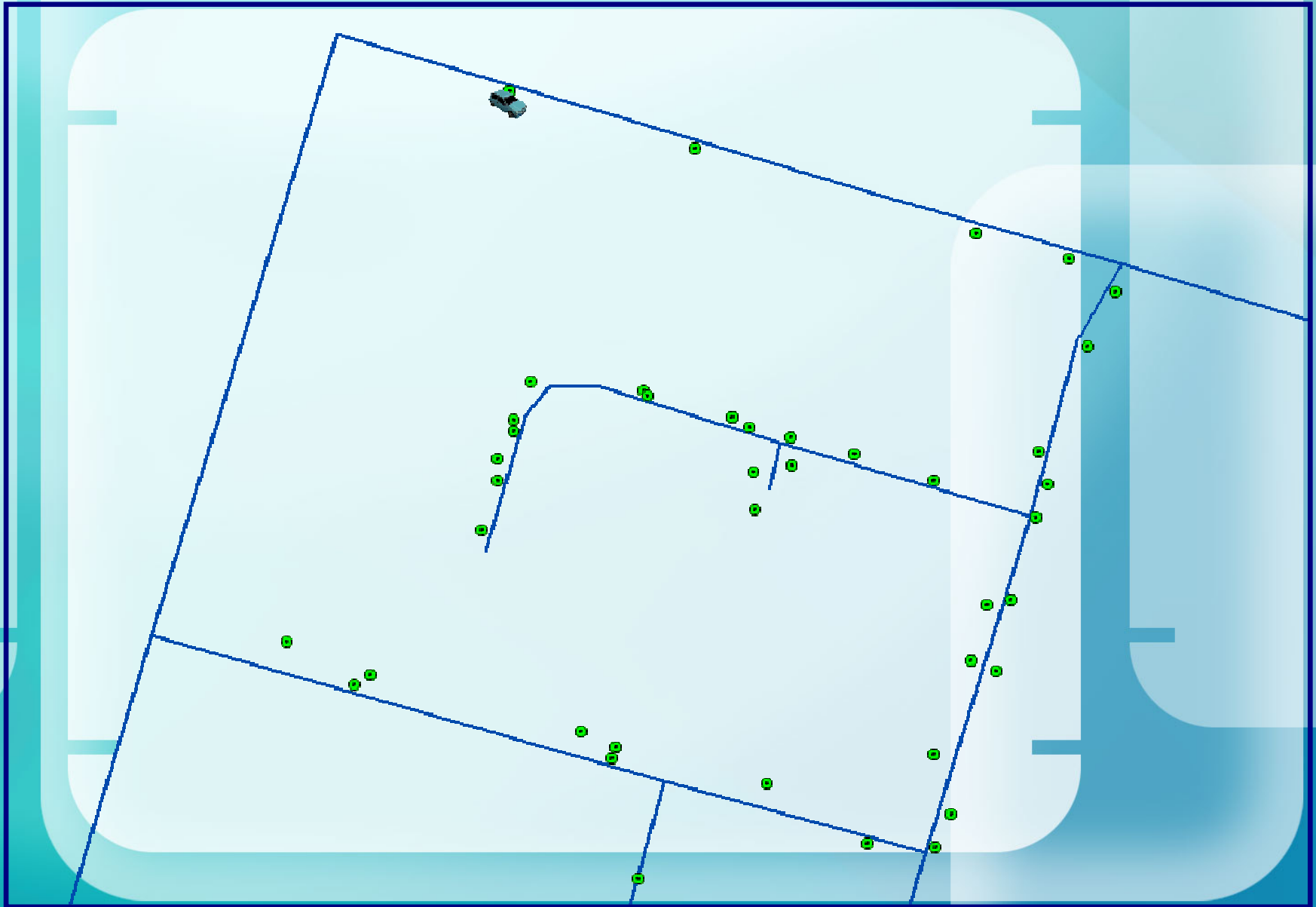




GPS Unit



GPS data



Part 2: Fuel consumption

Fuel consumption rates of collection trucks

- Consume fuel during two activities:
 - ❖ **Traveling**: between garage & collection areas & transfer stations
 - ❖ **Idling**: at routes & transfer stations
- Fuel consumption rate for **idling**:
 - Estimated: **3.1** L/hr (Lim, 2002)
- Fuel consumption rate for **traveling**:
 - Based on fuel and mileage records
(Nov 03 – Jun 04)

Fuel consumption rates of collection trucks (cont.)

- Total **Idling** fuel consumption (IFC) =
Idling times (hr) x 3.1 (L/hr)
 - Total **Traveling** fuel consumption (TFC) =
Total fuel record (L) – IFC(L)
 - Fuel consumption **rate** for traveling =
TFC(L) / total mileage (km)
- 1.104 (km/L); 1.087 (km/L); 1.098 (km/L)

Chose: 1.1 km/L

MSW collection stages

Morning preparation

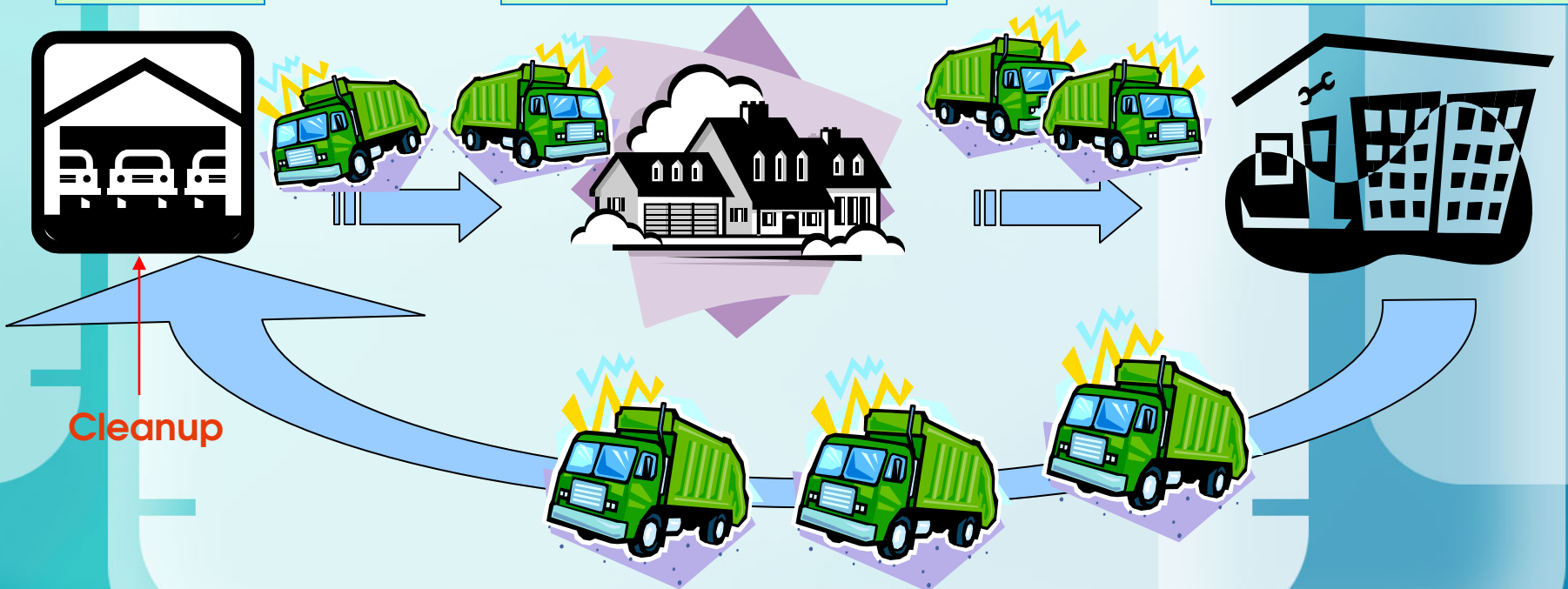
Collect waste house-to-house

- Weigh - Unload
- Weigh

Garage

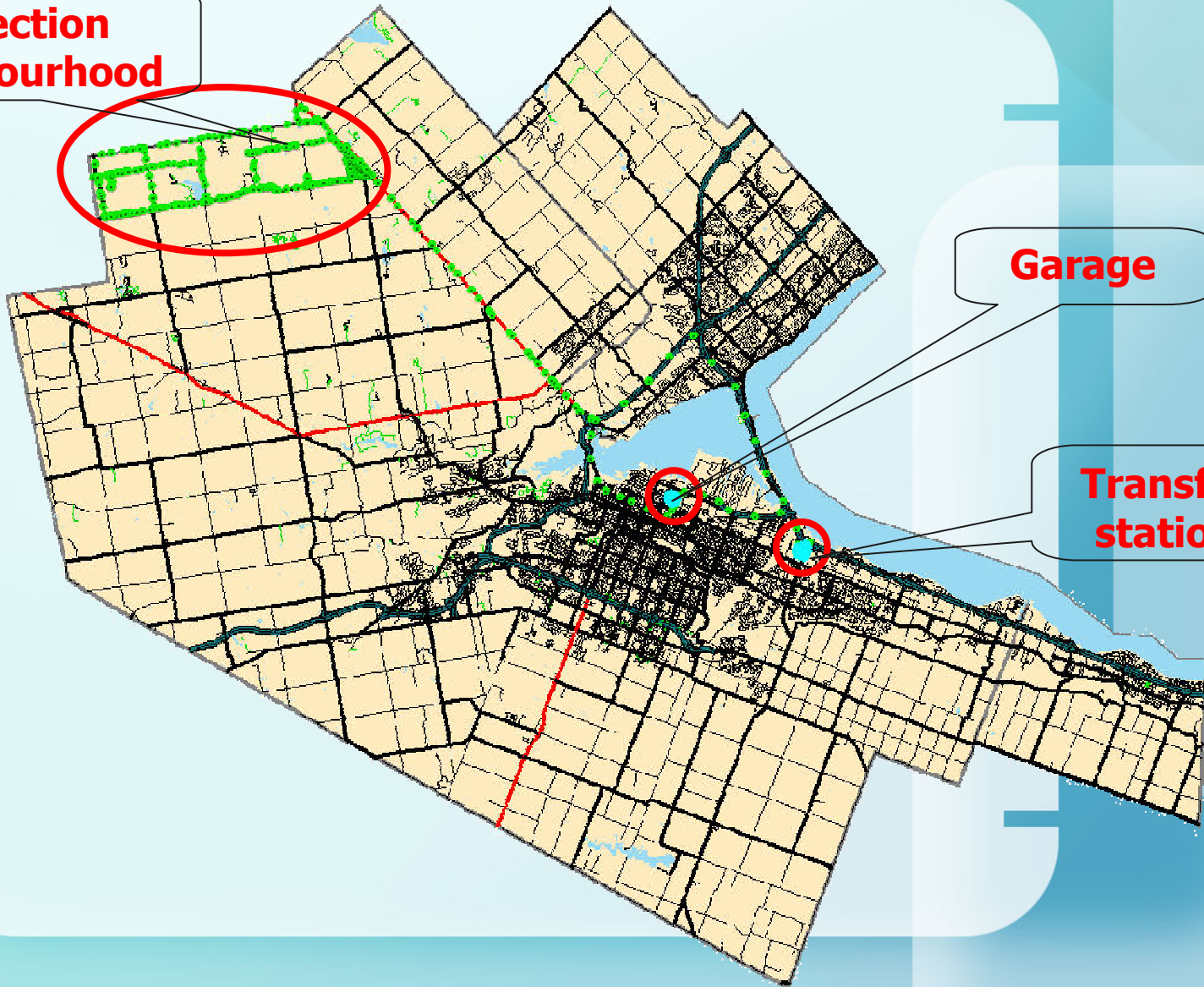
Neighbourhoods

Transfer station



Monday collection activities of truck 900076

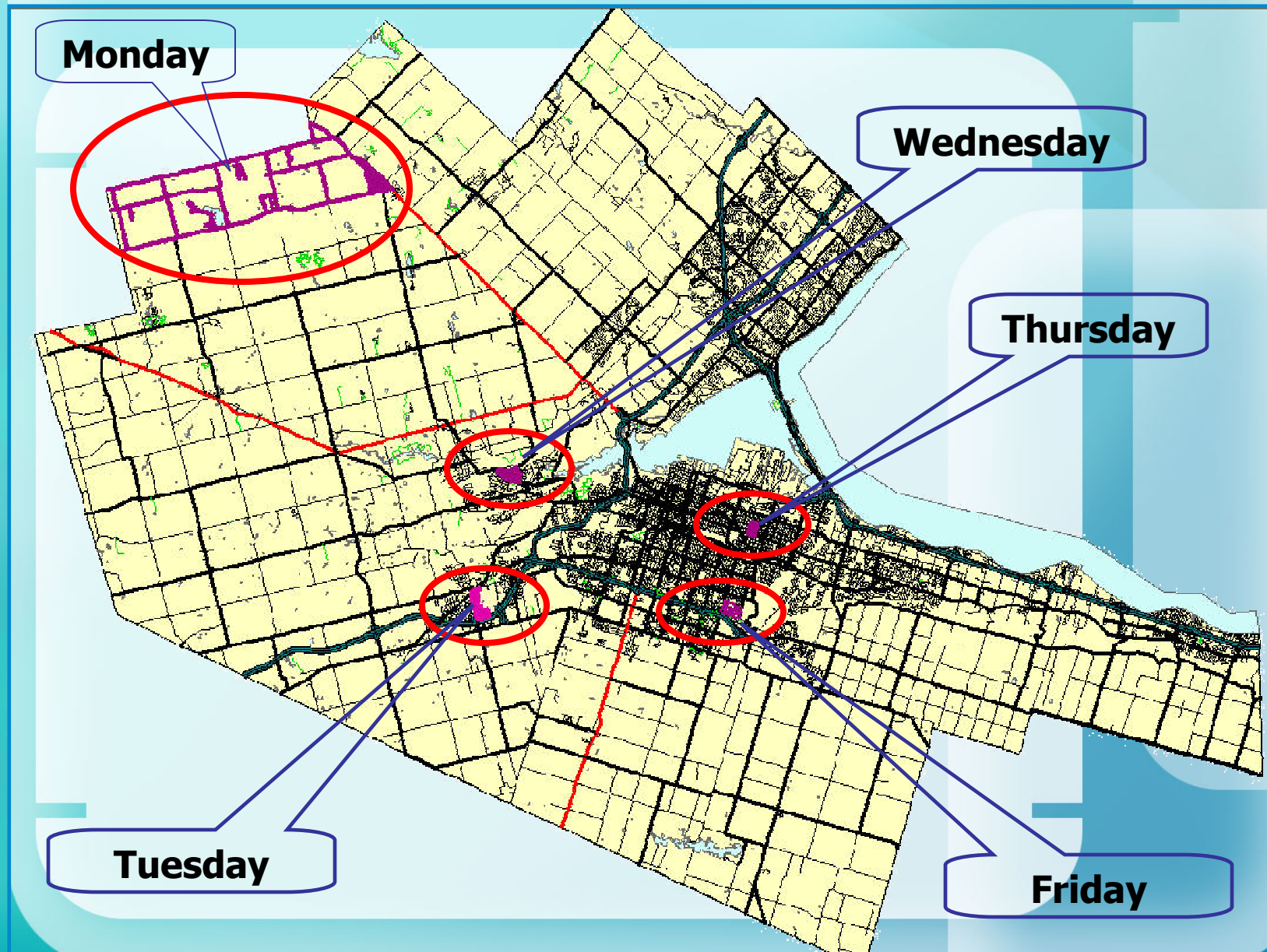
Collection neighbourhood



Garage

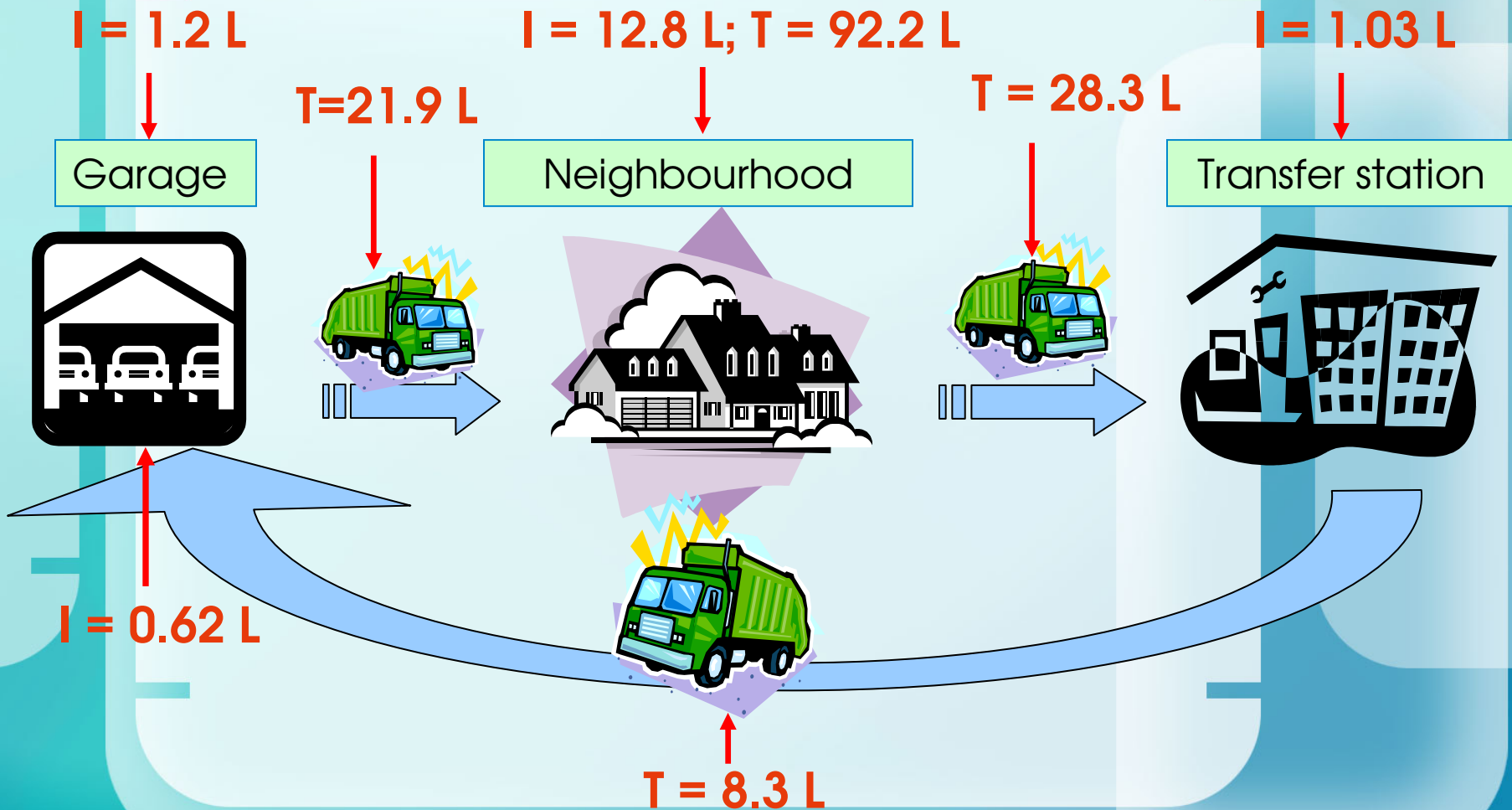
Transfer station

5 main collection areas of truck 900076



Fuel consumption of each collection stage

Truck 900076 - Monday route – Low density

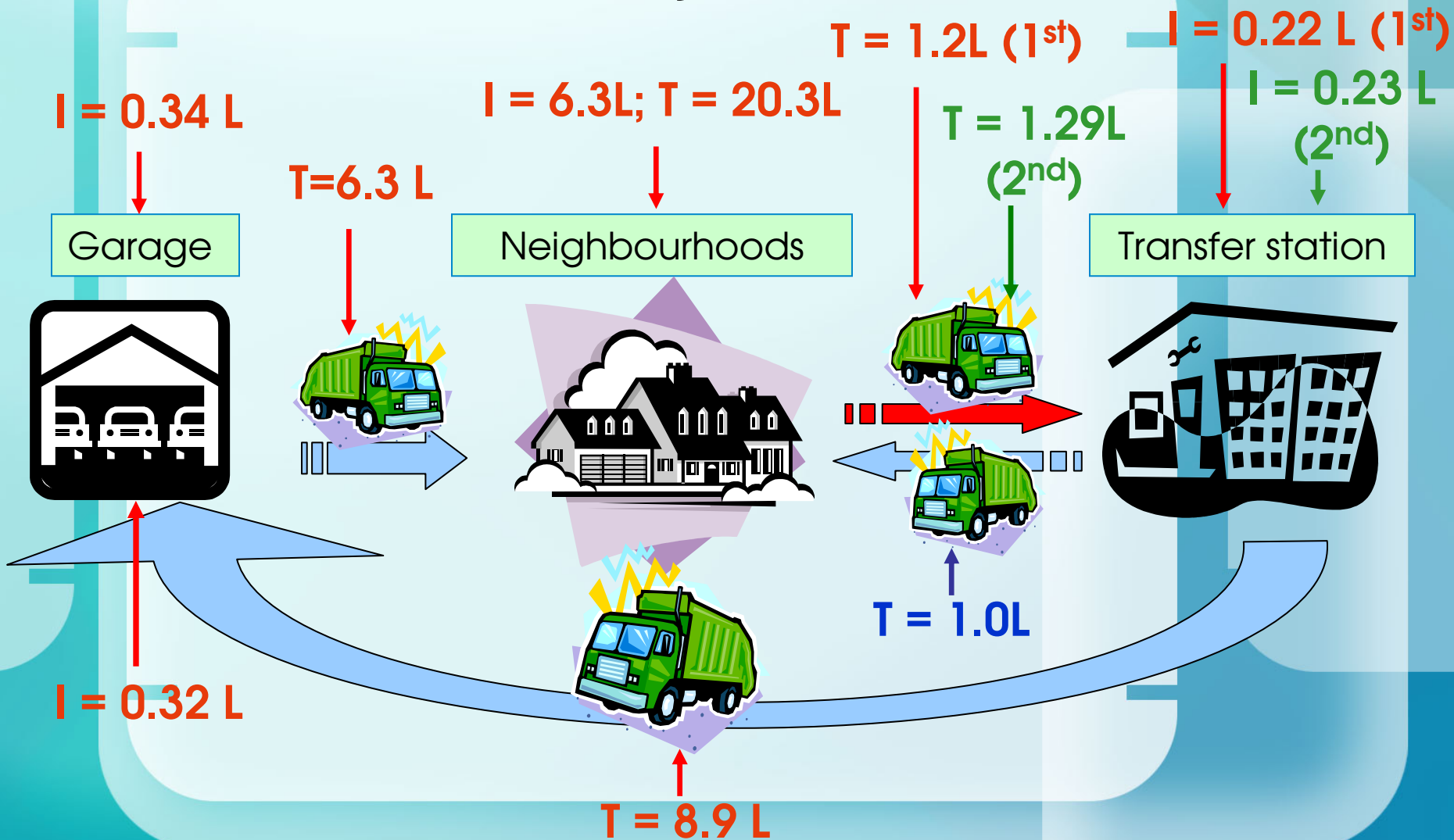


Truck 900076 – Monday route ...

	Stage	Fuel (L)	Fuel (%)	Total
Idling	Garage (start)	1.20	0.72	15.67 L (9.4%)
	Neighbourhood	12.82	7.70	
	Transfer station	1.03	0.62	
	Garage (end)	0.62	0.37	
Traveling	Garage to route	21.99	13.21	150.83L (90.6%)
	Neighbourhood	92.24	55.40	
	Route to TS	28.35	17.03	
	TS to garage	8.28	4.97	
Total		166.50	100.00	

Fuel consumption ...

Truck 107007 - Friday route



Fuel consumption ...

- Total amount of fuel consumed for:
 - ❖ **Low density routes:** 83 to 166 L/day
 - ❖ **Medium density routes:** 70 to 80 L/day
 - ❖ **High density routes:** 35 to 60L/day
- Low density routes:
 - ❖ far from garage and transfer stations
 - ❖ larger area (**rural neighborhoods**)

Fuel consumption ...

- Over 50% of total daily fuel for 'At route' stage
 - During "At route" stage, 10% to 20% for **idling** (medium and high density neighbourhoods)
- reduce idling time to save energy

Fuel consumption ...

- **‘At route’ stage, co-collection truck had greater % of fuel for **idling** than garbage trucks:**
 - + High-density: co-collection truck consumed approx. 20% (traveling) and 20% (idling);
 - use of co-collection trucks will increase the amount of fuel use while idling.
 - needs to be considered if implement a co-collection system.

Fuel consumption ...

- **'At transfer station'** stage, fuel was used for queuing and unloading waste
 - approximately 0.66 liter of fuel each time
 - co-collection truck required more fuel while idling than the other trucks

Part 3: GHG emissions

GHG emissions for each collection stage

- No specific GHG emission rates for garbage trucks
- Used GHG emission rates for HDDVs:

2730 gCO₂/L,

0.13 gCH₄/L

0.082 g N₂O/L

(idling & traveling) (*Environment Canada, 2005*)

→ GHGs emission quantity for each collection stage

Daily GHG emissions

up to
120MTCO₂E/
truck /year

Low density areas								
Truck	109135	109135	109135	109135	109135	109135	109135	900076
Route day	Mon	Wed_A1	Wed_A2	Thu_A1	Thu_A2	Fri_A1	Fri_A2	Mon
CH ₄ (g/day)	21.2	12.2	9.9	10.8	12.7	14.8	12.5	21.6
CO ₂ (g/day)	446,091	255,848	262,427	227,098	250,167	311,126	262,168	450,469
N ₂ O (g/day)	13.4	7.7	0.6	6.8	5.9	9.3	7.9	13.7
Total (MTCO ₂ E/D)	0.451	0.258	0.263	0.229	0.252	0.314	0.265	0.459

Areas	Medium density		High density							
Truck	900076	900076	109135	107007	107007	107007	107007	107007	900076	900076
Route day	Tue	Wed	Tue_A2	Mon	Tue	Wed	Thu	Fri	Thu	Fri
CH ₄ (g)	10.4	9.1	7.3	7.6	8.0	7.8	6.5	6.0	4.5	6.9
CO ₂ (g)	217,726	191,444	153,758	159,484	167,087	163,129	135,871	126,554	94,357	145,759
N ₂ O (g)	6.5	5.8	1.1	4.8	5.0	4.9	4.1	3.8	2.8	4.4
Total (MTCO ₂ E)	0.220	0.193	0.154	0.161	0.169	0.165	0.137	0.128	0.095	0.147

Part 4:
Effects of Optimal routes

Use of optimal routes to collect waste 'At route' stage

Truck	Area	Actual (L)	Optimal (L)	Diff (L)	% of total	Total (L)
109135	Wed_A1	61.9	56.2	5.7	6.1	93.5
109135	Fri_A1	79.4	63.6	15.9	13.9	114.0
900076	Mon	105.0	81.3	23.7	14.2	166.5
900076	Tue	23.3	12.0	11.3	14.1	79.8
900076	Wed	24.4	10.5	13.9	19.9	70.1
109135	Tue_A2	27.5	18.4	9.1	16.2	56.3
107007	Mon	25.1	12.1	13.0	22.2	58.4
107007	Tues	18.4	11.4	6.9	11.3	61.2
107007	Wed	24.6	11.5	13.1	21.9	59.8
107007	Thu	20.3	13.2	7.1	14.2	49.8
107007	Fri	26.6	12.4	14.2	30.5	46.4
900076	Thu	13.9	5.2	8.7	25.2	34.6
900076	Fri	20.5	10.1	10.4	19.6	53.4

- Shortest routes save a considerable amount of fuel
- should find optimal routes

Part 5: Conclusions

Conclusions

- Total amount of fuel: **35 to 166** L/truck/day
- Consumed **double or triple** the amount of fuel if the collection routes are in **rural areas**
- Consider reducing the **collection frequency** in **low density** collections areas
→ reduce fuel consumption

Conclusions (cont.)

- More than 50% of daily fuel in the 'At route' stage
- Idling fuel consumption: 10% - 20% ('At route' stage)
- Co-collection truck used more portion of fuel for idling
- 0.1 to 0.46 MTCO₂E of GHGs were emitted daily
- Using optimal routes save up to 30% of total daily fuel

Thank you !!!