

LIFE CYCLE BASED FRAMEWORK FOR URBAN SOLID WASTE MANAGEMENT FOR LOCAL AUTHORITIES

ANNEXURES

Annexure 01 - Table 1: Impact category used in LCA Inventory Analysis

Description of Impact	Indicator
Global Climate Change	CO ₂ emissions (CO ₂ , CH ₄ , CFC)
Photochemical Smog	VOCs and NO _x
Resource use	Depletion rate of minerals and other resources

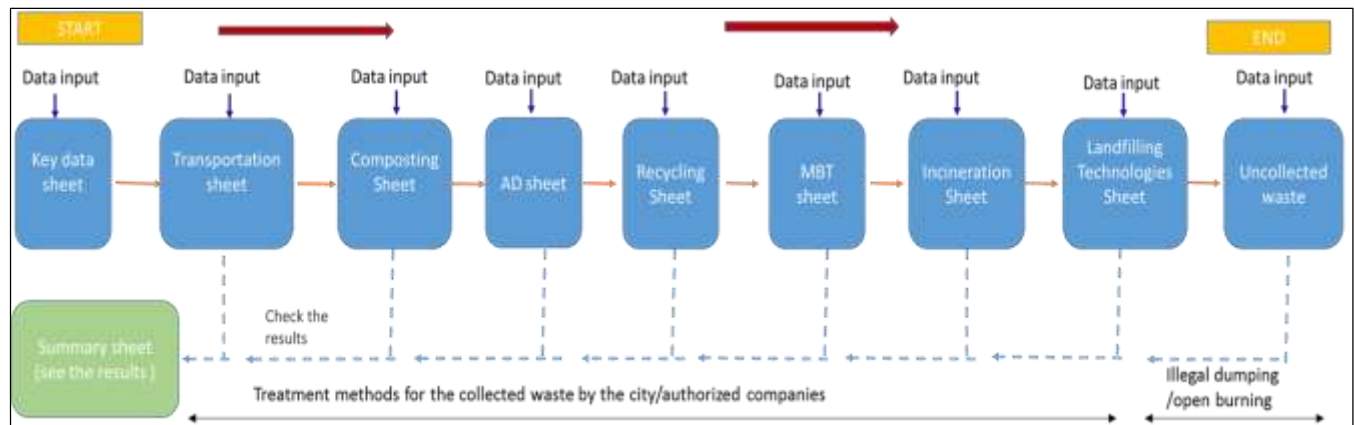
Source: (McDougall, White, Franke, & Hindle, 2001)

Annexure 02 - Table 2: Data Requirement for LCA based model

Key Step of Life Cycle	Data Type
Waste Generation and Collection	Per capita waste generation and Waste collection rates of local authorities
Waste Transportation	Fuel consumption per 1km distance travelled by vehicles
Recycling	Fossil fuel consumption per one ton of recycling
Composting	Emissions per one ton of organic waste composting
Land Filling with Gas Collection	Fossil fuel consumption per one ton of landfilling
Incineration (Waste to Energy)	CH ₄ and N ₂ O emissions per ton in waste combustion
Uncollected waste	Black Carbon emissions per ton of waste disposal and burn

Source: (Menikpura, Gheewala, & Bonnet, 2012; McDougall, White, Franke, & Hindle, 2001)

Annexure 03: Key steps in EQT model



Source: (IGES, 2018)

Annexure 04: Scenario justification

Interviewee Code	Field	Experience	Highlighted ideas/facts in Scenario formulating
01	Waste Management (Karadiyana dumping site)	2	<ul style="list-style-type: none"> • Composting & AD plants are not sufficient to cater the existing waste collection. • Incineration will be a suitable WM technique.
02	Composting (Waste Management Authority)	5	<ul style="list-style-type: none"> • Implementation of composting, AD plants & recycling plants both are not sufficient. • Sanitary landfilling will be the most effective method for disposal.
03	Urban Community Development & Urban Solid Waste Management (Private organization)	30	<ul style="list-style-type: none"> • Sanitary landfilling will be the most environmentally friendly method for disposing compared with open dumping. • Incineration is not a suitable method for Sri Lanka according to its waste composition.
04	Solid Waste Management (Private organization)	4	<ul style="list-style-type: none"> • Implementation of sanitary landfilling plants will be a turning point in SWM in Sri Lanka. • Promoting 3R concept and waste segregation is a general need.

(Source:- Prepared by Author as a result of expert opinion survey)

Annexure 05: Amounts that can collect from each vehicle type, depends on waste collection and vehicle capacity

For 1 vehicle (m3)	Vehicle type need for whole Transport	Waste - 154 Tonnes	Waste - 166 Tonnes	Waste - 175 Tonnes	Waste - 185 Tonnes	Waste - 182 Tonnes
8m ³	Compactor large	19.25	20.75	21.875	23.125	22.75
2m ³	Dump Truck	77	83	87.5	92.5	91
12m ³	Carrier	12.83333333	13.83333333	14.58333333	15.41666667	15.16666667
1m ³	Tractor	154	166	175	185	182

(Source-: Prepared by Author)

Annexure 06: Vehicle mix in each scenario

**S2 & S4 are using Train and it is consuming 4l fuel per 1km distance travelling.*

(Train Details from -: <http://www.crrcgc.cc/en/g6630/m12939/mp2.aspx>)

	<i>BAU</i>	<i>S1</i>	<i>S2</i>	<i>S3</i>	<i>S4</i>
Compactor (8m ³)	10	12	0	0	0
Dump Truck (2 m ³)	37	35	0	0	0
Carrier (12 m ³)	0	0	15	16	15

(Source-: Prepared by Author)

Annexure 07: Analysis of 2nd Round of EOS

Expert Opinion Survey (EOS), consists two rounds. 1st round has 12 open ended question and round 02 consists 12 questions with 1- 10 Linkert-scale. (1= totally disagree, 10 = totally agree with the statement). Considering 70% consensus, 8/12 questions have reached consensus and 4/12 have not reached. Annexure 16 shows the results of second round.

Q- No.	LS 1-4	% (1-4)	LS 5	% (5)	LS 6-10	% (6-10)	Distribution	Consensus (70%)
1.	2	29%	0	0%	5	71%	<p>Results for Q-1</p> <p>Quantity</p> <p>0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%</p> <p>■ 1-4 (Disagree/Strongly Disagree) ■ 6-10 (Agree/Strongly Agree)</p>	Agreed
2.	1	14%	0	0%	6	86%	<p>Results for Q-2</p> <p>Quantity</p> <p>0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%</p> <p>■ 1-4 (Disagree/Strongly Disagree) ■ 6-10 (Agree/Strongly Agree)</p>	Agreed
3.	2	29%	4	57%	1	14%	<p>Results of Q-3</p> <p>Quantity</p> <p>0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%</p> <p>■ 1-4 (Disagree/Strongly Disagree) ■ 5 (Other Agree not Disagree) ■ 6-10 (Agree/Strongly Agree)</p>	No consensus
4.	3	43%	0	0%	4	57%	<p>Results for Q-4</p> <p>Quantity</p> <p>0% 20% 40% 60% 80% 100%</p> <p>■ 1-4 (Disagree/Strongly Disagree) ■ 6-10 (Agree/Strongly Agree)</p>	No consensus

5.	2	29%	0	0%	5	71%		Agreed
6.	7	100%	0	0%	0	0%		Disagreed
7.	7	100%	0	0%	0	0%		Disagreed
8.	0	0%	0	0%	7	100%		Agreed
9.	4	57%	1	14%	2	29%		No consensus
10.	2	29%	1	14%	4	57%		No consensus

11.	0	0%	0	0%	7	100%		Agreed
12.	1	14%	1	14%	5	71%		Agreed

Source: Developed by author

The above Table 08 is interpreting, Question No 1, 2, 5, 8, 11 & 12 are agreed with the statement and Question No 6 and 7 are disagree with the statement. But Question No 3, 4, 9 and 10 consider asking again to reach consensus.

Annexure 08: Questionnaire of Expert Opinion Survey

Research Topic - **Study of an alternative framework for sustainable solid waste management strategy for the local authorities in Sri Lanka**

Delphi Survey No:

Interviewee Name and ID:

Basic Information of the expert:

Expert Name:

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Designation:

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Field of Expertise:

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Experience (No. of years):

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Exposure: A short description of recent projects/ plans involved in waste management field

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ROUND 01: Open Ended Questions

1. What is your opinion on success or failure of current Solid Waste Management (SWM) practices used by local authorities in Colombo and suburbs?

2. What are the key impacts (positive and negative) to the society (people and environment) caused by existing waste management systems?

3. In your opinion, what are the key factors determining the selection of the SWM techniques for local authorities?

4. According to you, what is the most neglected, yet important step in SWM methods used by local authorities? (Collection/transportation/processing/ recycling/disposal) Why you say so?

5. What are the key negative impacts in the steps of SWM methods used in local authorities?
 - a) Generation-:
 - b) Collection-:
 - c) Transportation-:
 - d) Processing-:
 - e) Recycling-:
 - f) Disposal-:

6. What are the suggested strategies by you to reduce the impacts of each category?

7. What are the types of evaluation methods for selecting SWM strategies based on the future needs of waste management sector?

8. Do you have any experience with Life Cycle Assessment based impact prediction tool?

9. Will local authorities be able to decide upon impact minimization tool, (If introduced?)

10. What are the current problems, barriers faced by local authorities in implementation of such prediction based framework?

11. What are your suggestions in overcoming those barriers and applying impact prediction tool for SWM in Sri Lanka?

12. Is there any framework available within local authorities or national agencies to evaluate the effectiveness of existing waste management strategies? If so, how can that be implemented?

ROUND 02: Closed Ended Questions

Fully Disagree with the Statement – 1

Fully Agree with the statement – 10

1. In your opinion, waste management decision making in Sri Lanka (Colombo and suburbs) have restricted to financial availability rather than scientific impact assessment?

1	2	3	4	5	6	7	8	9	10
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Why? (Short Answer)

2. Do you think impact prediction tools would be most appropriate to understand the future impacts of waste management strategies in Sri Lanka?

1	2	3	4	5	6	7	8	9	10
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Why? (Short Answer)

3. Global warming potential (GHG emissions) can be the most impactful category for municipal solid waste as generated from end disposal of MSW?

1	2	3	4	5	6	7	8	9	10
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Why? (Short Answer)

4. Waste separation at source/ generation point is effectively practiced by people with the support of local authorities in Colombo and Suburbs (DMMC)?

1	2	3	4	5	6	7	8	9	10
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Why? (Short Answer)

5. Waste collection process is effectively conducted by local authorities in Colombo and suburbs (DMMC)?

1	2	3	4	5	6	7	8	9	10
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Why? (Short Answer)

6. Composting and Bio Gas plants are sufficient for the existing waste collection by local authorities in Colombo and suburbs (DMMC)?

1	2	3	4	5	6	7	8	9	10
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Why? (Short Answer)

7. Recycling/ MRF/ RDF plants are sufficiently operating in Colombo and Suburbs?

1	2	3	4	5	6	7	8	9	10
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Why? (Short Answer)

8. Sanitary landfilling could be the most effective environmentally friendly method for final disposal in Sri Lanka?

1	2	3	4	5	6	7	8	9	10
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Why? (Short Answer)

9. Incineration plants could be expensive, but a suitable method for Sri Lanka due to its fast reduction of waste quantity and volume?

1	2	3	4	5	6	7	8	9	10
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Why? (Short Answer)

10. Socio economic impacts of waste management methods can be directly related to environmental impacts caused by existing waste management strategies?

1	2	3	4	5	6	7	8	9	10
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Why? (Short Answer)

11. Local authorities must take immediate actions to use community participation for waste management decision making?

1	2	3	4	5	6	7	8	9	10
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Why? (Short Answer)

12. Scientific calculations based tools are more important for waste management decision making than the cost or land based solutions?

1	2	3	4	5	6	7	8	9	10
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Why? (Short Answer)

13. Any other comments