Decision Together©: Development of Integrated SLCA-AHP for Environmental Decision Making

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Outline

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• Research Objectives
• Background
  • Life Cycle Assessment (LCA)
    • Streamlined LCA
  • Multicriteria Decision Analysis (MCDA)
    • Analytic Hierarchy Process (AHP)
• Development of Integrated SLCA-AHP
• Elicitation
• Concluding Remarks
Environmental decision making is challenging!
Motivation – Challenges [2]

- Diverse stakeholders
  - Environmental decision making involves stakeholders with diverse backgrounds – from experts to citizens
  - Stakeholders approach decisions with diverse perspectives and frames of reference
  - The outcomes of environmental decision affect stakeholders in different ways
  - Achieving consensus among decision makers is critical and challenging to making a choice, or at least narrowing the choices
Motivation – Challenges [3]

• Multiple criteria
  • Several factors influence and impact the outcome (e.g., environmental, social, and economic, among others)
  • One criteria cannot be used to make multifaceted decision – for example economics alone
  • Multiple criteria must be considered at one time to provide a thorough evaluation
  • The challenge is to integrate all criteria into one evaluation to allow for equal consideration
Motivation – Current Conditions

- Municipal Solid Waste (MSW) in Tennessee
  - The major MSW landfill in Middle Tennessee will be at out of airspace in 5 to 8 years
  - No current plans exist to permit an expansion due to public opposition (NIMBY)
  - Population is growing in Middle Tennessee, but waste production is not slowing
- Decision Making Process
  - Local stakeholders have conflicting views on the next steps for MSW management (e.g., transfer stations vs. zero waste)
  - Decisions are currently made based on evaluation of a single alternatives or a limited set of criteria

It is time for the region to consider the next end of life waste management system.
Research Objectives

• Develop an integrated Life Cycle Assessment (LCA) and Multicriteria Decision Analysis (MCDA) Methodology
  • LCA defines system boundaries and evaluate environmental impacts of a system
  • MCDA structures the decision making process for stakeholders
• Develop way to simplify and perform for elicitation for diverse stakeholders
• Apply the integrated LCA-MCDA to guide future MSW management in Tennessee
Life Cycle Assessment (LCA) is a tool used to evaluate impacts of a given system.

- ISO 14040:2006 presents the principles and framework for LCA.
- LCA is a means to assess environmental impacts associated with all stages of a product’s life:
  - Cradle to Grave
  - All material inputs and outputs, as well as energy use/production to determine environmental impacts.
Limitations of Full LCA

- Does not always consider time and spatial aspects of evaluated system
- Is difficult to utilize in the early stages of planning due to the amount of unknowns/data gaps
- Requires expensive software/databases
- Evaluated complex systems that are almost impossible to model completely
- Requires simplification
  - Impossible to include all inputs
Streamlined LCA (SLCA) can be applied during planning and development stage:

- Identifies environmental hot spots and highlights opportunities for creating environmental improvement
- Involves limiting data collection and analysis
- Limits or eliminates LCA stages
- Includes only selected environmental impacts and inventory parameters
- Is completed using simplified assessment methods
Streamlined LCA System

Life Cycle Stages

Inputs
- Municipal Solid Waste
- Energy

Collection of Waste → Management at Transfer Station → Transportation to End of Life Management Facility → Management at End of Life Facility → Long Term Management at End of Life Facility

Outputs
- Impacts to Water, Land, Air
- Energy
SLCA Process

• Streamline the LCA process is based on the Environmentally Responsible Product Assessment (ERPA) (Graedel 1998)

• 5x5 matrix evaluates life cycle stages with respect to environmental impacts
  • Scoring for each matrix element is on a scale of 0-4
  • 0 represents the most environmental impact
  • 4 represents superior environment performance

• Prior to scoring, a rubric is developed to aid evaluators in understanding the system being evaluated

SLCA for MSW Systems

- SLCA evaluates from point of residential collection to final management/disposal
  - Gate to grave rather than cradle to grave
- SLCA is used to evaluate three end of life MSW systems
  - Landfilling
  - Waste to Energy with Landfilling
  - MSW Composting with Landfilling
- Completion of SLCA requires solid waste experts to inform the matrix, since impact data is not provided
- Results will be compared against LCA performed using MSW-DST LCA software to assess how the full and SLCA align
<table>
<thead>
<tr>
<th>Life Cycle Stages</th>
<th>Environmental Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Solid Waste Managed</td>
</tr>
<tr>
<td>Collection of Waste</td>
<td>Energy</td>
</tr>
<tr>
<td>Management at Transfer Station</td>
<td>Air Emissions</td>
</tr>
<tr>
<td>Transportation to End of Life</td>
<td>Water Emissions</td>
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<tr>
<td>Management Facility</td>
<td>Land Impacts</td>
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<td>Management at End of Life Facility</td>
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<td>Long Term Management at End of</td>
<td></td>
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<tr>
<td>Life Facility</td>
<td></td>
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Introduction to MCDA

- Multicriteria Decision Analysis (MCDA)
  - Rational decision making model:
    - Identifies decision problem
    - Generates alternatives and criteria
    - Evaluates and identifies optimal decision
  
- Analytical Hierarchy Process (AHP) (Saaty 1980)
  - Is commonly used in environmental decision making
  - Utilizes pairwise comparison and verbal importance scale
  - Allows for the development of consensus

Pairwise Comparison

- Analyzes multiple items (criteria, alternative) in pairs to determine their significance to one another
- Uses numerical and verbal means for comparisons
- Ranks preference of each evaluation category
- Allows for quantitative and qualitative information to be considered in pairwise comparisons
- Determines ordering for preference
## AHP Verbal-Numerical Scale

<table>
<thead>
<tr>
<th>Importance Level</th>
<th>Verbal Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Extreme Importance</td>
</tr>
<tr>
<td>8</td>
<td>Very, very strong</td>
</tr>
<tr>
<td>7</td>
<td>Very strong or demonstrated importance</td>
</tr>
<tr>
<td>6</td>
<td>Strong plus</td>
</tr>
<tr>
<td>5</td>
<td>Strong importance</td>
</tr>
<tr>
<td>4</td>
<td>Moderate plus</td>
</tr>
<tr>
<td>3</td>
<td>Moderate importance</td>
</tr>
<tr>
<td>2</td>
<td>Weak or slight</td>
</tr>
<tr>
<td>1</td>
<td>Equal importance (indifference)</td>
</tr>
</tbody>
</table>
Example

PURCHASE A NEW FAMILY CAR
Pairwise Comparison – New Family Car

**With respect to buying a new family car, which criteria is more preferred?**

- **Cost**
  - 9
  - 7
  - 5
  - 3
  - 1
  - 3
  - 5
  - 7
  - 9

- **Fuel Economy**

**With respect to person/cargo space, which alternative is most preferred?**

- **Chevy Corvette**
  - 9
  - 7
  - 5
  - 3
  - 1
  - 3
  - 5
  - 7
  - 9

- **Honda Odyssey**

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Integration of LCA and MCDA

INTEGRATED SLCA-AHP METHODOLOGY
Need for Integrated LCA-MCDA

- Though LCA/SLCA can assess the environmental impacts of a system, they do not provide a means to evaluate or rank alternatives
- AHP guides stakeholders through criteria and alternative evaluation to allow for prioritization of preference
- In preliminary planning, definitive answers are not needed initially:
  - Instead, consensus is needed to further develop understanding of agreement and disagreement and to aid in future planning
  - Allows for way to evaluate multiple, diverse criteria
SLCA-AHP Integration

- SLCA simplifies evaluated MSW system boundary
- AHP allows for structured evaluation of criteria and alternatives
- The goal is to develop a web application to facilitate uses of the integrated methodology for diverse stakeholders:
  - Off the shelf software is expensive
  - Decision Together was created to facilitate the integrated LCA-AHP evaluation process

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CRITERIA DEVELOPMENT AND ELICITATION
Collect input from multiple, diverse stakeholders
  - Stakeholders complete pairwise comparison to determine preferences for criteria, attributes, and alternatives

Evaluate results of elicitation to show areas of consensus and disagreement for future planning

Provide data to determine if Decision Together© methodology can be used to evaluate and develop consensus for diverse stakeholders for specific communities/issues
• Web application was developed to lead stakeholders through elicitation: decisiontogether.com

• Three Parts:
  • Part 1: Criteria Pairwise Comparison: Which criterion is considered more important when evaluating end of life residential MSW systems for Middle Tennessee?
  • Part 2: Attribute Pairwise Comparison: For each criterion, which attribute is considered more important when evaluating end of life residential MSW systems for Middle Tennessee?
  • Part 3: Based on the criterion, which end of life municipal solid waste system is most preferred?
Because elicitation is based on theoretical scenarios, limited quantitative data is available
- In the cases where additional information is available, a link within the web application is provided
- Elicitation process has been reviewed by Vanderbilt University’s Institutional Review Board
- Participation in the elicitation is voluntary
- Only stakeholder designation and email address will be collected
  - Email addresses are for identifying stakeholder responses for evaluation
Elicitation process will take approximately 20 minutes
Stakeholders will be taken through a series of pairwise comparisons
Stakeholders are encouraged to provide comments for their selection to help inform the results
Elicitation can not be stopped and restarted, but stakeholders can navigate forwards and backwards through the questions within each part
Elicitation will be open from May 15 to June 1
Participate will be in the running for a $50 Amazon gift card drawing
Elicitation information provide on handout
Criteria Development

- Literature review was completed for MCDA criteria utilized in MSW and environmental evaluations
- Survey was sent out in 2018 to compare literature criteria with perspectives of solid waste stakeholders
- Based on the review, five main criteria were selected:
  - Economic
  - Environmental
  - Social
  - Technical Feasibility
  - Regulatory Acceptance
Criteria and Attributes

- Environmental
  - Impacts to Water
  - Impacts to Air
  - Impacts to Land

- Economic
  - Capital Investment Costs
  - Operational and Maintenance Costs
  - Economic Incentives on Communities Surrounding Facility
  - Property Values Around Facility
Criteria - Attributes

Social
• Employment
• Location with respect to community
• Noise/Odor
• Ease of removal and management of MSW

Technical Feasibility
• Availability of Land/Land Use
• Energy Efficiency
• Distance from Community/Transfer Station
• Beneficial Reuse/Resource Conservation
• Available Infrastructure
Criteria - Attributes

• Regulatory Acceptance:
  • Applicable Regulations in Place
  • Presence of Permitting System
  • Zoning Limitations
System Boundary

Life Cycle Stages

Inputs:
- Municipal Solid Waste
- Energy

Outputs:
- Impacts to Water, Land, Air
- Energy

Stages:
1. Collection of Waste
2. Management at Transfer Station
3. Transportation to End of Life Management Facility
4. Management at End of Life Facility
5. Long Term Management at End of Life Facility
Alternatives

End of Life Waste Management Scenarios:

- Scenario 1: Class I Municipal Solid Waste Landfill
- Scenario 2: Waste to Energy
- Scenario 3: MSW Composting

All scenarios assumed to have the same methods of residential collection, management of MSW at transfer station, and transport distance to end of life waste management facility.
Concluding Remarks

• Your participation is appreciated

• Elicitation results will be available in Summer 2019
  • Will provide perspective to allow for future decision making activities and allow for consideration of next step

• Path Forward
  • Utilize results of initial elicitation to improve Decision Together© methodology
  • Apply Decision Together© for community specific waste evaluation
  • Help build consensus for difficult environmental siting decisions
Thank you

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