Applications of Optimization Modeling in Multi-Disciplinary Engineering Research

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Applications of Optimization Modeling in Multi-Disciplinary Engineering Research

Anton F. Astner, Ekramul H. Ehite, Yang Li, and Colin Sasthav
BSE 519: Mathematical Modeling for Engineers (Instructor: Prof. Robert Freeland)

Introduction

Increased computing power has made optimization solvers readily available for business/research needs. For example, Microsoft Excel has a simple, but robust solver. Such solvers can model linear, nonlinear, and integer programming problems that are limited in size. This study shows the use of optimization model solvers in various research contexts.

General Example

Target: Shortest path (in terms of time) from the Food Science Building to the Neyland Stadium.

Graphical Solution 1

Graphical Solution 2

Solution using Excel Solver

Target: Optimal fluidized bed design for maximum solid biofuel (biochar) production from the pyrolysis process.

Decision Variables:
- \( T_i \) ~ Temperature (i)
- \( t_i \) ~ Vapor residence time (i)
- \( S_i \) ~ Particle size (i)

Objective:
- \( \text{max: } \sum T_i \cdot t_i \cdot S_i \cdot \text{Availability}_i \cdot \text{Cost}_i \)

Constraints:
- Maximum temperature achievable
- Plant operation time [1]
- Smallest particle size available [2]
- Capital Budget

Biomass Conversion

Target: Optimal screw conveyor design for switchgrass conveyance.

Decision Variables:
- \( \text{RPM}_i \) ~ Speed of screw conveyors (i)
- \( \text{SC}_i \) ~ Selection capacity (ft\(^3\)/hr) (i) [4]

Objective:
- \( \text{max: } \sum \text{RPM}_i \cdot \text{SC}_i \cdot \text{Availability}_i \cdot \text{Cost}_i \)

Constraints:
- Capital budget
- Maximum selection capacity
- Required capacity from reactor

Agricultural Mulches

Target: Profit maximization with ratios of biodegradable & LDPE mulches.

Decision Variables / Constraints

<table>
<thead>
<tr>
<th>Parameter</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit ($/A)</td>
<td>36</td>
<td>35</td>
</tr>
<tr>
<td>Profit ($/B)</td>
<td>2250</td>
<td>2350</td>
</tr>
<tr>
<td>Max. Profit (A)</td>
<td>3690</td>
<td>3690</td>
</tr>
</tbody>
</table>

Objective:
- \( \text{max: } \sum \text{Profit}_i \cdot \text{Area} \)
- \( y = -4/5x + O/45 \) [3]

Constraints:
- Capital budget
- Maximum selection capacity
- Required capacity from reactor

Biomass Conveyance

Target: Optimal design for a hydropower site given the rated head (H), efficiency, cost, and availability of each turbine type.

Decision Variables:
- \( i \) ~ Number of turbines
- \( Q_i \) ~ Rated flow for turbine (i)
- \( T_i \) ~ Type of turbine (i)

Objective:
- \( \text{max: } \sum Q_i \cdot H \cdot \text{Efficiency}_i \cdot \text{Availability}_i \cdot \text{Cost}_i \)

Constraints:
- Capital Budget
- Maximum footprint of the stream
- Environmental flow limits

References


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The authors would like to thank the Biosystems Engineering & Soil Science department, the Center for Renewable Carbon, and the Bredesen Center for supporting this study.