Decomposition Based Optimization of Biomass to Biofuel Supply Chain

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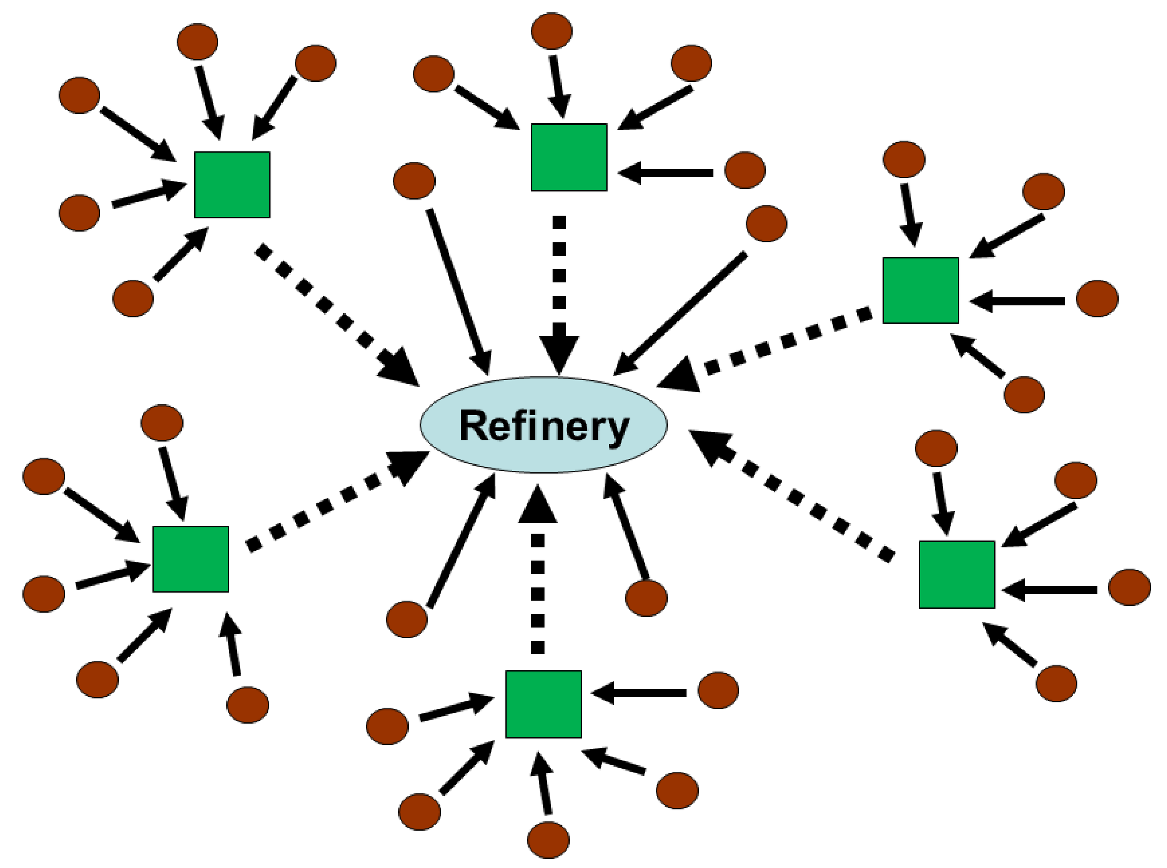
Background and Objectives

- Biomass to biofuel supply chain optimization critical
- Integration of design and management decisions important for maximizing benefits
- Integrated optimization problem computationally challenging

Objectives:

- Formulate an integrated optimization problem
- Develop a computationally efficient approach for solution of large scale problems

Optimization Model Formulation



Model structure:

- Farms (red circles) as supply points
- Regional biomass pre-processing depots (RBPDs) (green squares) for pelletization and storage
- Biorefinery (blue oval) for processing
- Simulation horizon: one year

Model constraints:

- Mass balance constraints
- Storage and processing capacity constraints
- Economic and biorefinery demand constraints

Decision variables:

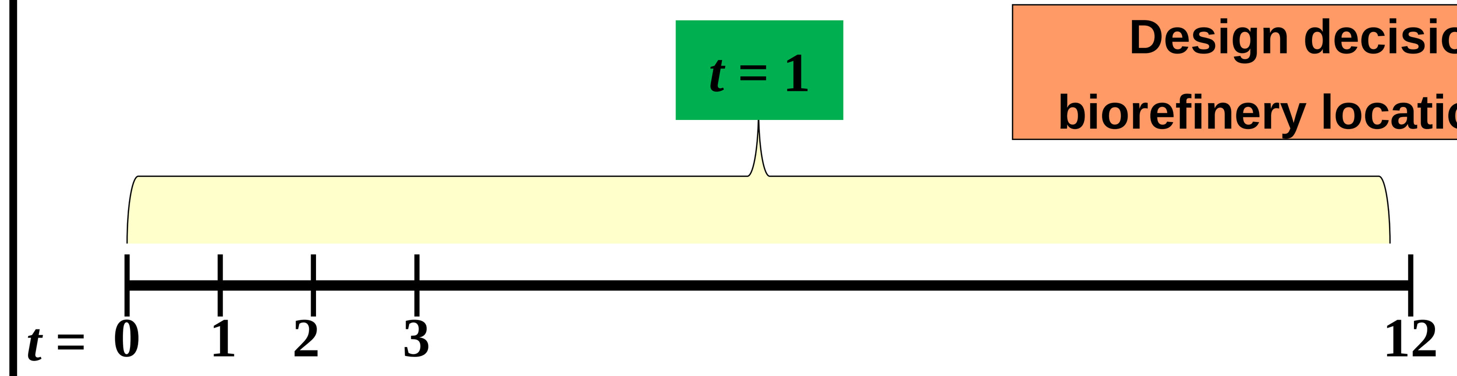
- **Design decisions**: RBPDs and biorefinery locations (integer variables)
- **Management decisions:** Biomass flow along each link, processing and storage capacities of RBPD
- Biomass flow decisions for each time step

Objective: Minimization of total procurement cost

Proposed Decomposition Approach

Stage I

- Optimize design and management decisions
- Use time aggregation (single simulation time step)
- Enforce storage requirement at RBPD

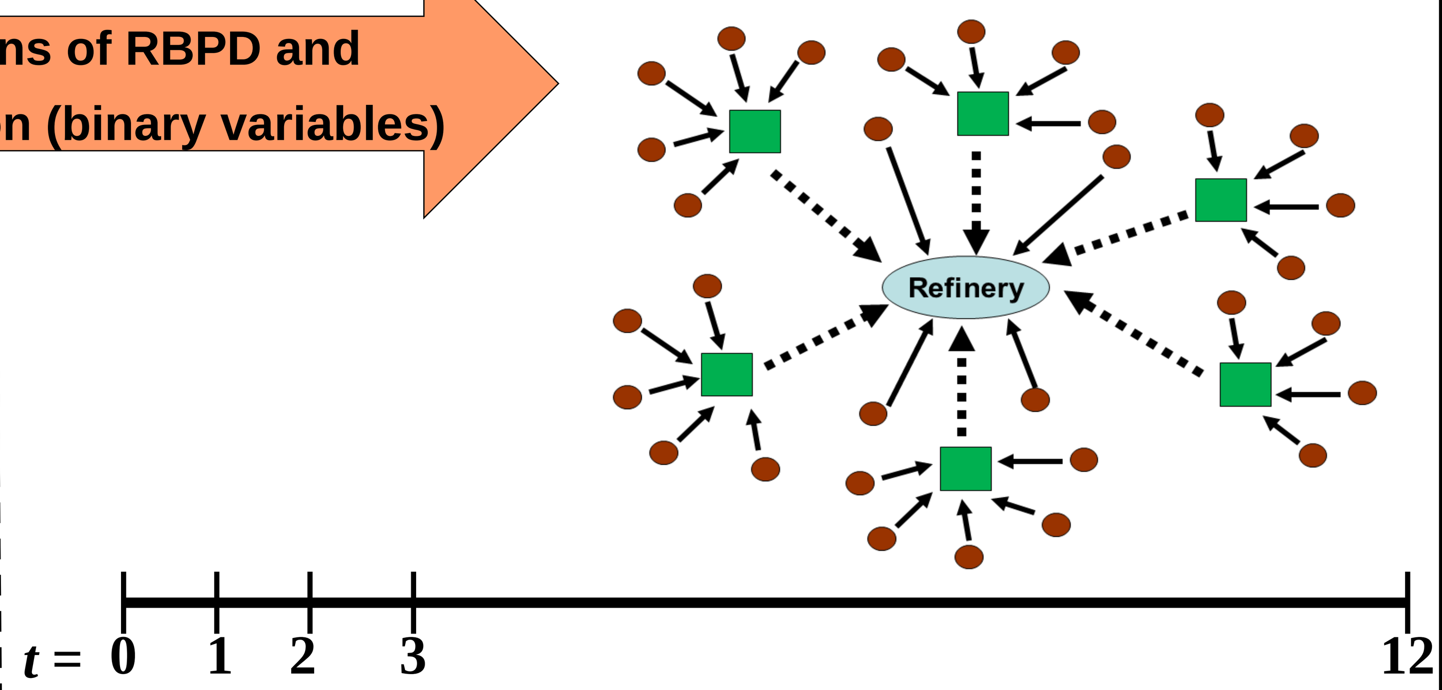


- Decision variables: Integer and continuous for only one time step (time aggregation)
- Objective function: Cost minimization

Stage II

- Optimize management decisions only (continuous variables)
- Use original time-step resolution one month

Design decisions of RBPD and biorefinery location (binary variables)



Results and Discussion

Base Case

- 95 farms: Potential RBPD and biorefinery locations
- **Integrated model:** 380 integer variables and 659,110 continuous variables
- **Decomposed model:**
  - Stage I: 380 integer and 55,100 continuous variables
  - Stage II: 650,110 continuous variables

	RBPD location	Biorefinery location	Objective function (million $)	Time (s)
Integrated model	32	62	17.893	**1395**
Decomposed model	32	62	17.893	**248**

Impact of temporal variability in transport cost

- Time aggregation loses temporal variability data
- Scenarios studied with higher cost of transport during first three months of simulations

	RBPD location	Biorefinery location	Objective function (million $)	Time (s)
Integrated model	18,55	90	18.153	**982**
Decomposed model	32	90	18.175	**229**

Impact of spatial variability in storage cost

- Storage cost not explicitly considered in stage I
- Location decisions in stage I mainly based on transportation costs
- Spatial variability in storage cost may lead to sub-optimal RBPD locations
- Consideration of ±10% variation in storage cost

	RBPD location	Biorefinery location	Objective function (million $)	Time (s)
Integrated model	43	62	17.869	**747**
Decomposed model	32	62	17.904	**248**

Conclusions

- Integrated biomass to biofuel supply chain model solved using a novel decomposition approach
- Approximate solution within ±1% of the true optimum
- Orders of magnitude reduction in simulation times
- Large scale problems could only be solved using the decomposition approach
- Spatial and temporal variability of parameters did not affect solution accuracy