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Applications of Optimization Modeling in Multi-Disciplinary Engineering Research

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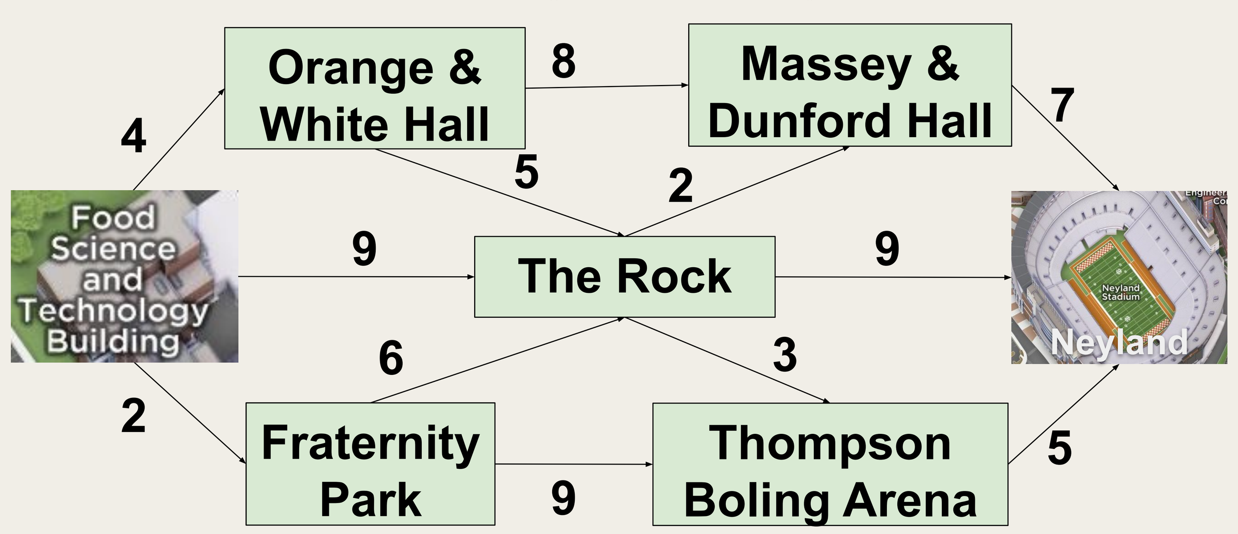
BSE 519: Mathematical Modeling for Engineers (Instructor: Prof. Robert Freeland)

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.



Solution using Excel Solver

From	To	Time	Travel?
Food Sciences	Orange & White Halls	4	0
Food Sciences	The Rock	9	0
Food Sciences	Fraternity Park	2	1
Orange & White Halls	The Rock	5	0
Orange & White Halls	Massey & Dunford Hall	8	0
The Rock	Massey & Dunford Hall	2	0
The Rock	Thompson Boling Arena	3	0
The Rock	Neyland Stadium	9	0
Fraternity Park	The Rock	6	0
Fraternity Park	Thompson Boling Arena	9	1
Massey & Dunford Hall	Neyland Stadium	7	0
Thompson Boling Arena	Neyland Stadium	5	1

Decision Variables

Objective ~ Minimize: SUMPRODUCT(Time, Travel) = 16

Constraint 1 ~ Travel variable must be binary
Constraint 2 ~ Flow in = Flow Out, except for first and last nodes

	Flow In	-	Flow Out	=	Requirement
Food Sciences	1	-	0	=	1
Orange & White Halls	0	-	0	=	0
Fraternity Park	1	-	1	=	0
The Rock	0	-	0	=	0
Massey & Dunford Hall	0	-	0	=	0
Thompson Boling Arena	1	-	1	=	0
Neyland Stadium	0	-	1	=	-1

Solution ~ Food Science > Fraternity Park > Thompson Boling Arena > Neyland Stadium
Total Time ~ 16min

Biomass Conversion

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:

- max: $\Sigma\, T_i * t_i * S_i * \text{Availability}_i - \text{Cost}_i$

Constraints:

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

Agricultural Mulches

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

Decision Variables / Constraints

Land available	Area [Ar]
Film	**Cost [$/Ar]**
A = BioAgri	10
B = Polyethylene	5
Working hours	**Time [h/Ar]**
BioAgri	3
Polyethylene	6

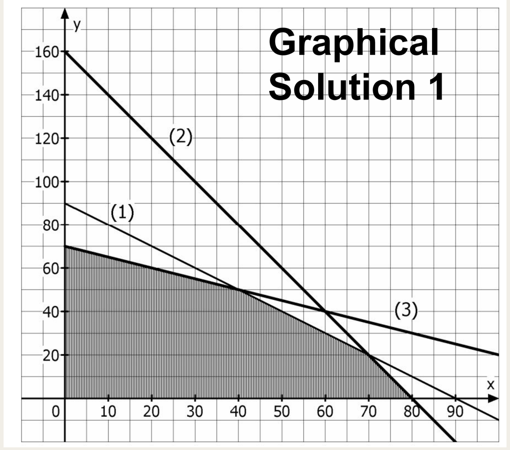
Area [Ar]	**90**	x+y <=90	y<= -x+90	(1)
Cost [$]	**800**	10x+5y <= 800	y <= -2x + 160	(2)
Time [h]	**420**	3x+6y <= 420	y <= -0.5x+70	(3)

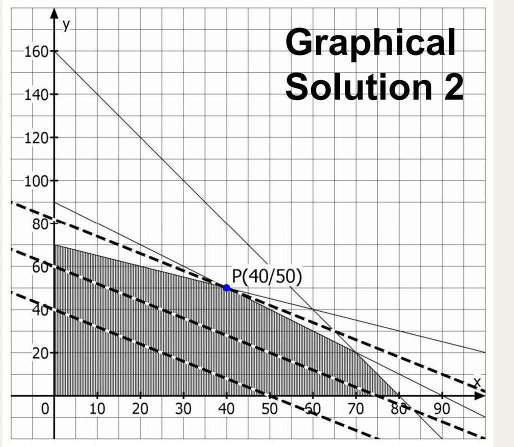
- x ~ opt. area of mulch A
- y ~ opt. area of mulch B

Parameter	A	B
x [Ar]	40	
y [Ar]		50
Profit [$/Ar]	36	45
Profit total [$]	1440	2250
Max. Profit [$]		**3690**

Objective:

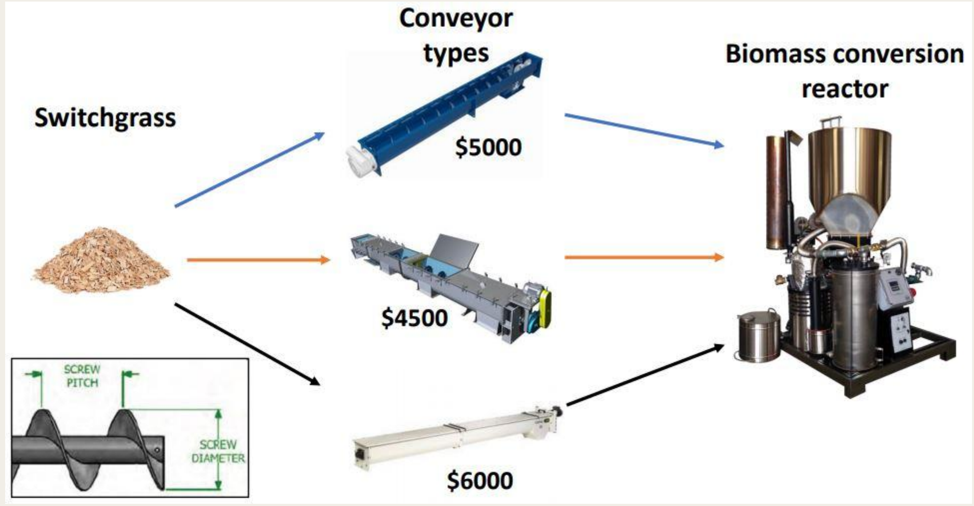
- max: Σ Profit*Area
- O = 36x+45y [3]
- **y = -4/5x+O/45**





Biomass Conveyance

Target: Optimal screw conveyor design for switchgrass conveyance.



Decision Variables:

- RPM_i ~Speed of screw conveyors (i)
- SC_i ~Selection capacity (ft^3/hr) (i) [4]

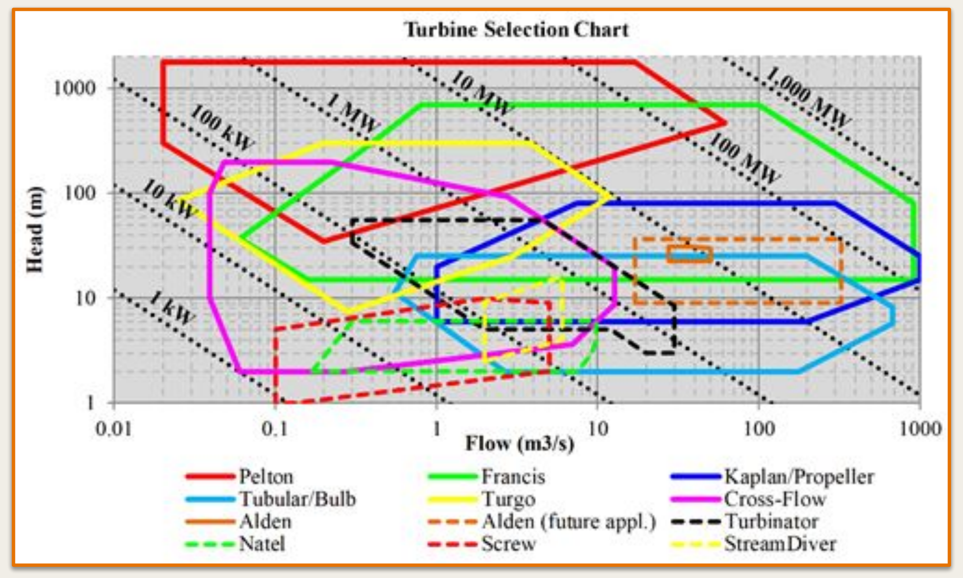
Objective:

- max: $\Sigma\, RPM_i * SC_i * \text{Availability}_i - \text{Cost}_i$

Constraints:

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

Standard Modular Hydropower



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:

- max: $\Sigma\, Q_i * H * \text{Efficiency}_i * \text{Availability}_i - \text{Cost}_i$

Constraints:

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

References

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