Strategic Planning

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Industrial Application

- Kruger Products: a leading provider of tissue consumer products to the North American market with leading consumer brands like Cashmere, SpongeTowels and Scotties
- Objective of the company: acquire a strategic planning tool that would help them to make decisions regarding expanding existing plants, acquiring new ones, or closing existing ones
- Currently, to make such decisions, the company uses rough estimates of costs and revenues and does not look at its whole logistics network

Problem Definition

- Network: suppliers → plants → customers
- Flow of materials: raw material → intermediate products → finished products
- Optimize over a 10-year planning horizon, with decisions made every year
- Once a plant is closed (opened), it remains so for the rest of the planning horizon

Problem Data

- Fixed costs for opening and operating plants and providing some material
- Variable (transportation) costs
- Demand estimates for every customer and finished product
- Capacities at the suppliers and at the plants
- Conversion factors between products at the plants

Summary of Activities

- Modeling the problem
  - Literature review
  - Basic model
  - Improved models
- Developing computer codes
  - Data format + generator
  - Implementation of the basic model (AMPL + Concert)
- Designing solution methods

Basic Model

- A standard arc-based network flow formulatior
- Past experience on similar models show that the LP relaxation can be weak, especially if fixed costs are high and capacities are tight
- Some simple valid inequalities can improve the formulation, but maybe it is possible to obtain even better lower bounds by using different representations of the flows

Disaggregated Model

- Idea: decompose (or disaggregate) the flow on each arc according to the paths followed from the terminal node of the arc to the final customer
- We can now improve the lower bound by adding forcing constraints associated to these disaggregated flow variables
- The result is a large-scale formulation

Cutting-Plane Approach

- Solve the LP relaxation of the basic model
- Generate disaggregated flow variables (along with defining flow conservation equations) only when they have a chance to lead to a violated forcing constraint
- Add violated forcing constraints
- Solve the resulting LP and iterate until there are no more violated forcing constraints

Lagrangian Relaxations

- LR1: relax constraints relating consecutive time period constraints
  - Subproblem decomposes by time period
  - $v(LD1) \geq v(LP)$
- LR2: relax demand and flow conservation constraints
  - Subproblem decomposes by node and by time period
  - $V(LD2) \geq v(LP)$

Path Model

- Idea: define an expanded network with each node corresponding to a pair (node, product) of the original network
- Assume we enumerate all paths in this expanded network
- Define flow variables corresponding to the amount of raw material on each path
- The result is again a large-scale formulation equivalent (in terms of LP bound) to the disaggregated model

Column Generation

- Generate a (small) subset of all paths
- Solve the resulting restricted LP
- Find (non-basic) paths with negative reduced costs
  - Path generation subproblem: for our model, it seems we cannot solve it using a standard shortest path algorithm
- Solve the resulting LP and iterate until there are no more negative reduced cost paths

Future Work

- Test the basic model
  - Randomly generated data
  - Real data
- Implement and test the improved models without decomposition
- Implement and test decomposition methods