Multiperiod Refinery Planning Optimization with Nonlinear CDU Models

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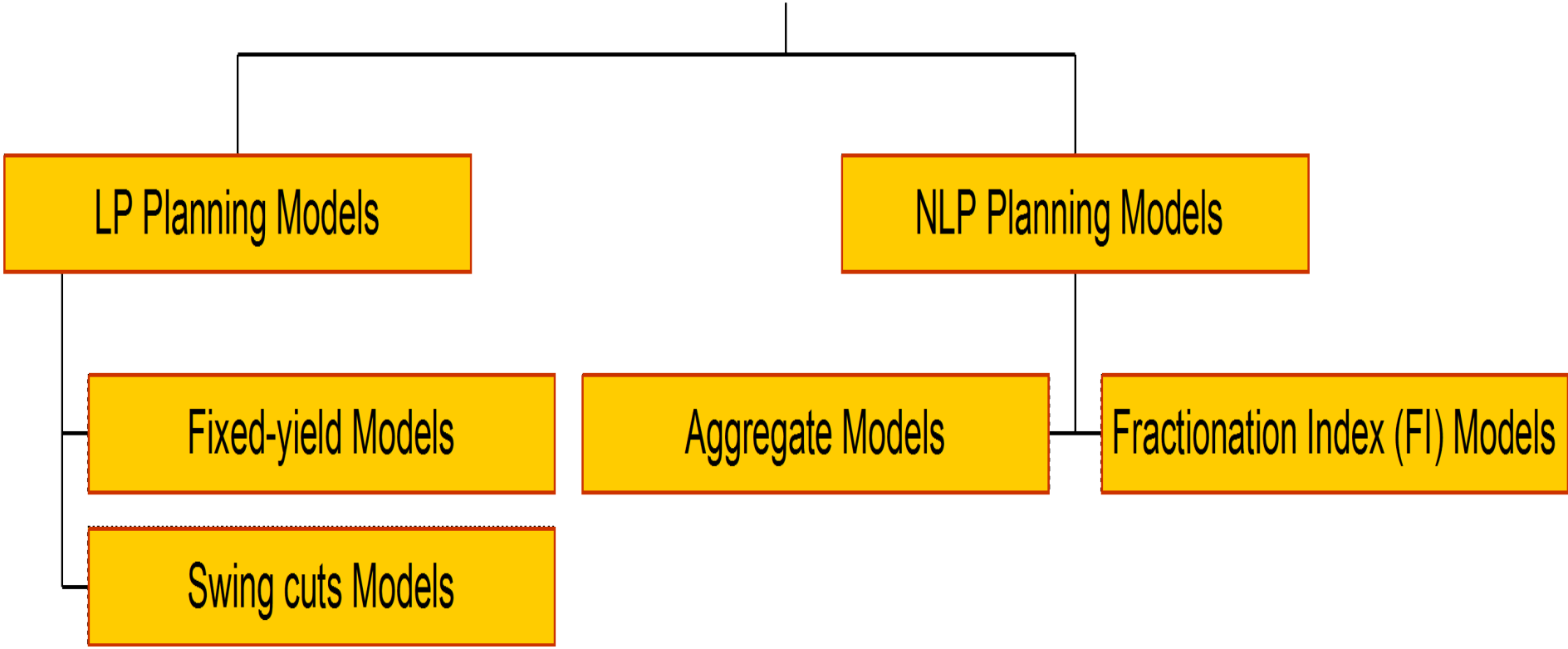
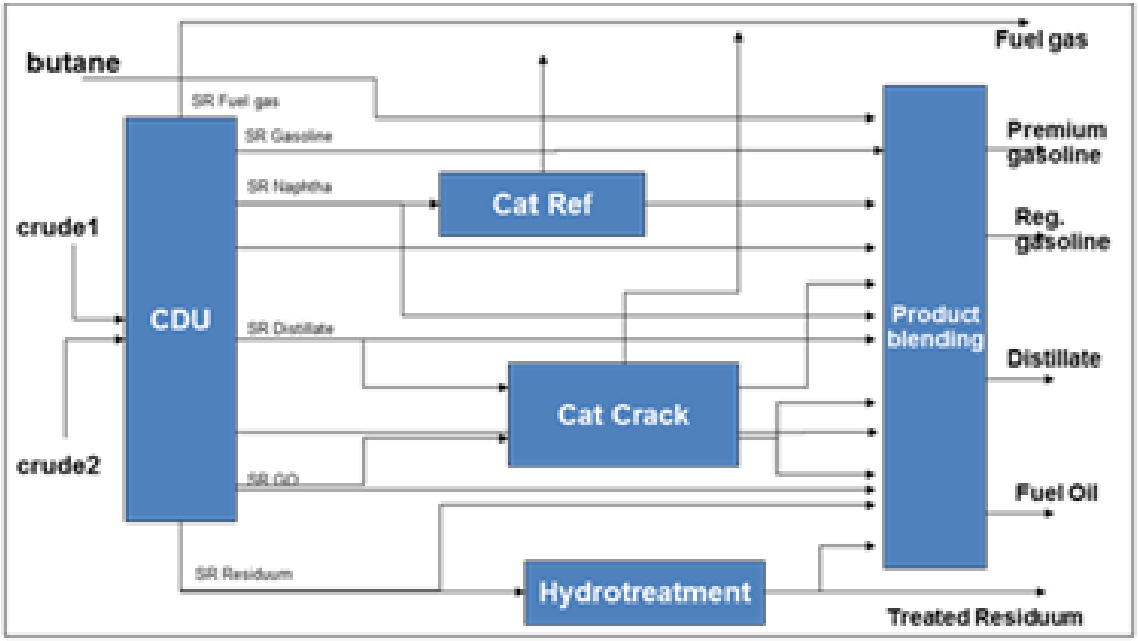
Refinery Planning Model Development



Extension to Multiperiod Planning

Multiperiod Refinery Planning Problem

- **Given:** refinery configuration

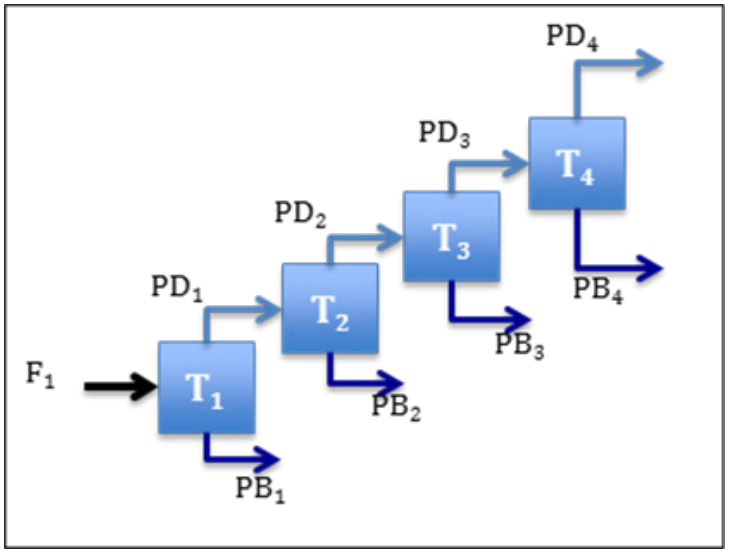


- Time horizon with N time periods
- Inventories and changeovers of M crudes

Determine

- What crude oil to process and in which time period?
- The quantities of these crude oils to process?
- The sequence of processing the crudes?

FI Model *(Fractionating Index)*



- FI Model is crude independent
  - *FI values are characteristic of the column*
  - *FI values are readily calculated and updated from refinery data*
- Avoids more complex, nonlinear modeling equations
- Generates *cut point temperature settings* for the CDU
- Adds few additional equations to the planning model

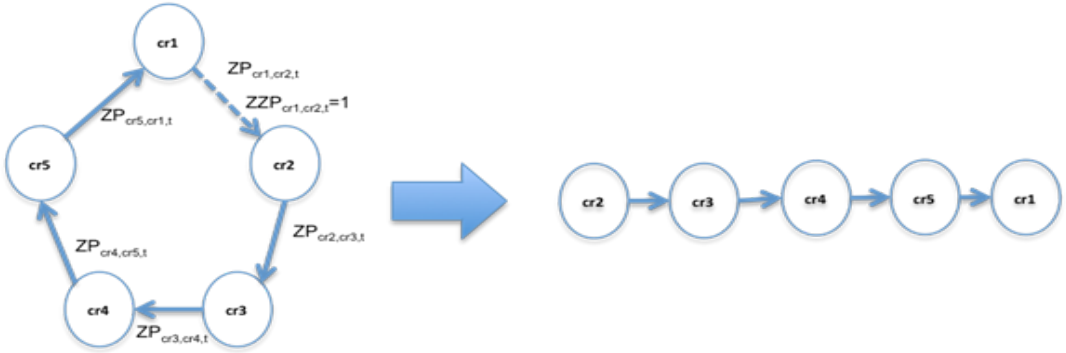
MINLP Model

Max Profit= ***Product sales minus the costs of product inventory, crude oil, unit operation and net transition times.***

s.t. **Performance CDU** ***(FI Model)*** **each crude, each time period**

Mass balances, inventories each crude, each time period

Sequencing constraints: ***Traveling Salesman, Erdirik, Grossmann (2008)***



0-1 variables to assign crude in period t
0-1 variables to indicate position of crude in sequence
0-1 variables to indicate where cycle is broken
Continuous variables flows, inventories, cut temperatures

Multi-period Refinery Planning Model

- Assignment

$$\theta_{cr,t} \leq H_t * YP_{cr,t}$$
$$F_{cr,t} * \theta_{cr,t} \leq CrAvail_{cr,t}$$
$$Inv_{p,t} = Invi_{p,t} + \sum_{p} rP_{p,cr,t} * \theta_{cr,t}$$
$$S_{p,t} \geq D_{p,t}$$

- Transition time & time balance

$$TTrans_t = \sum_{cr}\sum_{ccr} \tau_{cr,ccr} * ZP_{cr,ccr,t} - \sum_{cr}\sum_{ccr} \tau_{cr,ccr} * ZZP_{cr,ccr,t}$$

$$\sum_{cr} \theta_{cr,t} + TTrans_t + [\sum_{cr}\sum_{ccr} tau_{cr,ccr} * ZZZ_{cr,ccr,t}] = H_t$$

- Sequence

$$YP_{cr,t} = \sum_{cr} ZP_{cr,ccr,t} \qquad YP_{ccr,t} = \sum_{ccr} ZP_{cr,ccr,t}$$
$$YP_{cr,t} \geq ZP_{cr,cr,t} \qquad YP_{ccr,t} + ZP_{cr,cr,t} \leq 1$$
$$ZP_{cr,cr,t} \geq YP_{cr,t} - \sum_{ccr \neq cr} YP_{ccr,t}$$
$$\sum_{cr}\sum_{ccr} ZZP_{cr,ccr,t} = 1 \qquad ZZP_{cr,ccr,t} \leq ZP_{cr,ccr,t}$$

- Objective function

$$Profit = \sum_{t}\sum_{p} CP_{p,t} * S_{p,t} - \sum_{t}\sum_{cr} CF_{cr,t} * F_{cr,t} * \theta_{cr,t} -$$
$$\sum_{t}\sum_{cr} OpCost_{cr,t} * \theta_{cr,t} - \sum_{t}\sum_{p} Cinv_{p,t} * Inv_{p,t} -$$
$$\sum_{t}\sum_{cr} CTrans * TTrans_t$$

Example 1: 5 crudes, 4 weeks

Produce fuel gas, regular gasoline, premium gasoline, distillate, fuel oil and treated residu

Optimal solution ($1000's)	
Profit	2369.0
Sales	22327.9
Crude oil cost	16267.5
Other feedstock	44.6
Inventory cost	126.3
Operating cost	3246.5
Transition cost	274.0

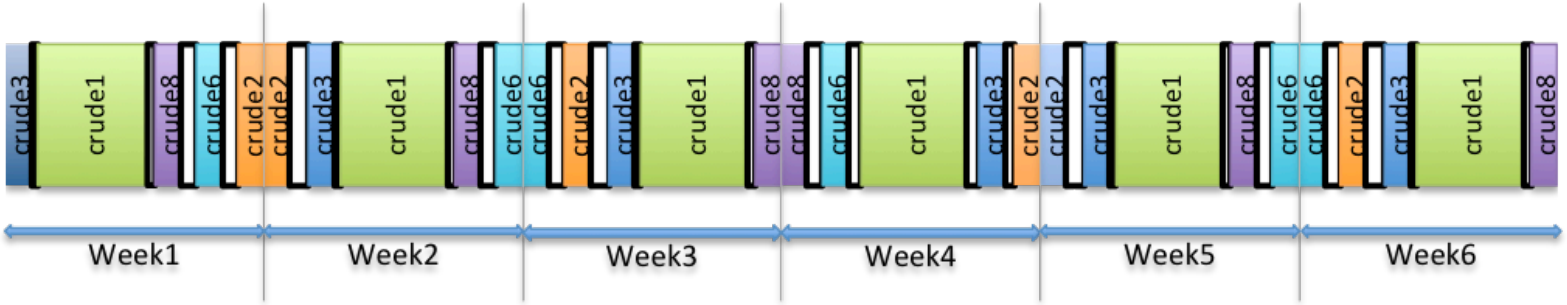
MINLP model: 13,680 variables (900 0-1), 15,047 constraints

Nonlinear variables: 28%

GAMS/DICOPT 23.3.3 (CONOPT/CPLEX): 37 seconds (94% NLP, 6% MIP)

Example 2: 8 crudes, 6 weeks

Produce fuel gas, regular gasoline, premium gasoline, distillate, fuel oil and treated residu



Optimal solution ($1000's)	
Profit	3641.3
Sales	33790.8
Crude oil cost	24385.7
Other feedstock	76.0
Inventory cost	201.6
Operating cost	5076.2
Transition cost	410.0

MINLP model: 20,522 variables (900 0-1), 22,757 constraints *(twice size)*

Nonlinear variables: 28%

GAMS/DICOPT 23.3.3 (CONOPT/CPLEX): 113 seconds (94% NLP, 6% MIP)

CPU-time only increases by factor of 3!

Conclusion

- Proposed FI model
  - Crude independent
  - Calculates cut point temperature settings
- Multi-period Extension
  - Traveling salesman problem
    - Sequence dependent change-overs
  - Solution includes crude processing times and sequence

Thank You