Quantitative Methods for Strategic Investment Planning in the Oil-Refining Industry

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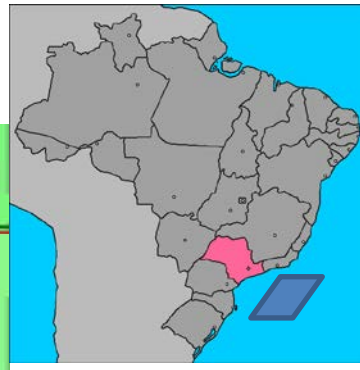
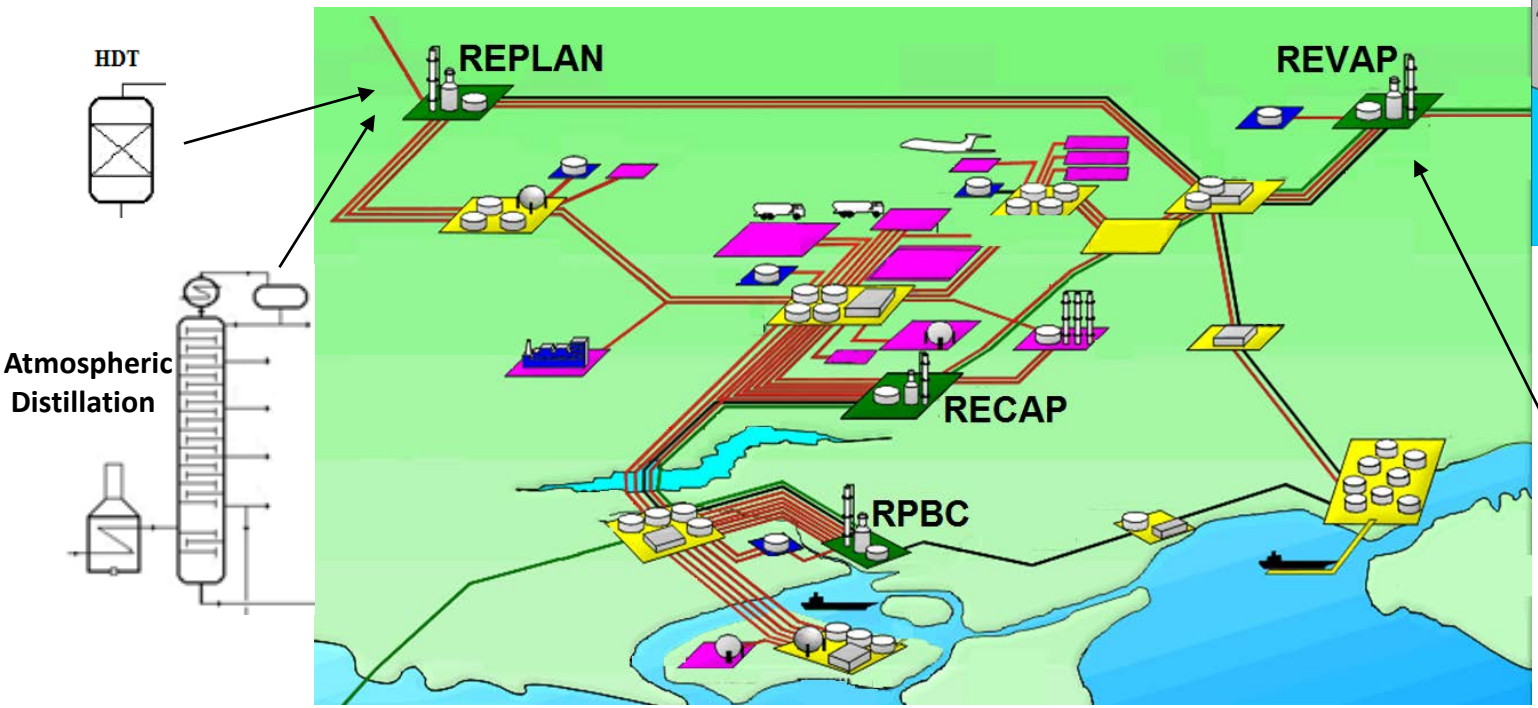
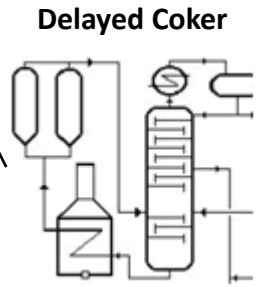
Goal: develop quantitative methods to predict structural modifications in refining assets through time



What, Where, When to Invest?





PETROBRAS Current Tool for Strategic Planning (PLANINV) – LP

No Process Design Synthesis

Only optimize stream transfers
(oil and fuels import/export, market supply)

Quantitative Methods

PLANINV

Process Design Opt. (MILP)
+
NLP { Processing, Blending }

Capital Investment Planning Formulation

Maximize: **NPV = DemandSales - SupplyCosts - OperatingCosts - InvestmentCosts**

Subject to:

$$QC_{r,u,n,t} = EXCAP_{r,u,n} + QC_{r,u,n,t-1} + QE_{r,u,n,t-1}$$

$$QC_{r,u,n,t} = QC_{r,u,n,t-1} + QI_{r,u,n,t-1}$$

$$ye_{r,u,n,t}\, QE_u^L \le QE_{r,u,n,t} \le ye_{r,u,n,t}\, QE_u^U$$

$$yi_{r,u,n,t}\, QI_u^L \le QI_{r,u,n,t} \le yi_{r,u,n,t}\, QI_u^U$$

$$QF_{r,u,n,t} \le QC_{r,u,n,t} \qquad (u,n)_{exp} \wedge (u,n)_{ins}$$

$$\text{expansion:} \quad (u,n)_{exp}$$

$$\text{installation:} \quad (u,n)_{ins}$$

(R,U,N,T)
R=Refinery
U=Unit type
N=Number of an unit type
T=Time

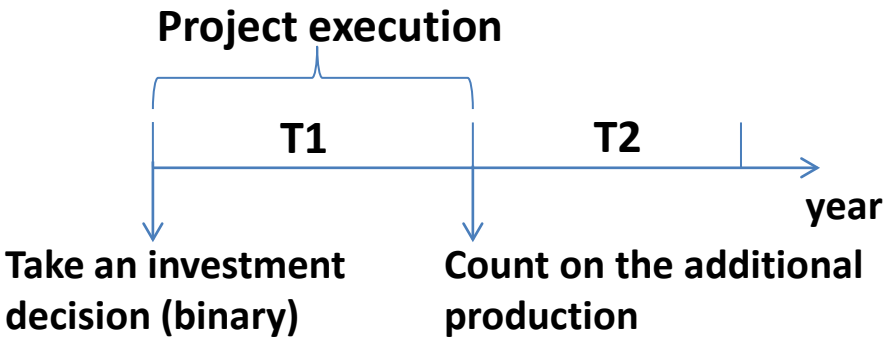
Where: **QF= operational flow** **QE= expanded capacity**
QC= total capacity **QI= installed capacity**

ye=expansion of an existent unit

yi= installation of a new unit

<u>Generalized formulation includes:</u>

- **Installation (grassroots);**
- **Project Execution;**
- **Sequence-dependent setups.**



Generalized Capital Investment Planning (GCIP) Model

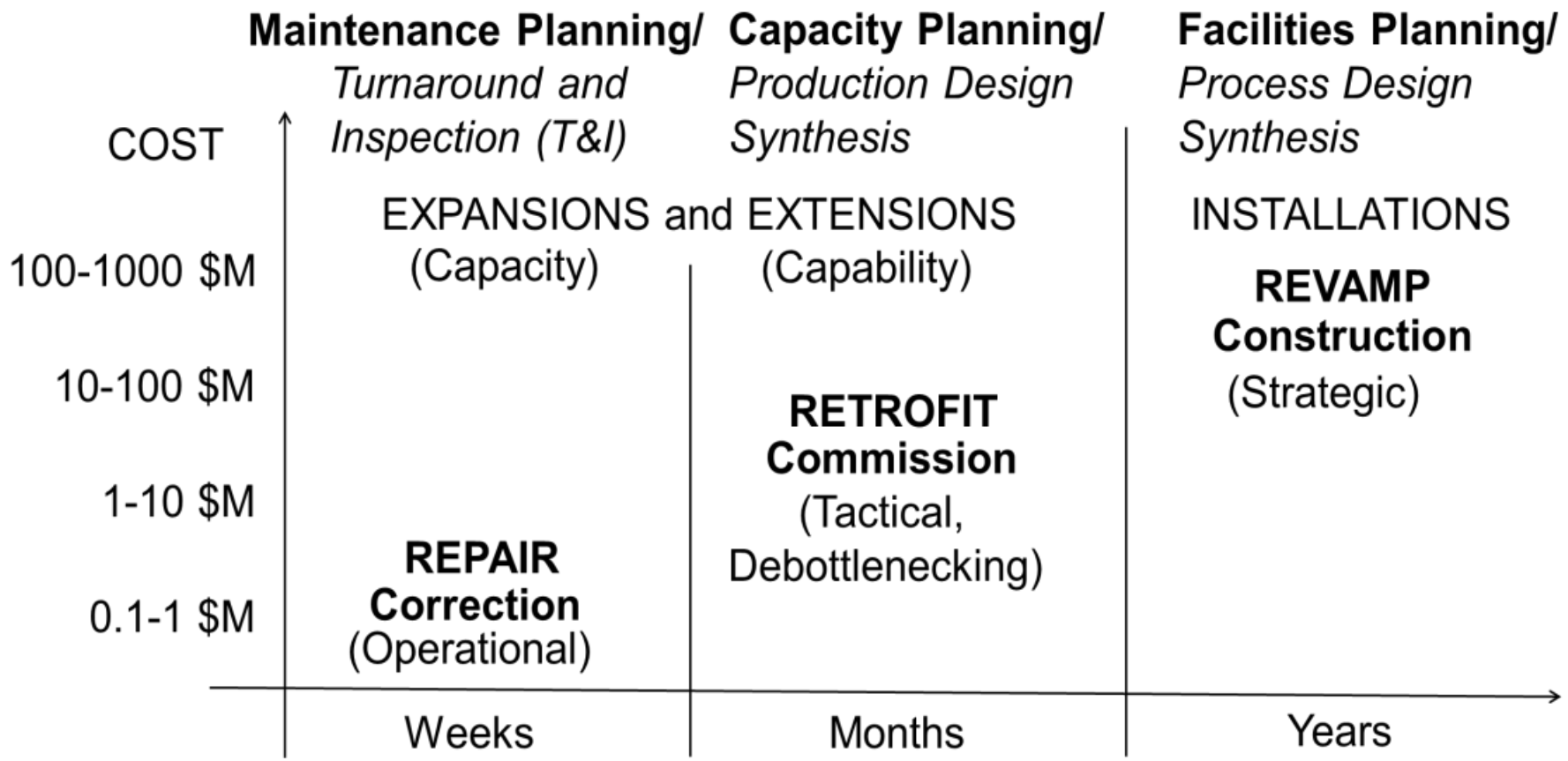
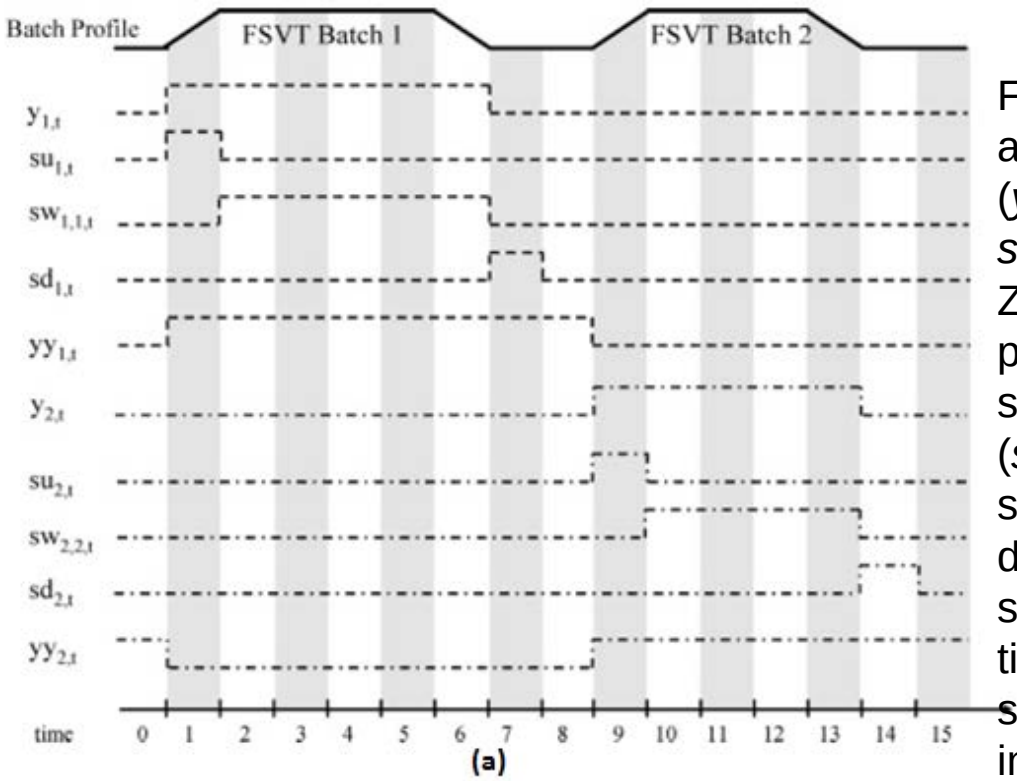
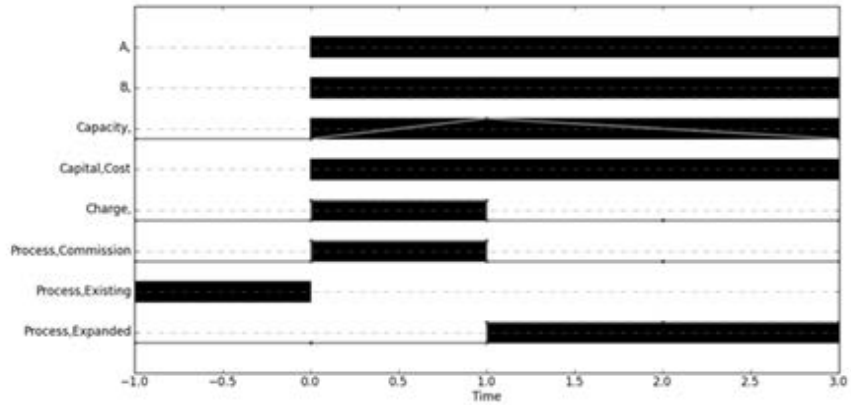


Figure 1. Three types of capital investment planning problems.

The sequence-dependent setup mathematics using a discrete-time model can be found in Kelly & Zyngier, I&ECR, 46, (2007), Equation 12.



(a)



(b)

Figure 2a shows the stages of two batches and the profiles of the independent variable ($y_{i,t}$) and the four dependent variables ($su_{i,t}$, $sd_{i,t}$, $sw_{i,i,t}$, and $yy_{i,t}$) extracted from Kelly and Zyngier (2007). For the capital investment planning case (Figure 2b), the startup, shutdown and switchover-to-itself variables ($su_{i,t}$, $sd_{i,t}$, $sw_{i,i,t}$) are disregarded, only the setup and the memory variables ($yy_{i,t}$) are defined to control the project scheduling and staging. In our project scheduling case, the time-duration of the dependent startup and shutdown transitions are covered by the intermediate stages (correction, commission, or construction).

$$\left(yy_{i,t} + yy_{i,t-1} - 1\right) + su_{j,t} - sd_{m,t} \leq 1$$

i, j = operation mode (batch 1, batch 2, existing, nonexisting, expanded, installed)

m = maintenance, commission, construction

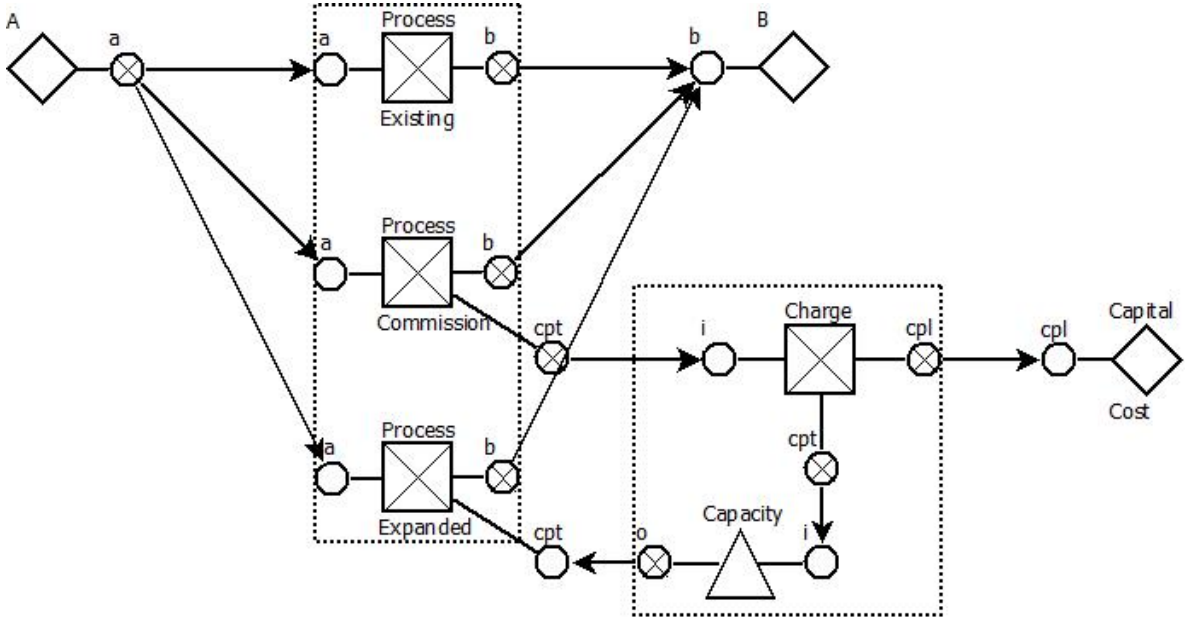


Figure 3. Motivating example 1: small GCIP flowsheet for expansion.

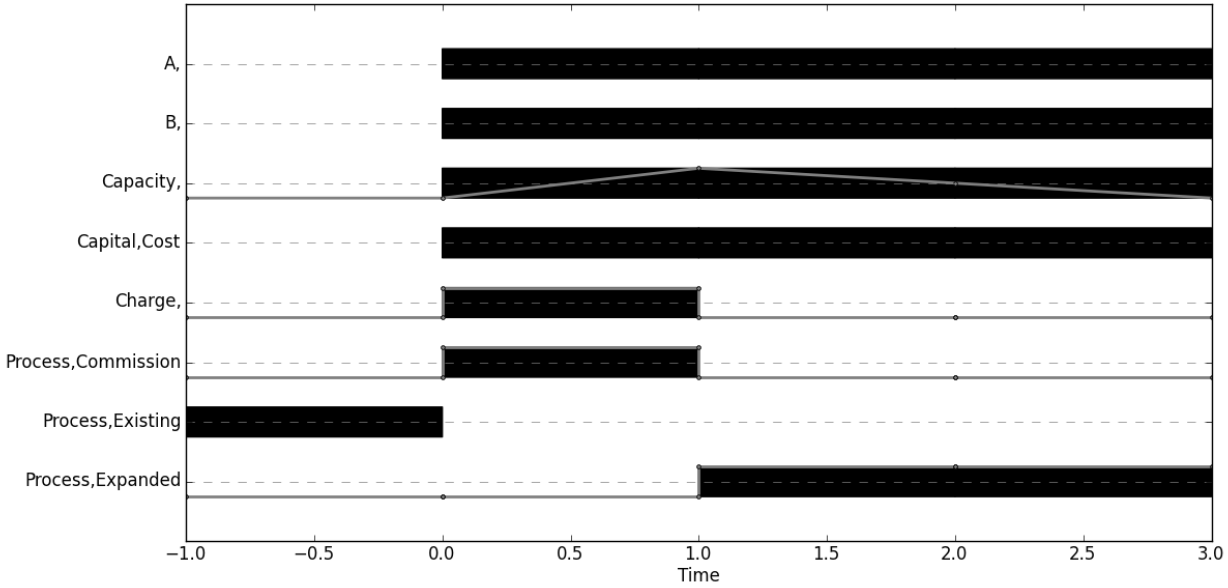


Figure 4. Gantt chart for expansion of a generalized CIP example.

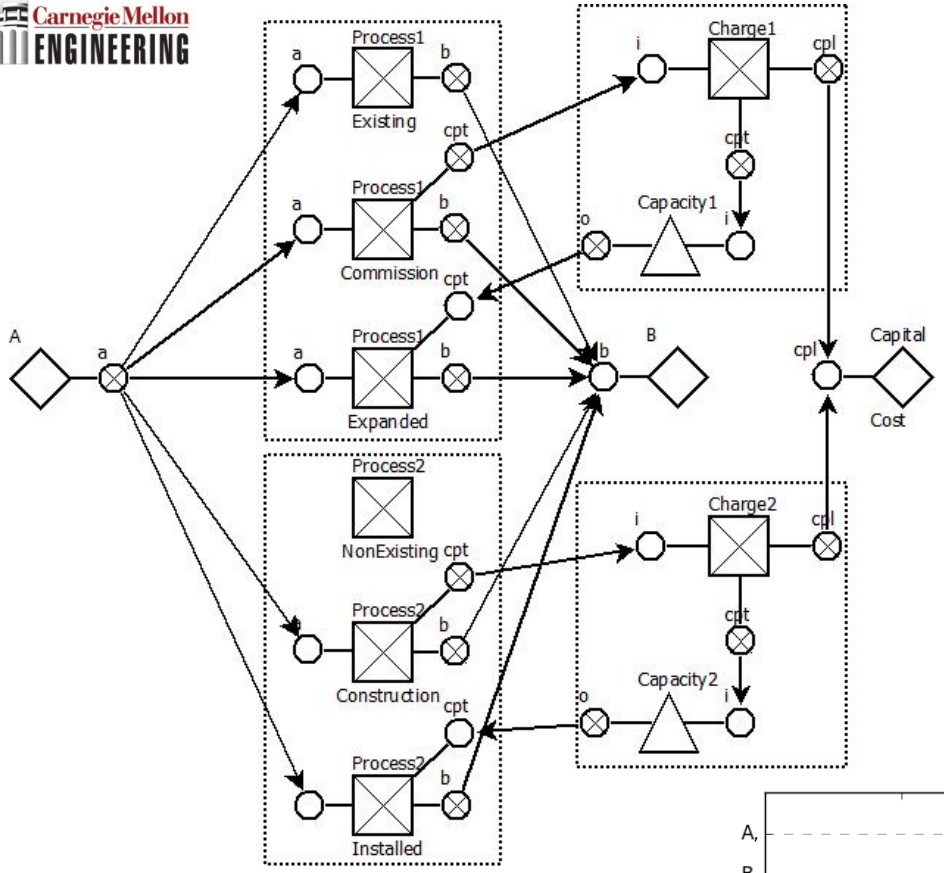
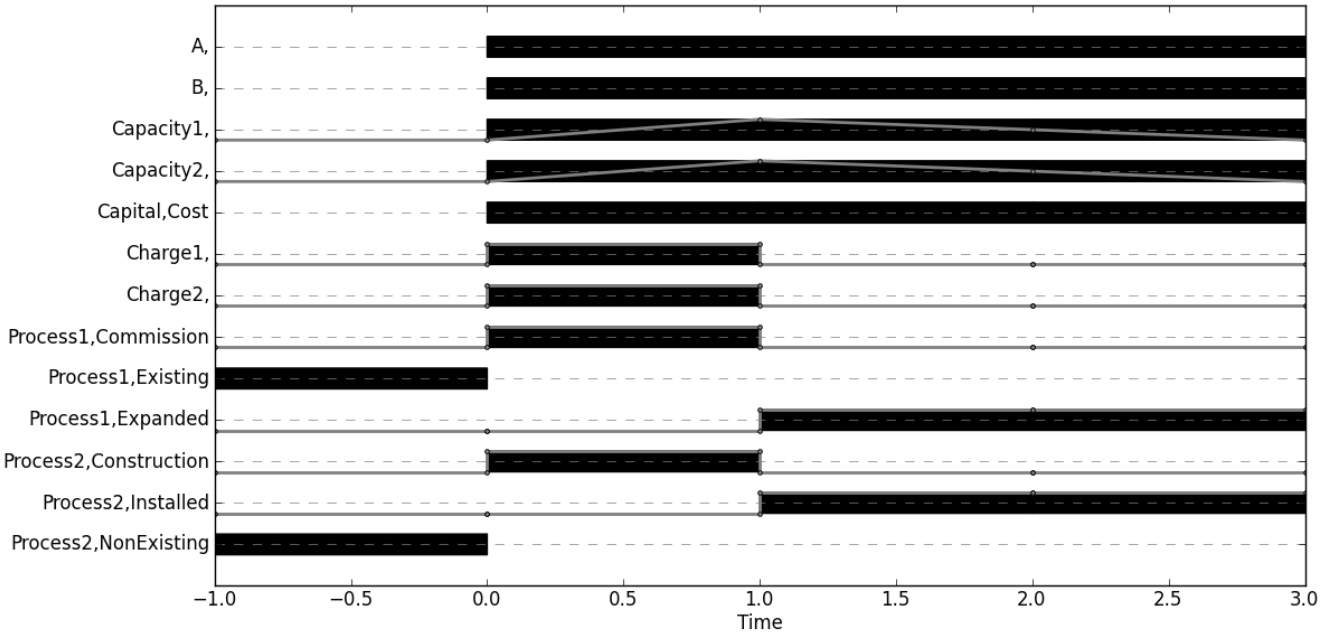


Figure 5. Motivating example 2: small GCIP flowsheet for expansion and installation.

Figure 6. Gantt chart for expansion and installation of a generalized CIP example.



Example Jackson and Grossmann (2002) example

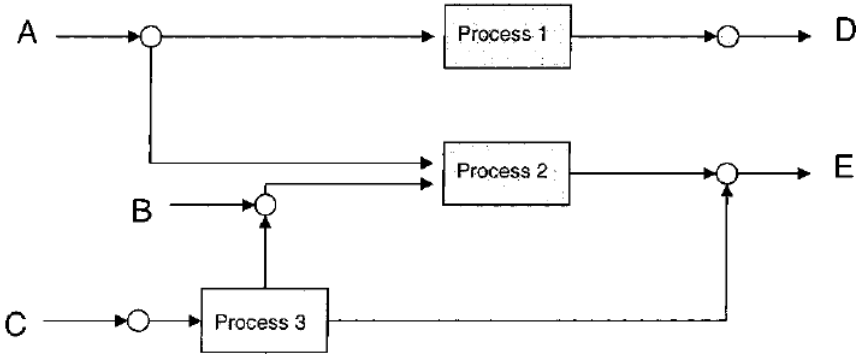


Figure 7. Retrofit example for capacity (expansion) and capability (extension) projects.

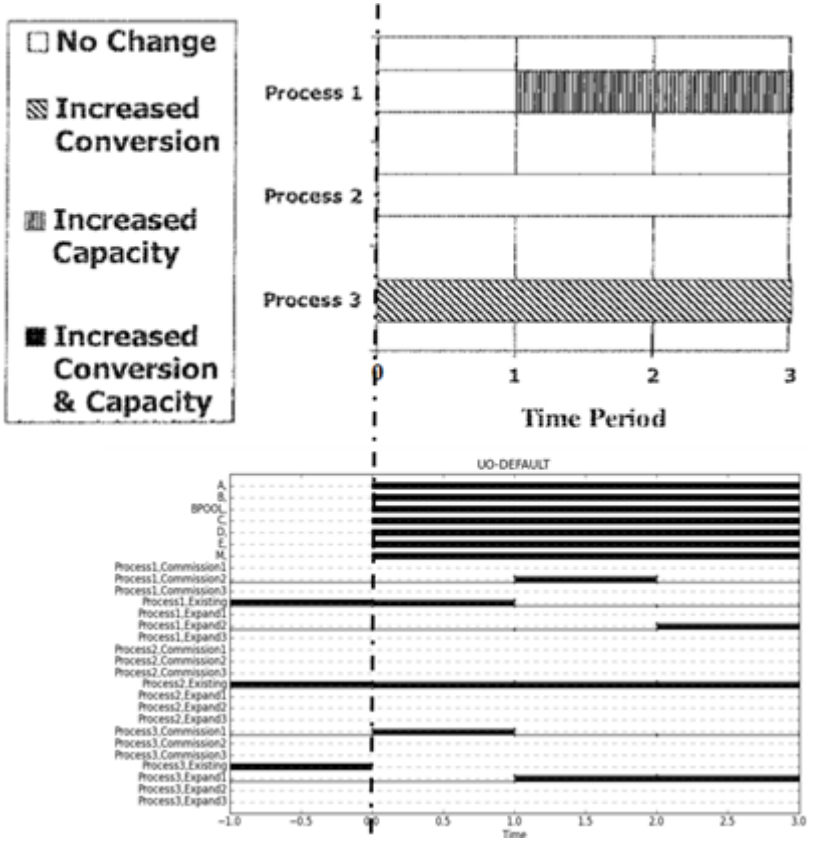


Figure 9. Gantt chart for Jackson and Grossmann (2002) example.

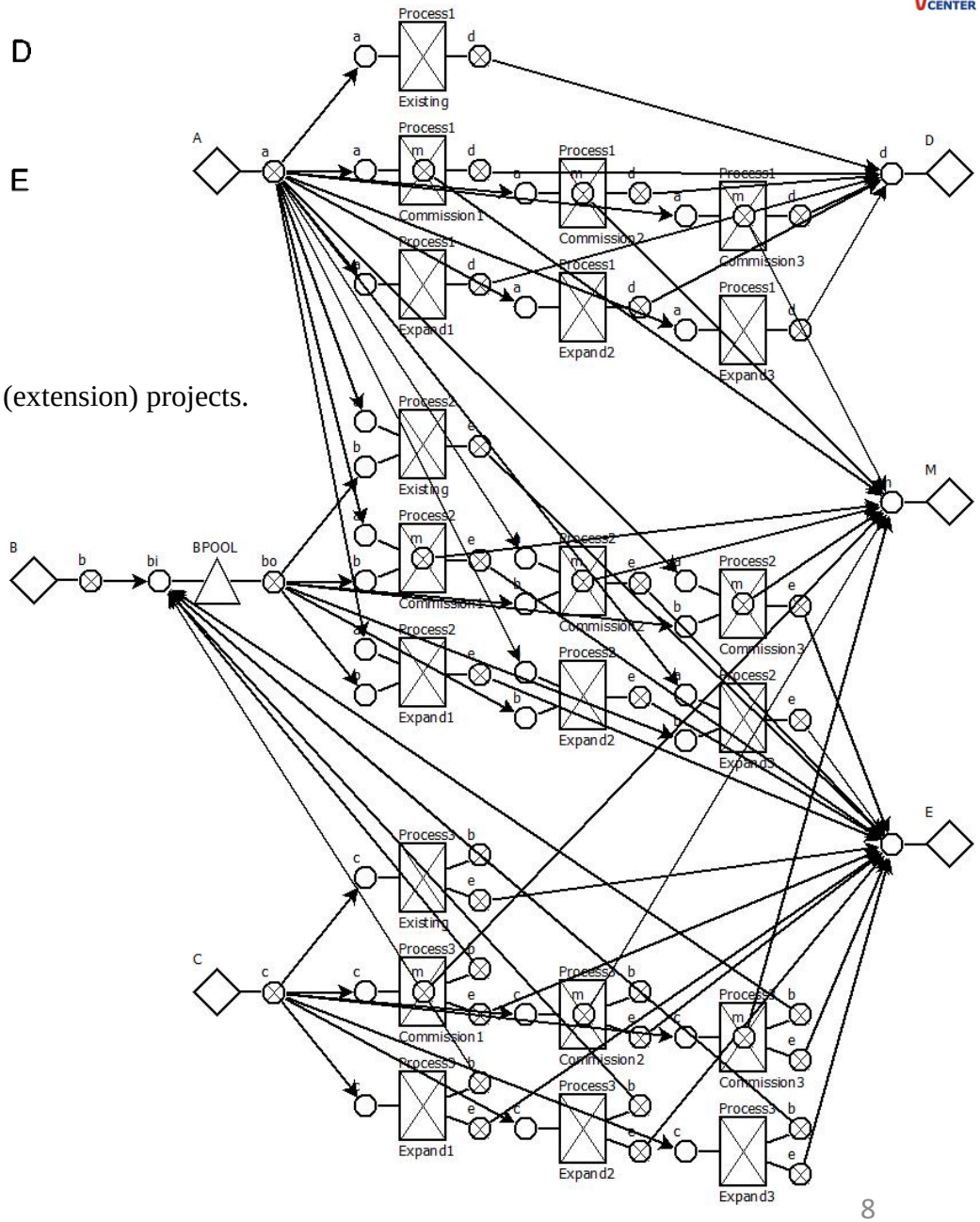


Figure 8. UOPSS flowsheet.

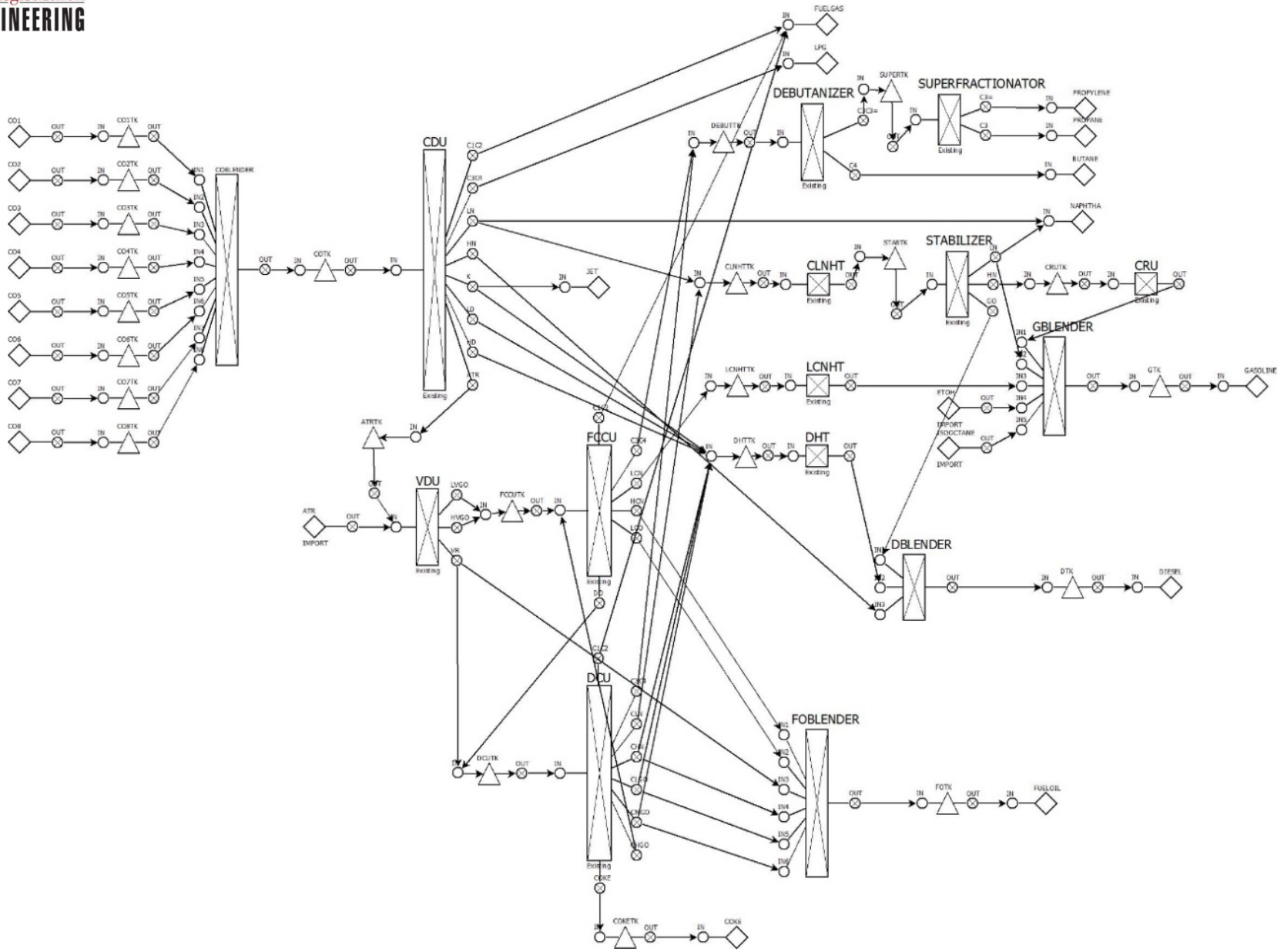


Figure 10. Oil-refinery example flowsheet.

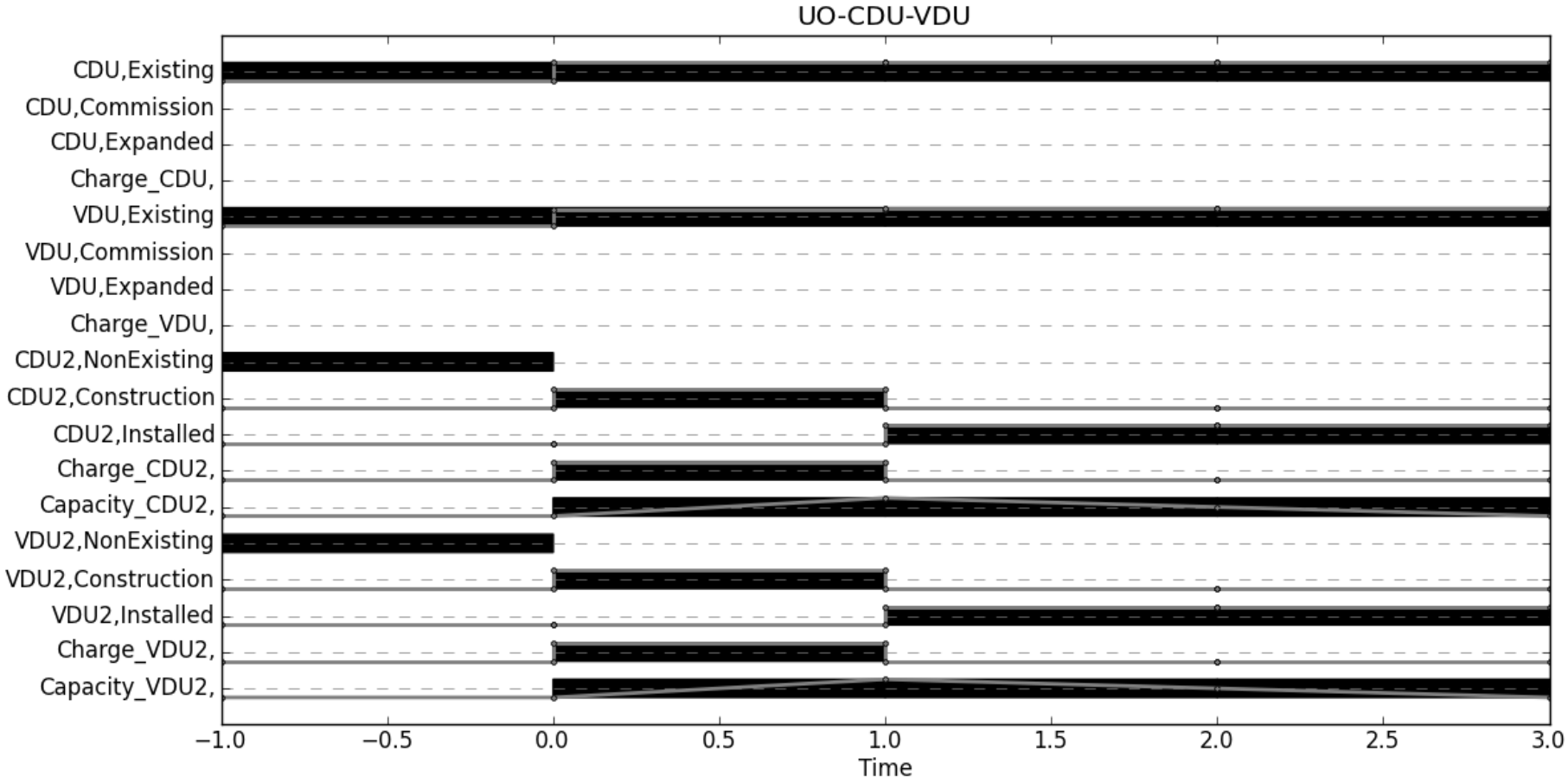


Figure 11. Gantt chart for the CDU and VDU installations.

Conclusions

Novelty:

- Includes project execution time (excluding the production from expanded units during this period)
- Expansion and Installation to control the capacity increment of units
- More realistic approach (in a quantitative manner) for strategic investment planning in the oil-refining industry
- The generalized capital investment planning introduces a novel modeling for optimization of project setups and phases using sequence-dependent logic, where capital and capacity are treated as flows in a scheduling environment.

Conclusions

Impact for industrial applications:

- Realistic formulation to predict investments in oil-refinery units, considering the stages of the projects.
- Avoids overestimating/underestimating capacity expansion/installation
- The strategic decision-making modeled in a scheduling environment can be extended easily to the entire supply chain for decisions on which units, tanks, pipelines, blenders, etc. to expand or newly build (economics) considering their operations (performance).