An Optimization Model to Program Process Schedule and Visualize Strategic Planning

Luqi Chen, Yi-Chun Ku, Yuchen Li, Yu-Chuang Tsai, Chunxuan Zhang, Yang Wang

Purdue University Krannert School of Management

chen1297@purdue.edu; ku19@purdue.edu; li2114@purdue.edu; tsai133@purdue.edu; zhan2381@purdue.edu; yangwang@purdue.edu

Abstract

A leading specialty chemicals company is seeking to evaluate process performance, optimize production capacity, and establish strategic plans. After measuring current equipment utilization rate and identifying bottleneck caused by inefficient planning and system constraints, an optimization model is being developed to minimize the process batch duration and thus maximize production volume. This model could be a strong tool to support management team to better make decisions on resource allocation, process planning and risks mitigation.

Introduction

The study aims to explore inefficient production planning and asset utilization issues in petrochemical industry by conducting operation analysis and developing the process optimization model.

The target Process A has followed an identical pattern for each batch. However, the production has not been operating in an optimal status due to inefficient planning, lack of manpower and functional constraints. The study aims to utilize data analytics and operation management tools to mitigate those potential risks to improve process performance.

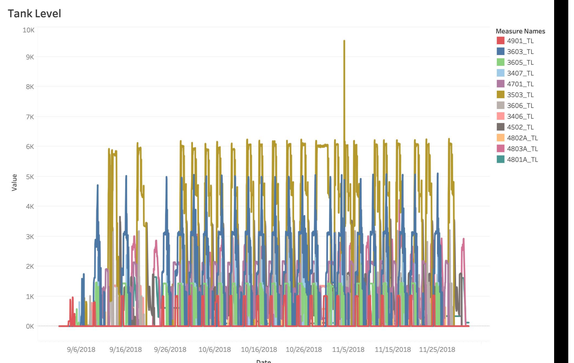


Figure 1. Real-Time Tank Operating Status

CPM (Critical Path Method) was adapted to diagnose the bottleneck of each process block and provide a high-level story flow visualization

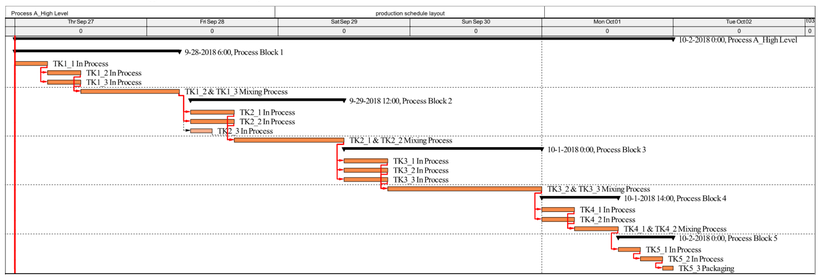


Figure 2. Flow Chart – Process A

Literature Review

This study aims to analyze asset utilization and improve production planning, so we cross reference with previous studies and propose the most satisfactory optimization solution.

Study	Chemical Plant Operation	Scheduling	Operation Research	Optimization Model	PERT
(Cottrell, 1999)					✓
(Law & Kelton, 2000)		✓	✓	✓	
(Sharda & Vazquez, 2009)	✓	✓			
(Mendez & Cerda, 2002)		✓	✓	✓	
(Williams, 2013)			✓	✓	
Our Study	✓	✓	✓	✓	✓

Table 1: Literature Review Summary

Methodology

Data

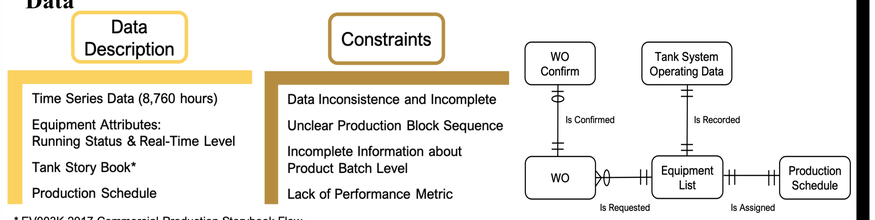
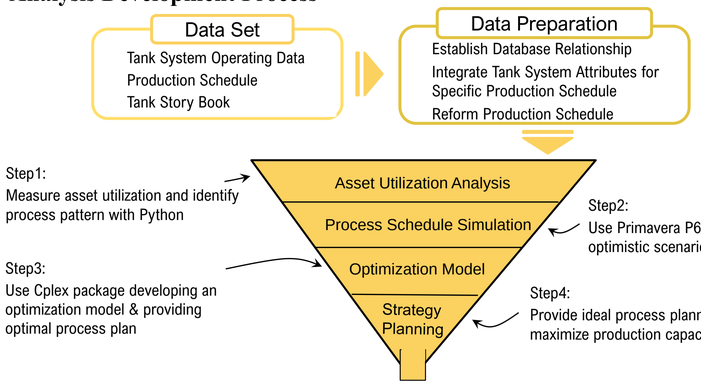


Figure 3. Business Information & Constraints

Figure 4. Data Relationship Diagram

Analysis Development Process



Optimization Model Building

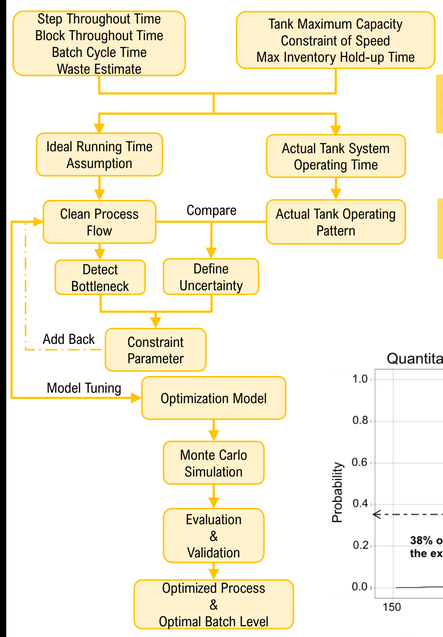


Figure 5. Optimization Model Development Process

Operation analysis
Ideal Process versus Actual Process

Ideal Process	B1	B2	B3	B4	B5	Total Throughout Time	Process Capacity
Block Throughout Time	40.5	32.5	46.5	14	11.5	142	46.45

Actual Process*	B1	B2	B3	B4	B5	Total Throughout Time	Process Capacity
Block involved Tanks	54.93	49.60	47.90	45.41	91.63	289.47	23.53

* Base on Actual Average Equipment Level

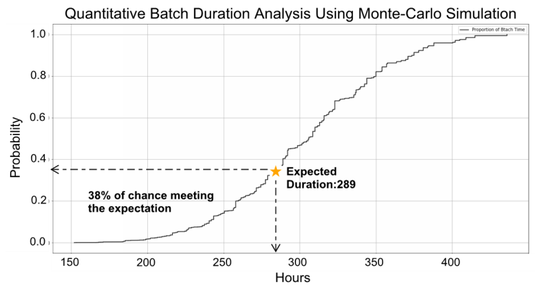


Figure 6. Monte – Carlo Simulation Cumulative Probability of Batch Time

Results

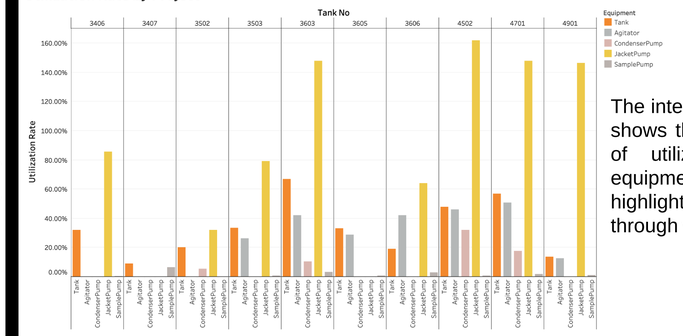


Figure 7. Utilization Interactive Dashboard

The interactive dashboard shows the detailed report of utilization at each equipment level and highlight the information through visualization

Model Summary

Precedence Constraint

Tank No	Task	Predecessor	Duration	Task Explanation
TK4901	1UO1_B	1UO1_A	2	Heat & Stir
TK3603	1UO9_C	1UO9_A	1	Stir
TK3605	1UO10_A	1UO9_A	3	Charge Water & Material
TK3407	1UO13_E	1UO13_C	1	Transfer Lower Layer
TK4802A	2UO2_A	1UO14_C	3	Charge Water & Material

Resource & State Constraint

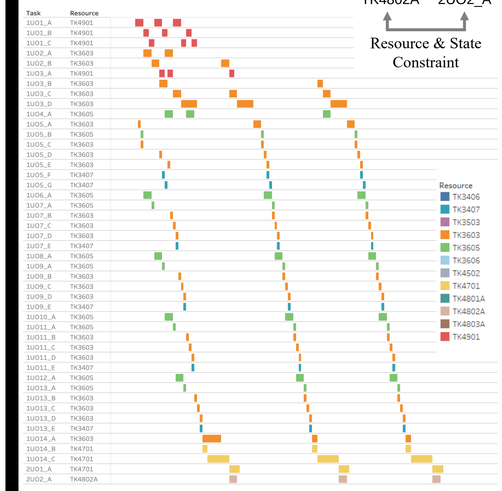


Figure 8. Simulated Optimal Process Schedule

For each batch $b \in B$ and each task $t \in T$, we introduce continuous non-negative variables $S_{b,t}, E_{b,t}$. The interval variable can be formulated as:

$$S_{b,t}, E_{b,t} \geq 0 \; \forall b \in B, \forall t \in T$$

$$0 \leq S_{b,t} < E_{b,t} \; \forall b \in B, \forall t \in T$$

The objective is to minimize the overall completion date (the completion date of the batch that is completed las):

$$Min\ (Max \sum_{b \in B} \sum_{t \in T} E_{b_n,t})$$

Conclusions

Through the analysis of target process, redundant and inefficient equipment setup may prolong whole process, extend bottleneck, induce single equipment's over-usage and waste. Further analysis requires more operation data on each steps, labors, and risk events. Combine with six sigma analysis, managers could leverage the optimization model in controlling manpower effects, improve process planning and boost production efficiency.

Acknowledgements

We thank our industry partner for their trust, support and encouragement while approaching this business problem. We also thank Professor Wang for constant guidance on this project.