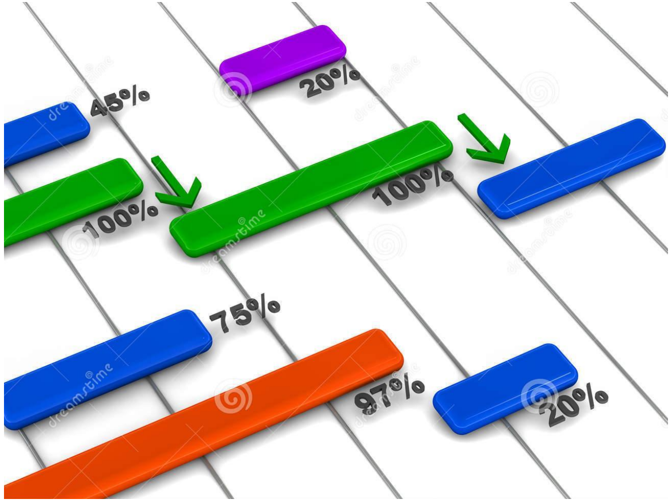
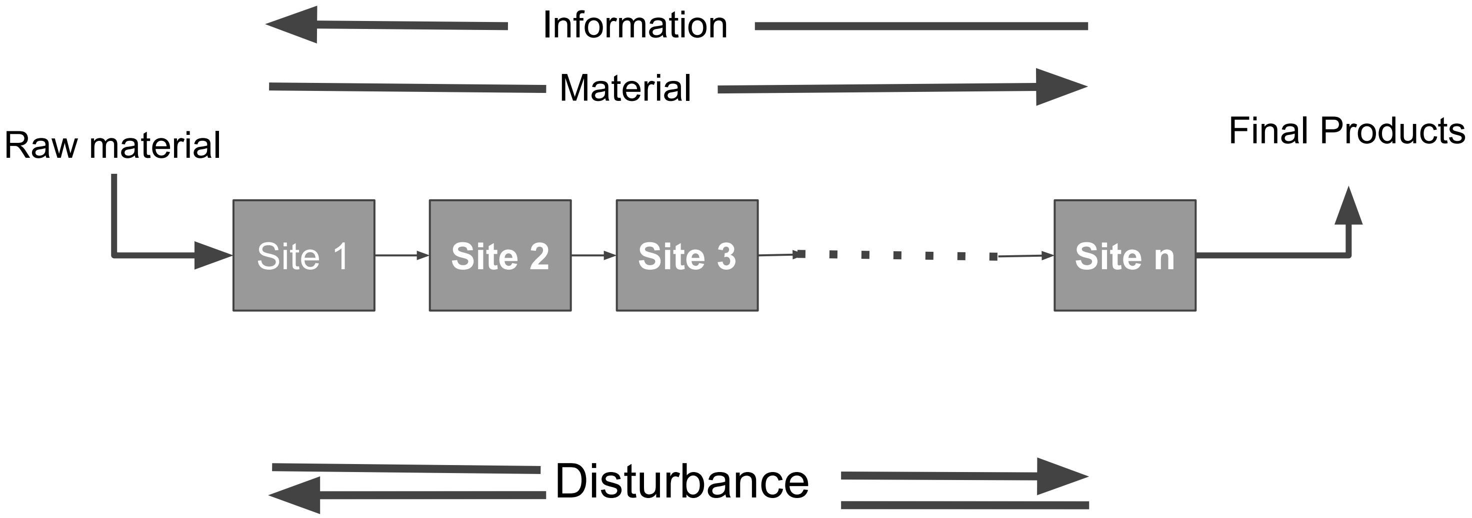
Production Scheduling of a Multi-site Manufacturing Facility



Team 04:
Apurva Pradhan* **Dong Qin*** **Geethanzali Kamalanathan*** **Kedar Dabhadkar***
*Department of Chemical Engineering
Carnegie Mellon University, Pittsburgh, PA

1. Motivation
2. Scheduling strategies
3. Math modeling
4. Results & discussion
5. Conclusions

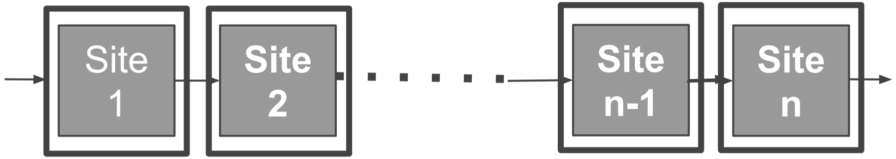
Motivation



1. Motivation
2. Scheduling strategies
3. Math modeling
4. Results & discussion
5. Conclusions

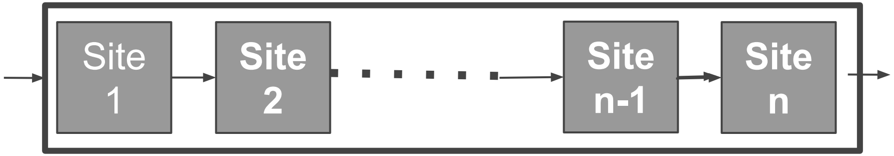
Three scheduling strategies

1. **Local Optimization Strategy (LOS)**



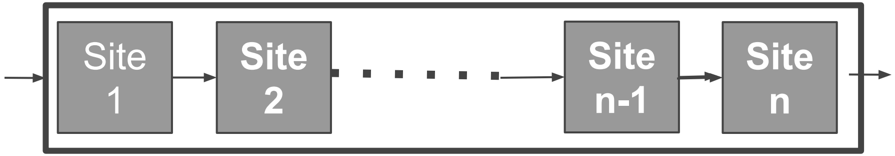
Yearly
demand consideration

2. **Yearly Global Optimization Strategy (Yearly GOS)**



Yearly
demand consideration

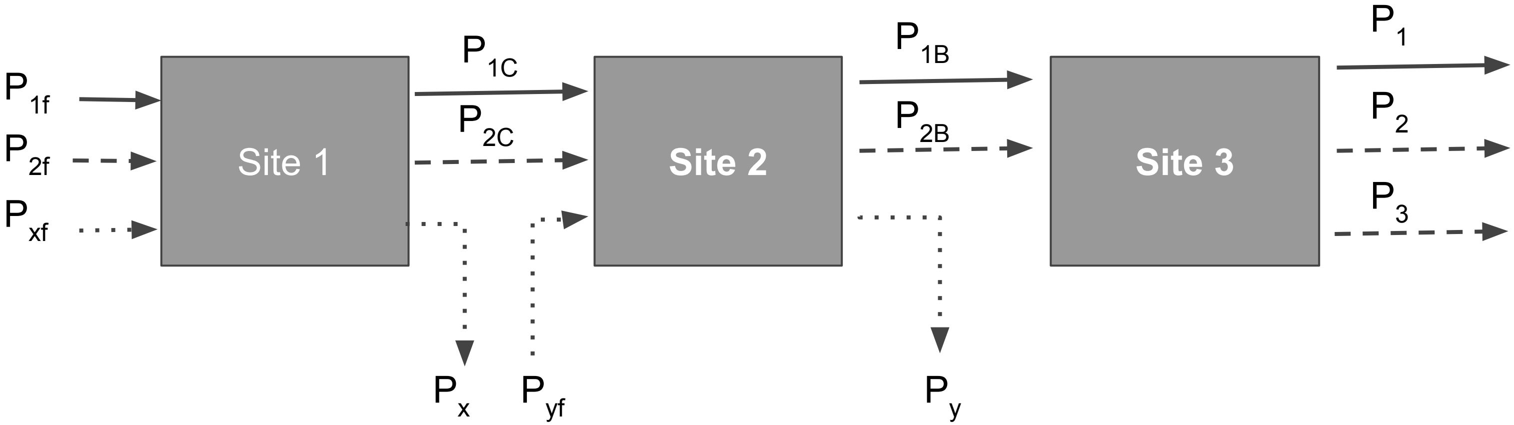
3. **Monthly Global Optimization Strategy (Monthly GOS)**



Monthly
demand consideration

Case study: Automobile breaking components manufacture

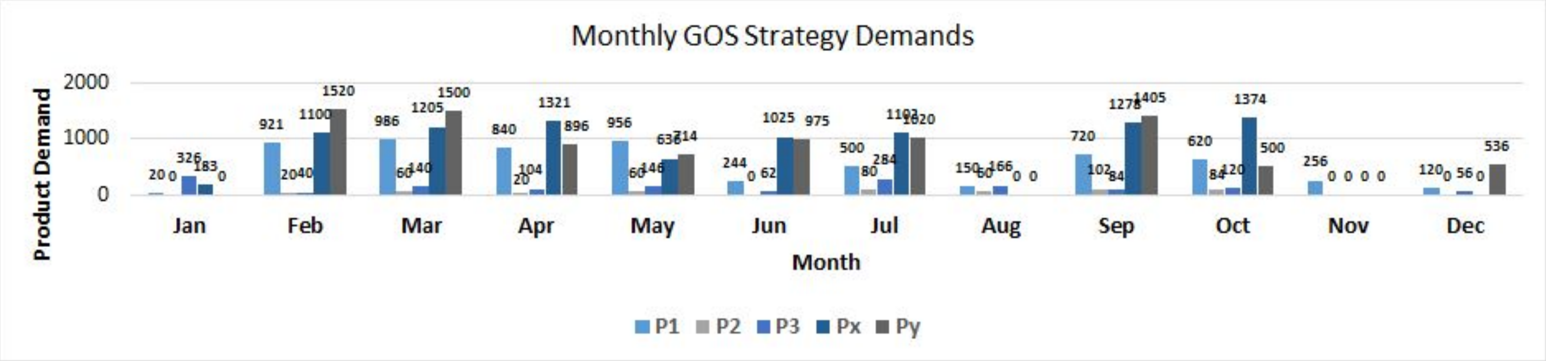
1. Motivation
2. Scheduling strategies
3. Math modeling
4. Results & discussion
5. Conclusions



Monthly and Yearly Global Optimization Strategy (GOS)

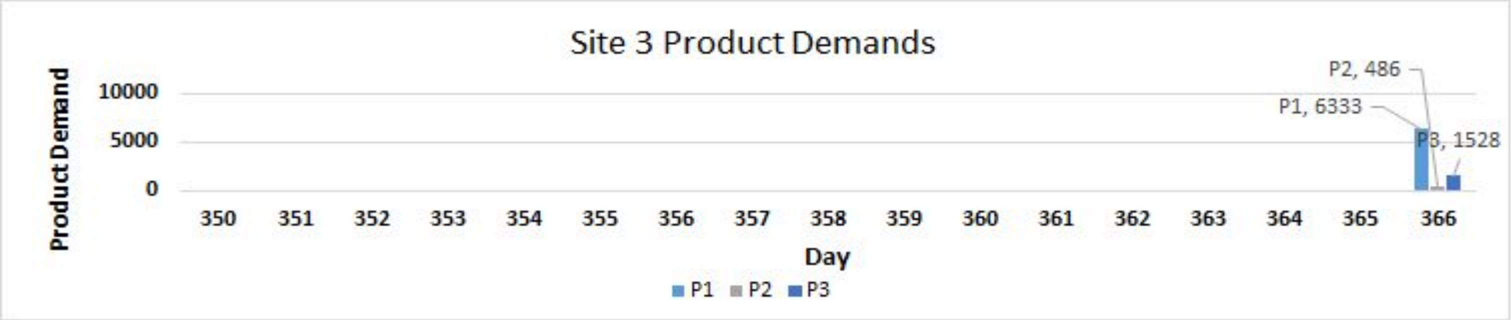
1. Motivation
2. Scheduling strategies
3. Math modeling
4. Results & discussion
5. Conclusions

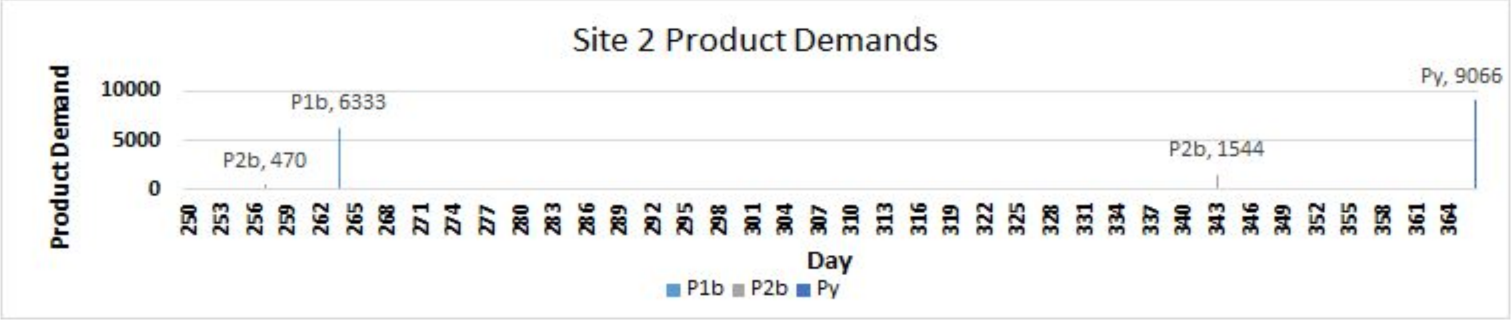
$F_{dem}(i,t)$ varies by month or year and products are delivered at the end of each month or year

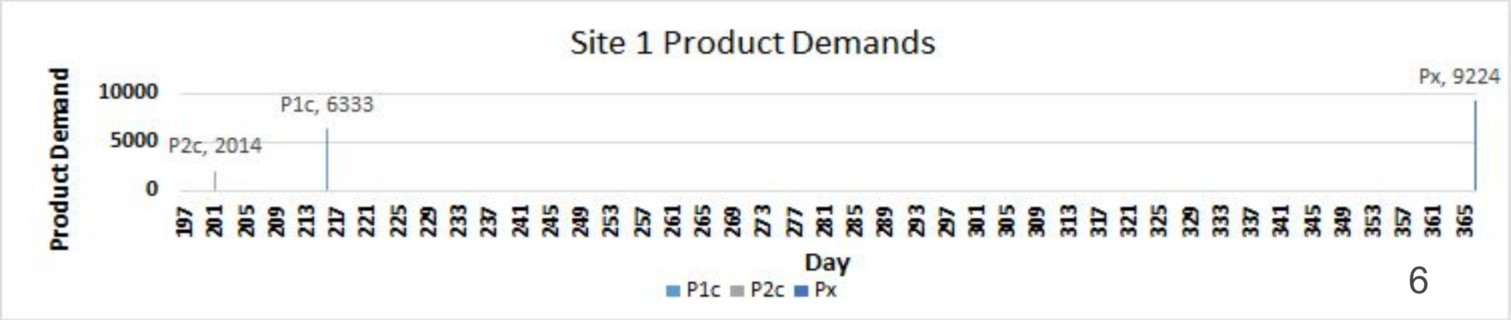


Local Optimization Strategy (LOS)

1. Motivation
2. Scheduling strategies
3. Math modeling
4. Results & discussion
5. Conclusions







1. Motivation
2. Scheduling strategies
3. Math modeling
4. Results & discussion
5. Conclusions

Math Modeling

Cost Objective Function

$$\textbf{Minimize} \quad Tcost = \sum_{t=1}^{366}\sum_{i=1}^{11} C_{inv}(i) * I(i,t) + C_{fix}(i) * Y(i,t)$$

Sets

$i = [P_{1f}, P_{1c}, P_{1b}, P_1, P_{2f}, P_{2c}, P_{2b}, P_2, P_3, P_{xf}, P_x, P_{yf}, P_y]$ Each product *i* in our process

$t = [1, 2, 3, \ldots, 365, 366]$ Each day *t* in a year

Binary Equations

$Y(P_{1c}, t) + Y(P_{2c}, t) + Y(P_x, t) \leq 1$ Site 1

$Y(P_{1b}, t) + Y(P_{2b}, t) + Y(P_y, t) \leq 1$ Site 2

$Y(P_1, t) + Y(P_2, t) + Y(P_3, t) \leq 1$ Site 3

Only one product can be produced per site per day

Continuity Equation

$I(i, t-1) \geq F(i,t) + F_{dem}(i,t)$ Inventory of *i* is greater than feed of *i* to next site

Feed Equations

$$F(i,t) = Y(i+1,t) * \left[\frac{\Delta t}{\tau(i+1)}\right] \quad \forall \quad i \notin [P_1, P_{2b}, P_2, P_3, P_x, P_y]$$

$$F(P_{2b},t) = Y(P_2,t) * \left[\frac{\Delta t}{\tau(P_2)}\right] + Y(P_3,t) * \left[\frac{\Delta t}{\tau(P_3)}\right]$$

$$F(i,t) = 0 \quad \forall \quad i \in [P_1, P_2, P_3, P_x, P_y]$$

Number of *i* being consumed by a site on day *t*

Inventory Equations

$$I(i,t) = I(i,t-1) + F(i-1,t) - F(i,t) - F_{dem}(i,t) \quad \forall \quad i \notin [P_{1f}, P_{2f}, P_{3f}, P_{xf}, P_{yf}], t \in t > 1$$

$$I(i,t) = \infty \quad \forall \quad i \in [P_{1f}, P_{2f}, P_{3f}, P_{xf}, P_{yf}]$$

$$I(i,0) = 0 \quad \forall \quad i \notin [P_{1f}, P_{2f}, P_{3f}, P_{xf}, P_{yf}]$$

Number of *i* in inventory at the end of day *t*

GAMS Solver

- CPLEX Solver used for all scenarios
- Faster and more optimized than other solvers
- Converts MIP equations to linear sub-problems and solving with branch-and-bound

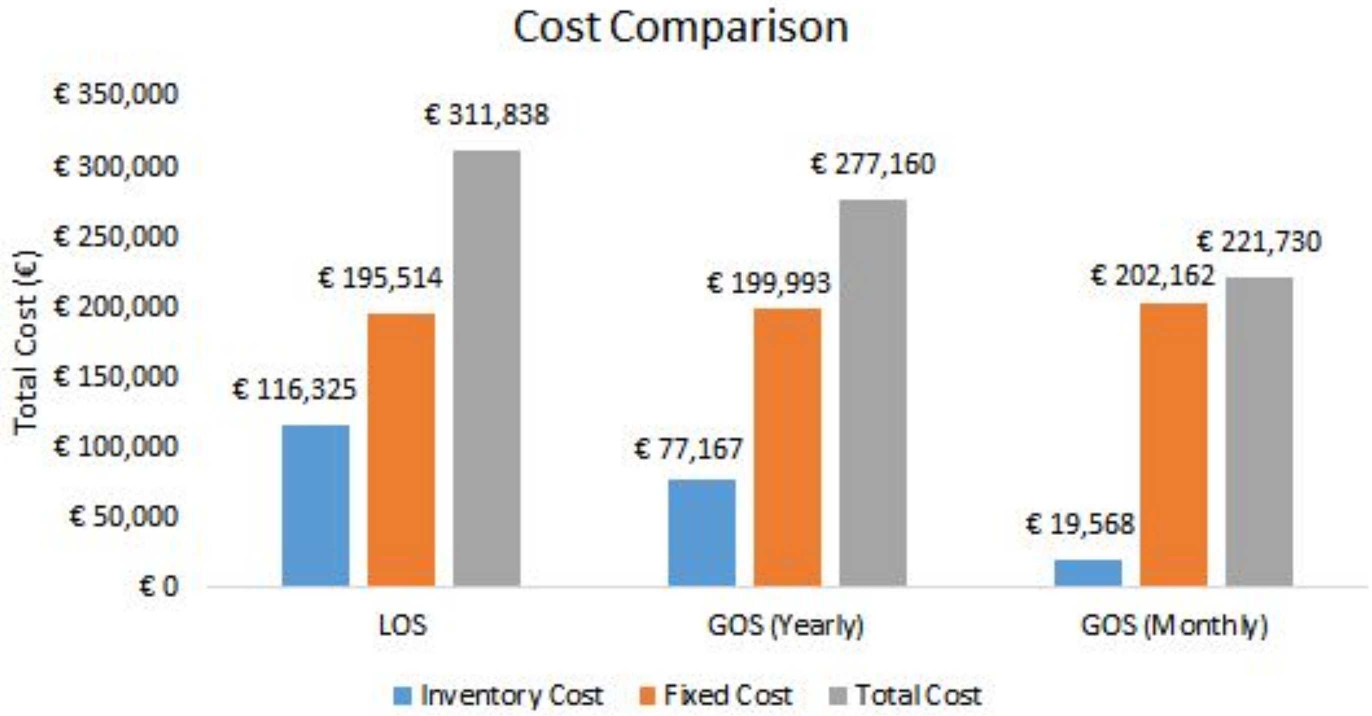
Solvers	Objective Function Value [€]	Execution time [seconds]
CPLEX	221726.2	0.03
BARON	222749	16.44
CBC	235836.5	1001
LINDO	Not Converged	-

1. Motivation
2. Scheduling strategies
3. Math modeling
4. Results & discussion
5. Conclusions

1. Motivation
2. Scheduling strategies
3. Math modeling
4. Results & discussion
5. Conclusions

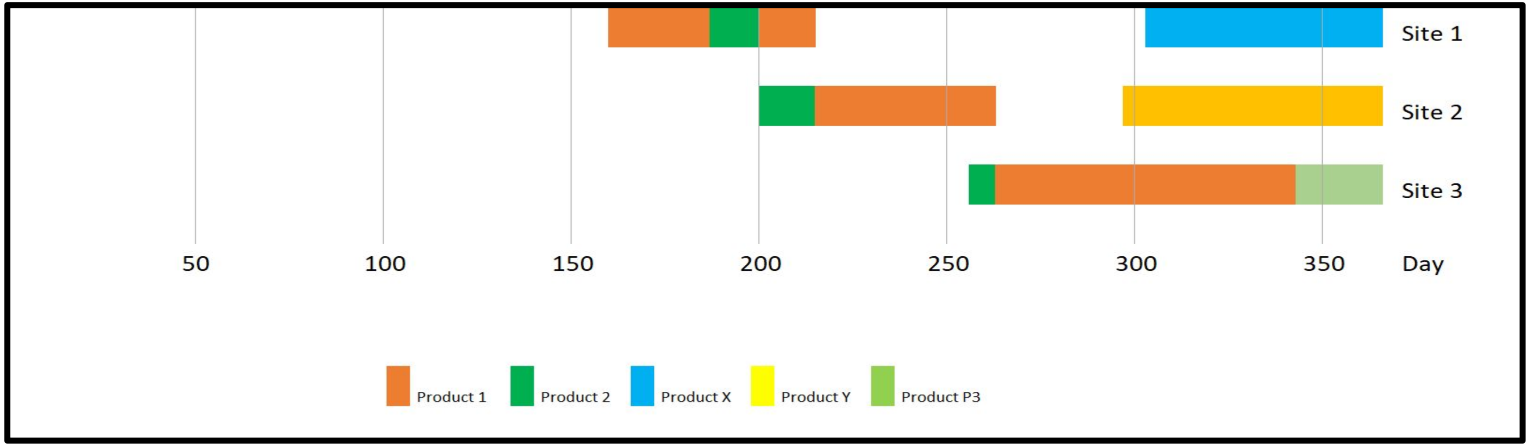
Total cost

LOS > Yearly GOS > Monthly GOS



1. Motivation
2. Scheduling strategies
3. Math modeling
4. Results & discussion
5. Conclusions

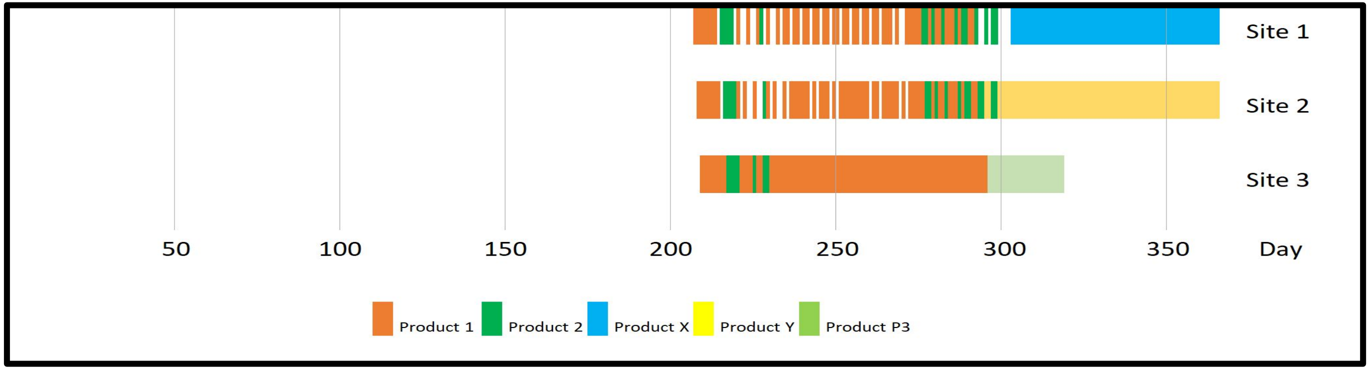
Amount of inventory is high in LOS



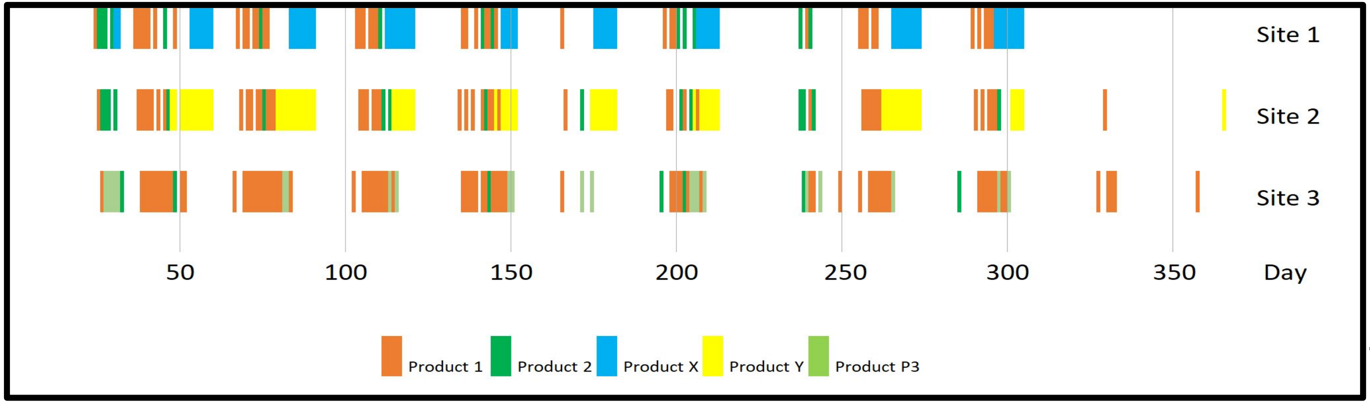
- Each site begins production early enough for “Just in Time” delivery
- Consolidated production means that products are being delivered to the proceeding site in one bulk shipment instead of continuously

GOS has distributed inventory

Yearly GOS



Monthly GOS



1. Motivation
2. Scheduling strategies
3. Math modeling
4. Results & discussion
5. Conclusions

1. Motivation
2. Scheduling strategies
3. Math modeling
4. Results & discussion
5. Conclusions

Conclusions

- Determined **optimal schedule** for each case of monthly and yearly demands.
- GOS **reduced total manufacturing costs** by over **28%** compared to LOS
- More cost reduction in monthly demand compared to yearly demand (due to reduced costs for inventory and storage).

Limitations

- **Further discretization** from a day to smaller or even continuous time scales would provide better optimum value.
- Incorporating penalty cost for **delayed deliveries** in the model
- Consideration of cost and the **manufacturing processes of feed**
- Considering **revenue** of the products

Future Work

- Including Bilevel optimization with time and profit.
- Considering **time as a continuous variables** by discretizing into smaller time intervals.
- Incorporating **delayed delivering cost & changeover costs** in the objective function