Optimal Tank Farm Operation

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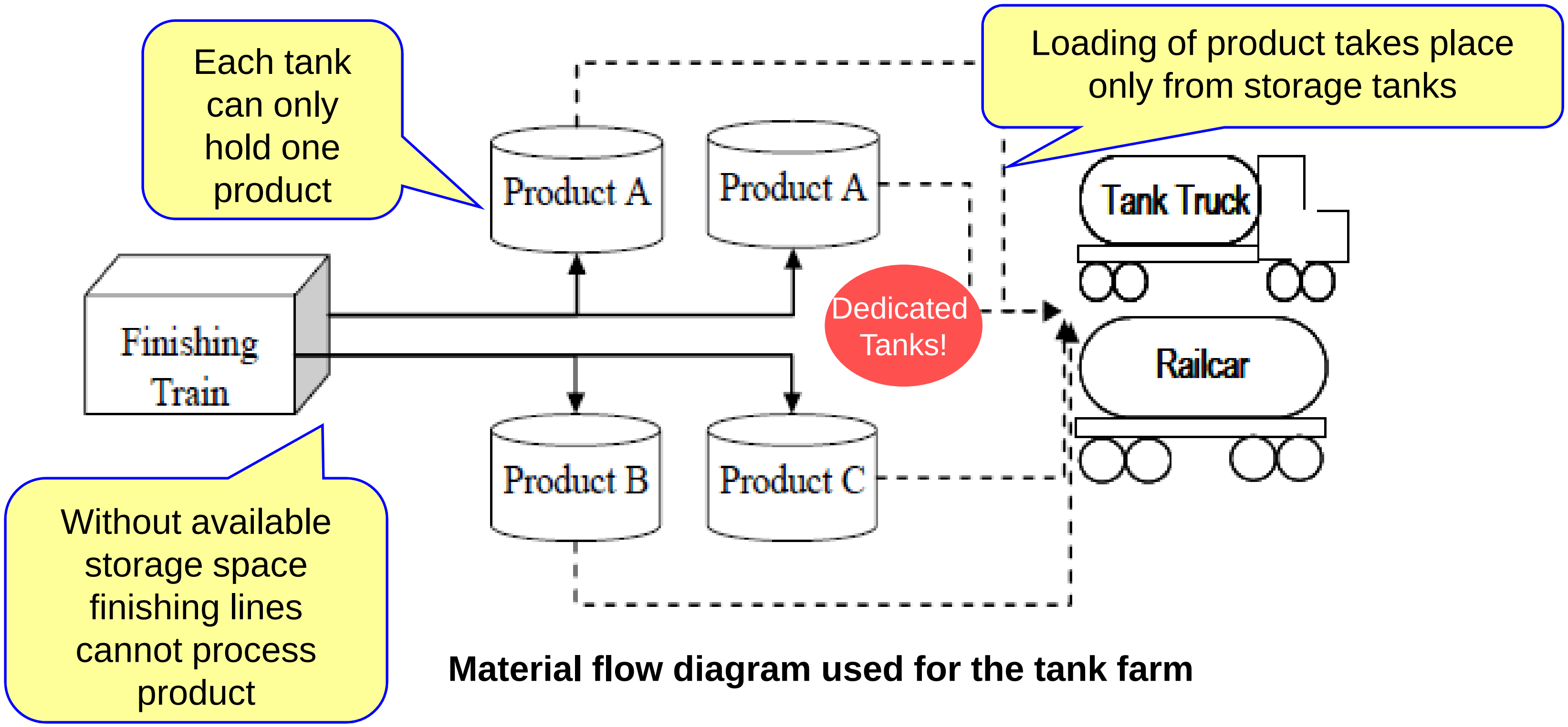
EWO Meeting
Carnegie Mellon University
March 2011

In collaboration with The Dow Chemical Company

A tank farm is a set of storage tanks that hold finished product until it is shipped



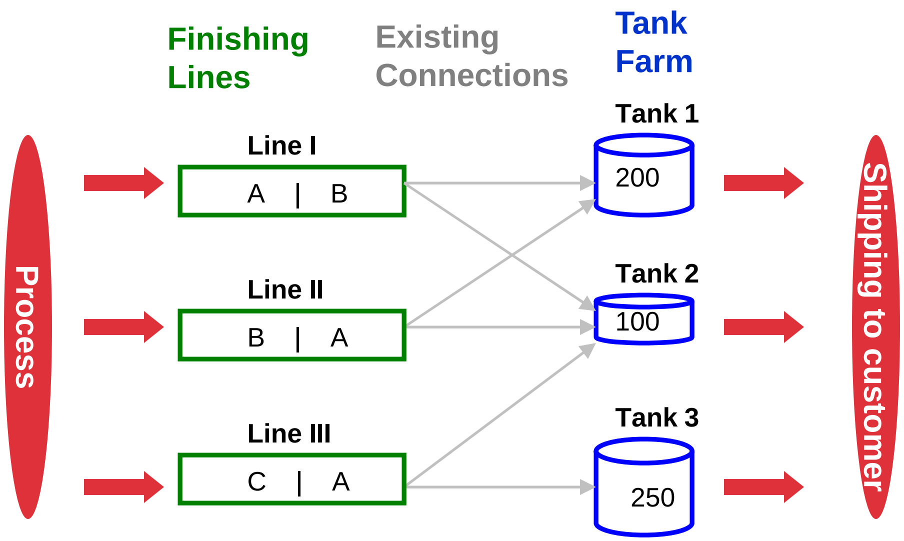
Material flow diagram used for the tank farm

- **Unsatisfied product** demand results from having no available storage space at the time scheduled for production
- This is referred to as **blocking finishing lines**

Dedicated storage tanks are assigned at the beginning of the operating horizon

Illustrative example

Order No.	Line	Product.	Quantity (klb)
1.	I	A	500
2	I	B	100
3	II	B	180
4.	II	A	100
5	III	C	450
6	III	A	100



Product	Production Rate any line (klb / hr)	Shipping rate any tank (klb / hr)
A	50	35
B	15	7
C	30	15

How should we choose which product to store in each tank?
i.e., determine product – tank assignment

Management of tank farm operation has an impact on the profitability of the manufacturing process

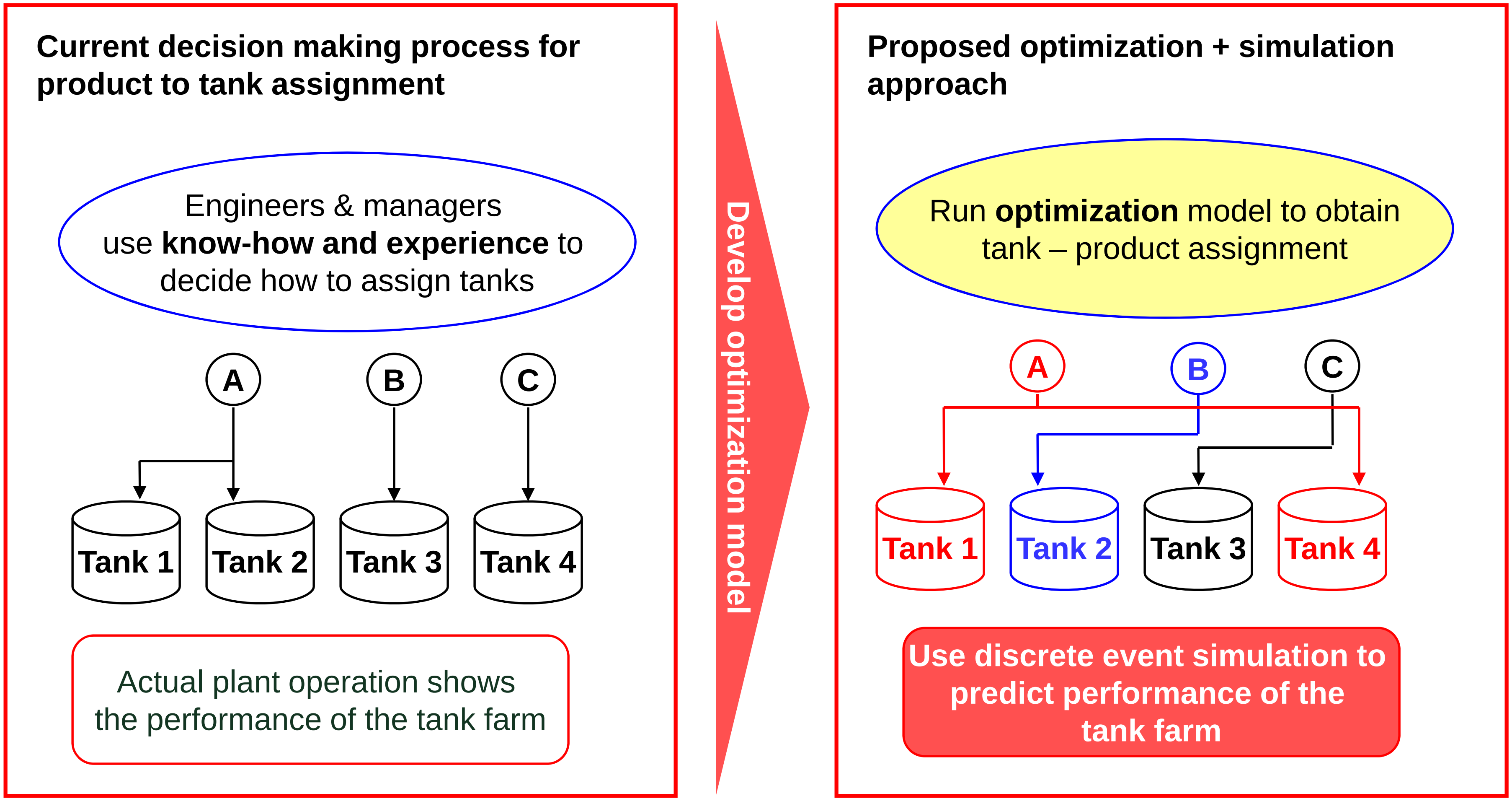
Profitability driver	Impact of tank farm operation
More productivity	• Unsatisfied product demand can be minimized by the optimal product to tank assignment
Less capital investment	• Optimal utilization of available tanks minimizes the need for additional investment in storage
Better asset utilization	• Optimal tank farm management allows the introduction of new products and the addition of extra volume for existing ones

In practice, the tank farm operation is highly constrained

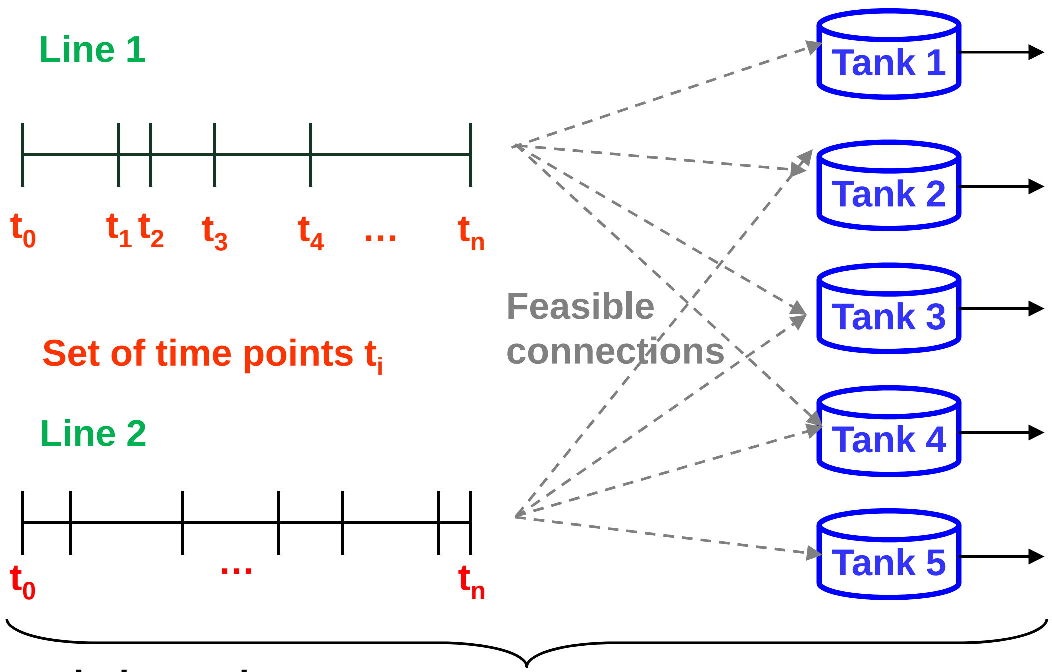
- Some tanks cannot be loaded and unloaded at the same time
- There might be a minimum volume for unloading a tank
- There might be a maximum level of loading for safety reasons
- Some tanks are not suitable for storing certain products
- Shipping is not done continuously but in discrete amounts using railcars and tank trucks
- Shipping can only take place during certain hours

- ❑ If all of these constraints are incorporated into an optimization model the problem becomes huge and hard to solve.
- ❑ A discrete event simulation can capture all of these constraints without becoming computationally intractable
- ❑ For this reason we propose a hybrid optimization – simulation approach

The objective is to test the potential of an optimization and simulation approach for management of tank farms



The optimization model is based on a simplified model of the tank farm operation



At each time point:

– Read from schedule the product being processed

– Determine how much product can be transferred to tanks

– Calculate mass balance at storage tanks

Given

- A set of products
- A set of production lines
- A set of tanks
- A production schedule
- A set of *possible* connections between lines and storage tanks
- A set of shipping resources (e.g., railcars)

Determine:

- Assignment of products to tanks.

With the objective of:

- Minimizing unsatisfied quantity

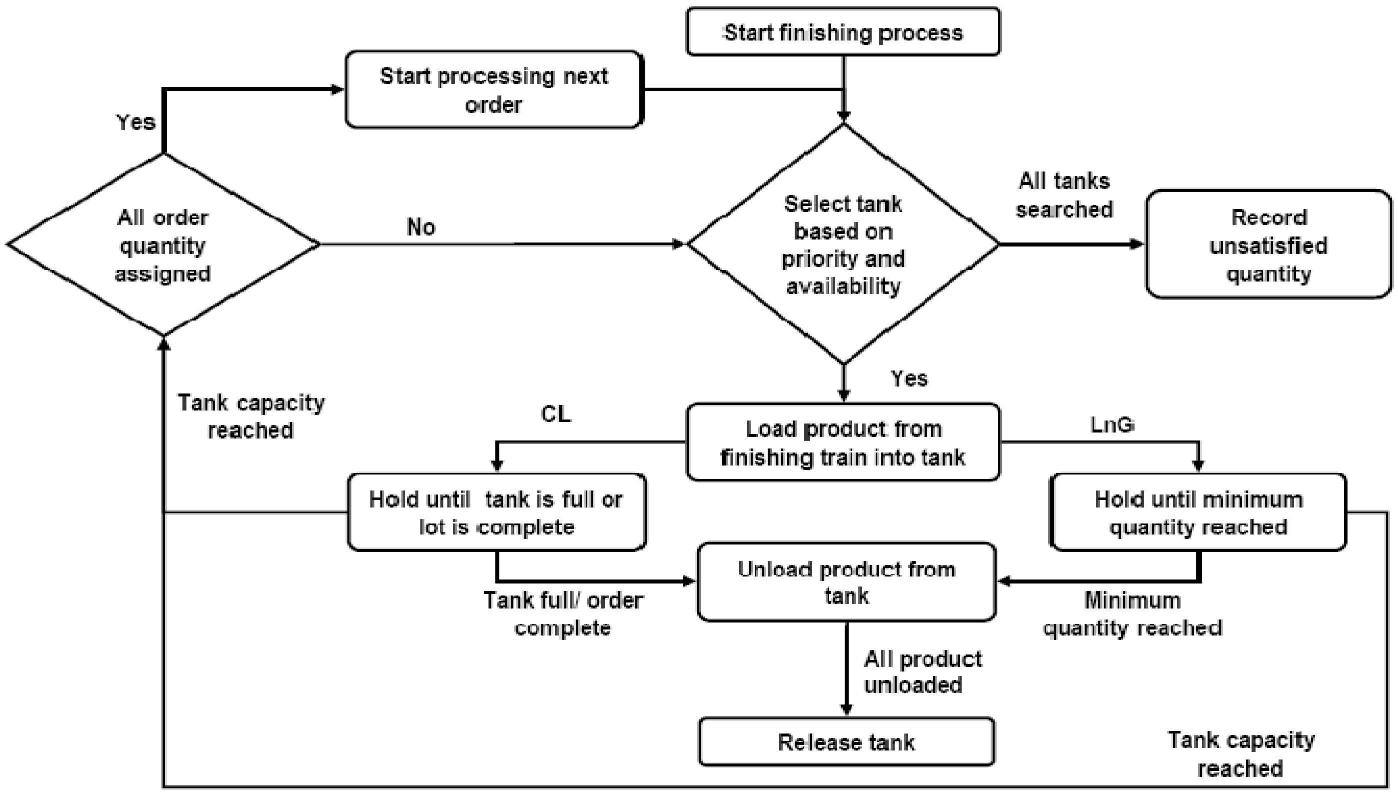
Optimization model is equation oriented;
it does not include detailed dynamics of tank farm operation

The problem is formulated as an MILP

$\sum_j z_{j,k} \le 1$	**Assignment constraint 1**
$z_{j,k} \le cmp_{j,k}$	**Assignment constraint 2**
$\sum_t p_{j,k,l,t} \le z_{j,k} rate_{j,l} \lvert T \rvert$	**Knapsack-type inequality; constraint on transfer rate**
$s_{j,k,t} = s_{j,k,t-1} - c_{j,k,t-1}(\tau_t - \tau_{t-1}) + \sum_l p_{j,k,l,t-1}(\tau_t - \tau_{t-1})$	**Inventory balance at time points**
$s_{j,k,t} \le v_k$	**Storage constraint**
$\sum_k c_{j,k,t} \le sh_j$	**Shipping constraint**
$ua_j \ge tgt_j - \sum_k \sum_l \sum_t p_{j,k,l,t}(\tau_{t+1} - \tau_t) \ge 0$	**Unsatisfied demand**
$\max obj = \sum_j (tgt_j - ua_j)$	**Objective function: Max satisfied demand = Min unsatisfied demand**

The optimal product – tank assignment is used as input in a detailed discrete-event simulation

The simulation model requires a fixed product tank assignment



Flow logic for discrete event simulation model

We tested the approach by using data from a real process

Get data from **Process**:
- Schedule for **60 finished products**
- Production capacity of **8 finishing lines**
- **80 tanks** of different sizes and load/unload characteristics
- Finished product shipping modes and rates[1]

Run optimization model with given data to obtain **optimal[2] product-tank assignment**. This step leads to a problem with millions of constraints and continuous variables and thousands of discrete variables. Solution times are in the order of hours.

Run **discrete-event simulation** model with optimal product-tank assignment **to predict performance**

Compare performance of optimal assignment vs. tank assignment provided by business (obtained without optimization) using existing Arena@ simulation model

(1) Shipping rates are approximate.
(2) It is rigorously optimal only for the simplified representation of the tank farm operation used in the optimization model

The simulation shows that the tank farm operation can be improved by exploiting the optimization tool

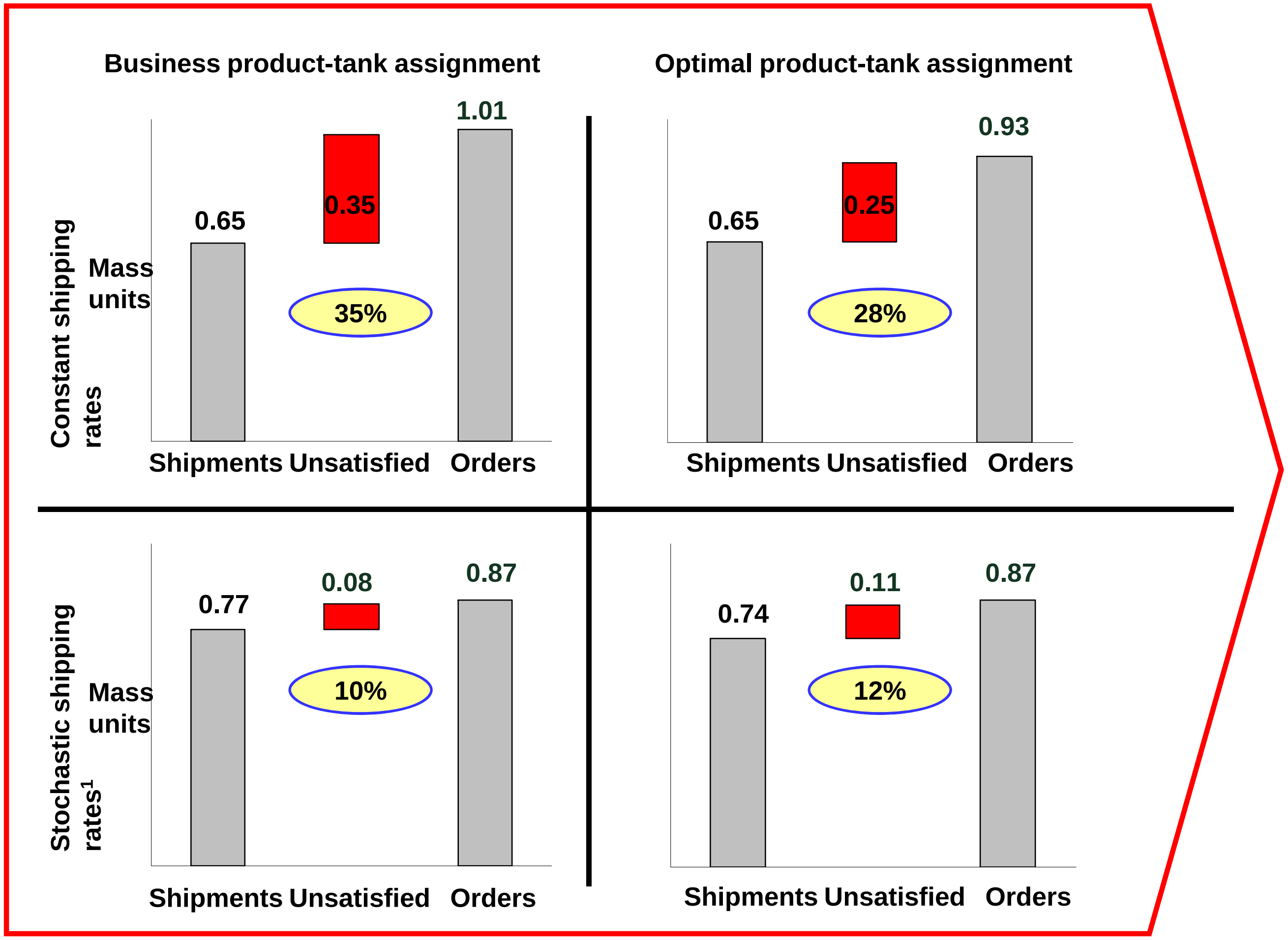
Total shipments, unsatisfied quantity and orders received in 1 year. Simulated with business provided assignment and optimal assignment
Mass units

Business product-tank assignment

Optimal product-tank assignment

(1) Difference in orders received between both assignments is explained as follows: An order is received when either of two conditions are met: a) production of previous order is finished or, b) previous order is identified as unsatisfied quantity. In business assignment more orders are considered unsatisfied allowing more total orders to be received.

The optimization approach needs to be extended to account for changing operating conditions



- Optimal assignment was determined for constant shipping rates
- When the same assignment is used to simulate the system with different (stochastic) shipping rates, performance is no longer better than business assignment
- **Optimization model needs to contemplate variability in operating parameters** (e.g., stochastic programming, robust optimization)

(1) Stochastic shipping rates are lower on average than the constant rates we used

Summary of results

- An optimization model was able to produce a product to tank assignment that resulted in better operation (less unsatisfied product) than the assignment proposed by the business

- The improvement was a result of more efficient utilization of tanks assigned to high volume lines

- Real process is subject to variable operating conditions. In order to generate a robust computational tool, variability of operating parameters must be considered in the optimization model

Next steps

- Include possibility of delaying production orders:
  Scheduling of finishing lines
- Include stochastic elements in optimization model:
  Variable shipping rates
- Variable number and size of additional storage tanks:
  Design as a degree of freedom

Thank You