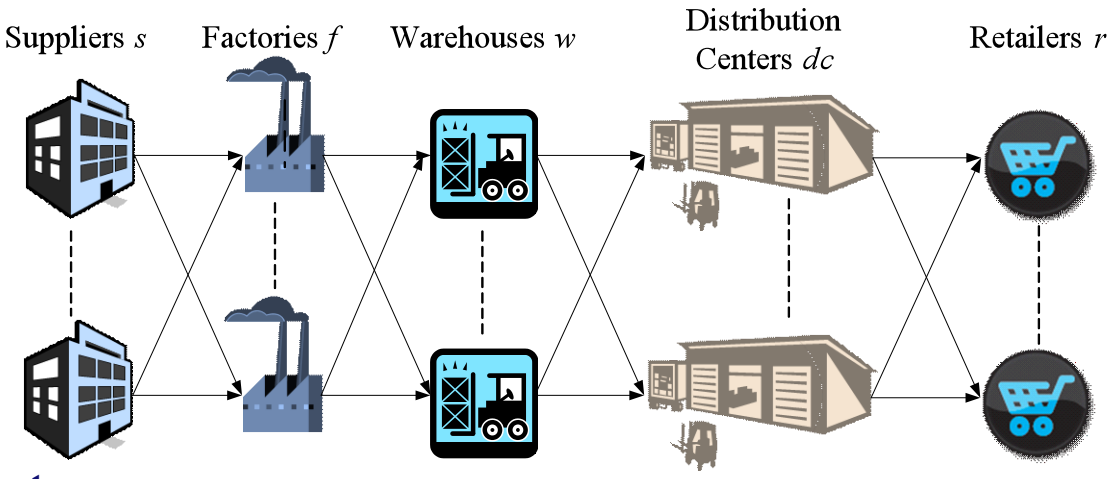
Problem Overview

Given Information

- **Supply Chain**
  - Topology & Capacities
- **Time Horizon**
  - 52 weekly periods
- **Demand (Weekly)**
- **Ingredient Availability**
- **Recipes & Production Rates**
- **Initial Inventories**
- **Economic costs**
  - Transportation Costs
  - Storage Costs
  - Safety Stock Costs
  - Set-up Costs
  - Missed Sales Costs



Determine

- Procurement from each supplier
- Production at each factory
- Transportation between all facilities
- Inventories in all facilities
- Delivery of products to retailers

Unilever

CAPD CENTER

TU/e Technische Universiteit Eindhoven University of Technology

Tactical Planning Model

- **MILP Model**
  - **Objective: Minimize Costs**
  - **Main Constraints**
    - Procurement capacity
    - Production capacity
    - Inventory balance
    - Safety stock
    - Missed sales
  - **Main Variables**
    - Procurement, production, transportation and inventory (Continuous)
    - SKU Set-up (Binary)

Shelf Life

- **Shelf-Life**
  - **m-w.com: The period of time during which a material may be stored and remain suitable for use**

- **Shelf life should be considered in the tactical planning for FMCG companies**
  - **Otherwise products may expire in storage or reach retailers with too short a remaining shelf life**
    - **Leads to unnecessary waste**

Direct Shelf Life

- **Directly model shelf life**
  - **Consider weeks in supply chain for**
    - **Each unit in storage**
    - **Each unit transported**

$$INVWH_{i,w,t} \rightarrow INVWH_{i,w,t,t'}$$

$$TransWHDC_{i,w,dc,t} \rightarrow TransWHDC_{i,w,dc,t,t'}$$

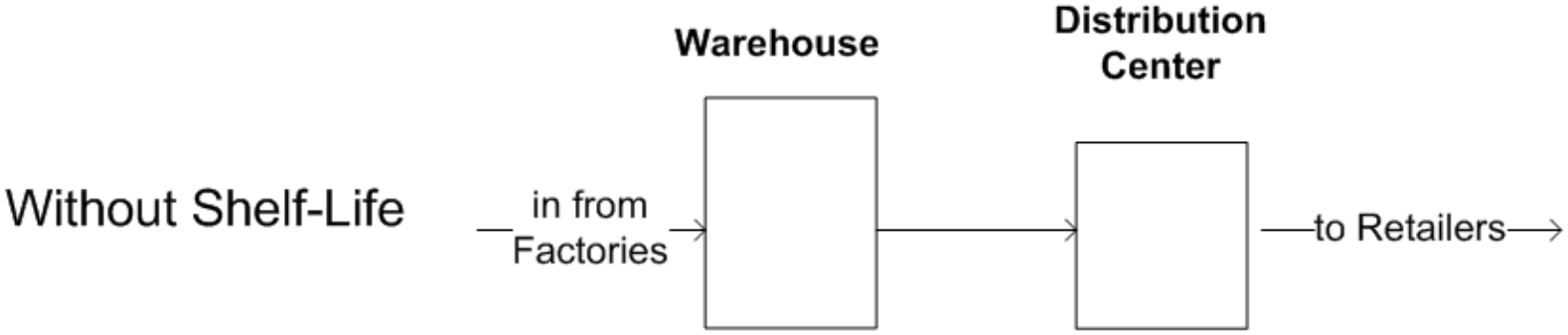
$$INVDC_{i,dc,t} \rightarrow INVDC_{i,dc,t,t'}$$

$$TransDCR_{i,dc,r,t} \rightarrow TransDCR_{i,dc,r,t,t'}$$

  - **Consider shelf life by limiting domain of *t'***
  - **Model size increases drastically!**

Direct Shelf Life

- **Direct shelf life implementation: additional variables**
  - **For each product in each location in each week:**



Indirect Shelf Life

- **Indirect shelf life modeling**
  - **If only single storage echelon in supply chain:**

$$\sum_{r,t' \le t+Shelf\ Lif\ e} TransDCR_{i,dc,r,t'} \ge \sum_{f' \in t} TransFDC_{i,f,dc,t'} \quad \forall i, dc, t$$

    - **Total amount received from all factories in week t must be sent on to retailers before week t+*ShelfLife***
  -

Indirect Shelf Life

- **Indirect shelf life modeling, multi-echelon storage**
  - **Divide available shelf life over echelons**
    - **Max 50% Shelf life at warehouse, max 50% at DC**
    - **Loss in flexibility ➔ Loss in solution quality**
    - **No products exceed their shelf life**

Hybrid Shelf Life

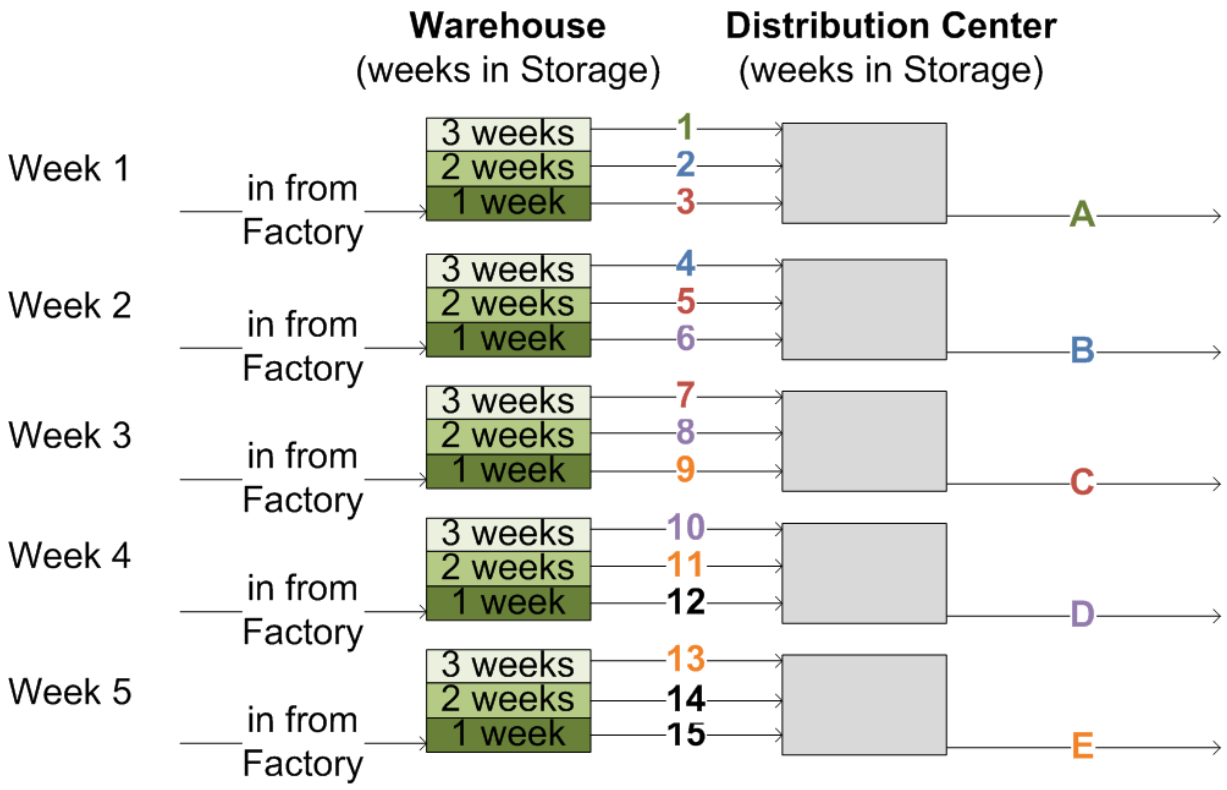
- **Hybrid Shelf life modeling**
  - **Shelf life on the <u>first storage echelon modeled directly</u>**

$$INVWH_{i,w,t} \rightarrow INVWH_{i,w,t,t'}$$

$$TransWHDC_{i,w,dc,t} \rightarrow TransWHDC_{i,w,dc,t,t'}$$

Hybrid Shelf Life

❑ Hybrid shelf life modeling



Constraints

$1 \le A$

$1+2+4 \le A + B$

$1+2+4+3+5+7 \le A + B + C$

$1+2+4+3+5+7+6+8+10 \le A + B + C + D$

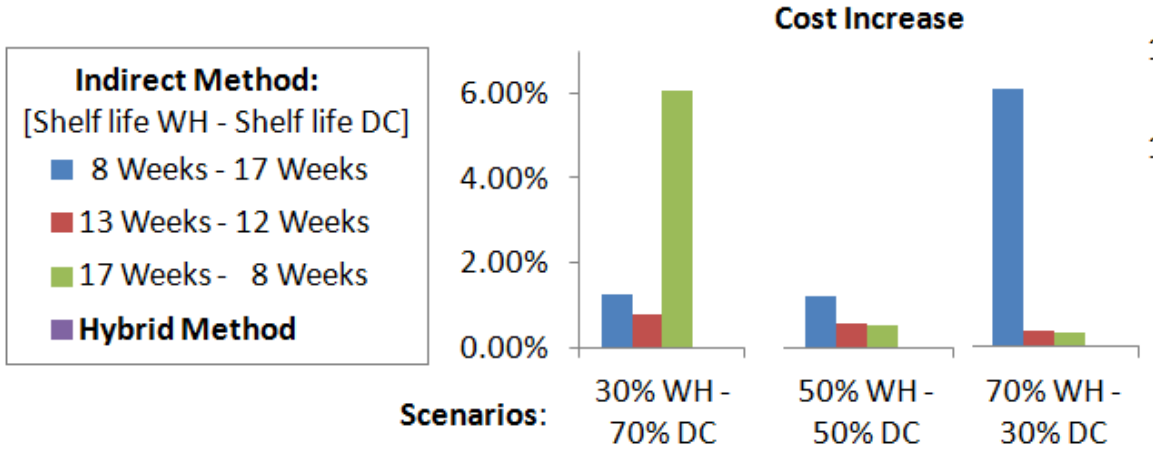
$1+2+4+3+5+7+6+8+10+9+11+13 \le A + B + C + D + E$

Example

- **Example**
  - **10 suppliers, 4 factories, 5 warehouses, 10 distribution centers and 20 retailers**
  - **52 weekly periods**
  - **25 Products with shelf life of 26 weeks**

Results

- Direct implementation leads to intractably large model
- Three different scenarios are used for the comparison
  - *Each scenario has a given storage capacity distribution*



  - Hybrid methods gives lower costs (approximately 1%)
  - Indirect method is more efficient (approximately 3 times)

Conclusions

- Three different methods of modeling the shelf-life restrictions have been tested
- The direct method leads to intractable models
- The indirect method is the most efficient but leads to a slight increase in costs
- The hybrid method can obtain global optimal solutions