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Optimizing the tactical planning in the Fast Moving Consumer Goods industry considering shelf-life restrictions

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ABSTRACT

This paper addresses the optimization of the tactical planning for the Fast Moving Consumer Goods industry using an MILP model. To prevent unnecessary waste and missed sales, shelf-life restrictions are introduced using three methods. The direct method tracks the age of products directly. While it provides optimal solutions, it is computationally inefficient. The indirect method forces products to leave inventory before the end of their shelf-life. It obtains solutions within a few percent of optimality. Moreover, compared to the direct method, the computational time was on average reduced by a factor 32. The hybrid method models the shelf-life directly in the first and indirectly in the second storage stage. It obtains near optimal solutions and, on average, reduces the required computational time by a factor 5 compared to the direct method. Cases containing up to 25, 100, and 1000 SKUs were optimized using the direct, hybrid and indirect method respectively.

1. Introduction

Due to the increasingly competitive global market, companies with a global supply chain have to continuously optimize their supply chain operations. Optimizing these operations could, for example, allow a company to reduce the inventory while maintaining high customer satisfaction levels (Papageorgiou, 2009). Grossmann (2005) and Varma, Reklaitis, Blau, & Pekny (2007) review the research on Enterprise-Wide Optimization (EWO), which focuses on optimizing the procurement, production and distribution operations.

In this paper, we consider these procurement, production and distribution operations over a one year horizon. Specifically, we optimize these decisions on the tactical planning level for a Fast Moving Consumer Goods (FMCG) company. Examples of FMCG are yoghurt, ice cream and shampoo.

FMCG are products that are replaced/used up within a relatively short period, which depending on the product ranges from days to a year. They are usually quickly substituted when not available, and they are generally produced in large quantities. Because of these large quantities, they are profitable despite typically low profit margins. Therefore, optimizing the tactical planning of a FMCG company is important to ensure that the products remain profitable, while ensuring that they are available in the right place at the right time.

For example, Kellogg greatly reduced its production, distribution, and inventory cost through the use of Linear Programming (LP) planning models (Brown, Keegan, Vigus, & Wood, 2001). For an extensive review on quantitative optimization methods for the food supply chain, we refer to Akkerman, Farahani, & Grunow (2010). These authors mention that the perishability of the products is an important challenge in the optimization of the operations in a food supply chain.

Considering perishability is important because product freshness is one of the primary concerns for consumers when buying food products. Consumers can judge the freshness of a product either by evaluating the sensory qualities of the product or by the Best-Before-Date (BBD) listed on the packaging. Since many products are fully packed, the consumer must often rely on calculating the remaining shelf-life based on this BBD (Entrup, 2005).

Shelf-life is defined by the Institute of Food Science and Technology (1993) as “the time during which the food product will remain safe, be certain to retain the sensory, chemical, physical and microbiological characteristics, and comply with any label declaration of nutritional data.”

Because product freshness is important for consumers, the retailers require that the products they receive have a certain minimum remaining shelf-life. Therefore, only part of the shelf-life can be used in the supply chain up to the retailers. For the remainder

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Nomenclature

Indices

a age of an SKU in weeks
dc distribution centers
f factories
fam SKU families
h ingredients
i SKUs
$mfam$ mixing families
$pfam$ packing families
r retailers
s suppliers
t, t' weeks
w warehouses

Subsets

FAM_{pfam} SKU families belonging to packing family *pfam*
IF_{fam} SKUs belonging to SKU family *fam*
IM_{mfam} SKUs belonging to mixing family *mfam*
IP_{pfam} SKUs belonging to packing family *pfam*

Variables

$Infeasibility_{i,dc,t}$ amount of SKU i in distribution center dc in week t that exceeds its shelf-life
$INVDC_{i,dc,t}$ amount of SKU i stored in distribution center dc in week t
$INVDC_{i,dc,t,a<SL}$ amount of SKU i stored in distribution center dc in week t with an age of t' weeks. Since the inventory is the inventory at the end of the week, the age of all SKUs must be less than their shelf-life. Otherwise they would need to be disposed of
$INVIng_{h,f,t}$ inventory of ingredient h at factory f in week t
$INVWH_{i,w,t}$ amount of SKU i stored in warehouse w in week t
$INVWH_{i,w,t,a<SL}$ amount of SKU i stored in warehouse w in week t with an age of t' weeks. Since the inventory is the inventory at the end of the week, the age of all SKUs must be less than their shelf-life. Otherwise they would need to be disposed of
$MissedSales_{i,r,t}$ shortage of SKU i at retailer r in week t
$Prod_{i,f,t}$ Amount of SKU i produced in factory f in week t
$SSVioDC_{i,dc,t}$ amount of SKU i short of the safety stock in distribution center dc in week t
$SSVioWH_{i,w,t}$ amount of SKU i short of the safety stock in warehouse w in week t
$TransDCR_{i,dc,r,t}$ amount of SKU i transported from distribution center dc to retailer r in week t
$TransDCR_{i,dc,r,t,a}$ amount of SKU i with age a transported from distribution center dc to retailer r in week t
$TransDCRC_{i,dc,r,t,a}$ amount of SKU i with age a transported from distribution center dc to retailer r in week t (This variable is only used in the correction model of the hybrid model)
$TransFW_{i,f,w,t}$ amount of SKU i transported from factory f to warehouse w in week t
$TransIng_{h,f,s,t}$ amount of ingredient h procured from supplier s to factory f in week t
$TransWDC_{i,w,dc,t}$ amount of SKU i transported from warehouse w to distribution center dc in week t
$TransWDC_{i,w,dc,t,a}$ amount of SKU i with age a transported from warehouse w to distribution center dc in week t
$WasteDC_{i,dc,t}$ amount of SKU i that is disposed of at the end of week t in distribution center dc
$WasteDC_{i,dc,t,a=SL_i}$ amount of SKU i that is disposed of at the end of week t in distribution center dc. This variable is only defined for SKUs that have reached the end of their shelf-life
$WasteDCC_{i,dc,t,a=SL_i}$ amount of SKU i that is disposed of at the end of week t in distribution center dc. This variable is only defined for SKUs that have reached the end of their shelf-life and is only used in the correction model of the hybrid model
$WasteWH_{i,w,t}$ amount of SKU i that is disposed of at the end of week t in warehouse w
$WasteWH_{i,w,t,a=SL_i}$ amount of SKU i that is disposed of at the end of week t in warehouse w. This variable is only defined for SKUs that have reached the end of their shelf-life
$WSU_{i,f,t}$ binary variable, indicates a set-up of SKU i in factory f in week t
$YFAMSU_{fam,f,t}$ 0–1 continuous variable, indicates if there is a set-up of SKU family *fam* in factory f in week t

Parameters

$CostIng_{h,s,t}$ unit cost of ingredient h at supplier s in week t
$D_{i,r,t}$ demand of SKU i at retailer r in week t
$DCCap_{dc}$ available storage capacity in distribution center dc
$DCSL_i$ part of the shelf-life of SKU i that is dedicated to the distribution centers
$FAMSUCost_{fam}$ average set up cost for SKU family *fam*
$FAMSUT_{fam}$ average set up time for SKU family *fam*
$INVDCini_{i,dc,a}$ the initial inventory of SKU i in distribution center dc that has been in storage for a weeks
$INVIngCAP_f$ available storage capacity for ingredients at factory f
$INVWHini_{i,w,a}$ the initial inventory of SKU i in warehouse w that has been in storage for a weeks
$MaxSupply_{h,s,t}$ available supply of ingredient h at supplier s in week t
$MixTime_{mfam,f}$ available mixing time at factory f for SKUs that are part of mixing family *mfam*
$MixRate_{i,f}$ mixing rate of SKU i in factory f
$MSpen_{i,r,t}$ penalty costs per unit of missed sales of SKU i at retailer r in week t
$PackRate_{i,f}$ packing rate of SKU i in factory f
$PackTime_{pfam,f}$ available packing time at factory f for SKUs that are part of packing family *pfam*
$Recipe_{h,i}$ amount of ingredient h consumed per unit produced of SKU i
$SCIng_{h,f}$ storage costs of ingredient h at factory f
$SCDC_{i,dc}$ storage costs of SKU i at distribution center dc
$SCWH_{i,w}$ storage costs of SKU i at warehouse w
SL_i maximum shelf-life of SKU i
$SSDC_{i,dc,t}$ minimum safety stock of SKU i in distribution center dc in week t
$SSWH_{i,w,t}$ minimum safety stock of SKU i in warehouse w in week t
$SSpenCost$ safety stock violation penalty cost
$SUCost_i$ average set-up cost for SKU i
SUT_i average set-up time for SKU i
$TCDCR_{dc,r}$ transportation cost between distribution center dc and retailer r
$TCFW_{f,w}$ transportation cost between factory f and warehouse w
$TCSF_{f,s}$ transportation cost between supplier s and factory f