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A Simulation based Optimization Framework for Inventory Management: A Case Study on PepsiCo Soft Drinks

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Introduction

PepsiCo was founded in 1965 by merged companies Pepsi-Cola and Frito Lay. In 1998, the company bought Tropicana, the world's largest fresh fruit juice production and marketing company, and in 2001 merged with Gatorade, known as a sports drink, and Quaker, which produces various rice cookies, fruit and oatmeal bars.

PepsiCo operates on various sales channels such as traditional channels as grocery stores and small markets, organized channels as supermarket chains and, on-site consumption, food services which also can be identified as out-of-home consumption such as fast-food chains, restaurants that include Pepsi products. Including its current operation points, PepsiCo always tries to improve its sales services and increase the accessibility of Pepsi products.

Figure 1. PepsiCO Brands

Sales System of PepsiCO

The current situation for the sales operation The On-Site Consumption channel in the PepsiCo includes warehouse operations, sales team management, and customer relations that managed through salesperson's visits.

PepsiCo Ankara sales operation teams provide sales services for the selected customer's 49 branches in Ankara.

REGION: ANKARA

49 RESTAURANTS

8 PRODUCT TYPES

5 SALESPERSON

The order is put through the system and orders shipment documents recorded and sales representative that responsible at a branch visit the branch for once every week time to conclude the sale processes for that time until the next visit and also check for any other necessary inventory replacement at the current situation that the branch has.

For the on-site consumption channels, the orders come from each customer and a salesperson regularly visits every customer, and every branch once a week. In case of an unexpected decrease in the stock, each customer contacts the salesperson and gets new products. The stock is controlled by the customers and PepsiCo only delivers the products and connects the sales team with the customers.

Figure 2. Map View of Branches

Problem Definition

The portrait situation on the foodservice sale system that sales representative has assigned branches and it requires that representative visits the branches once every week regularly to take orders and replacement of orders also provided as once every week schedule. Although the general replacement numbers depend on forecasted numbers and visits are scheduled, branches have freedom to reach out assigned sales representatives to take orders and new inventory replacement amounts according to the situations.

The irregularities on the demand can depend on several circumstances that customers face since the food sector depends on human consumption which includes trends or well put out seasonal changes, and the structural conditions that the branches have such as located area and inventory area. Even though the scheduled inventory renewal is once a week, the case is significantly irregular, hence causing the sales team's work inconvenience and performance issues on demand satisfaction.

The objective of the project is to find standard shipment frequencies and batch sizes for the restaurant branches with out of stock problems.

Methodology

In the first part of the methodology, a simulation model is prepared to simulate the current stock levels of the branches. Each branch simulated separately with the beverage sales data collected from the restaurant and Pepsi warehouse exit data. After these simulations, the branches that have out of stock problems are selected, and in the second part of the methodology, order shipment frequencies and the batch sizes per order is determined with an optimization model. This optimization model was repeated for the determined scenarios and the scenario with the best output is selected to again run in the simulation model. The outputs of the simulation model were compared with outputs of the current situation model outputs to evaluate changes.

Simulation Model:

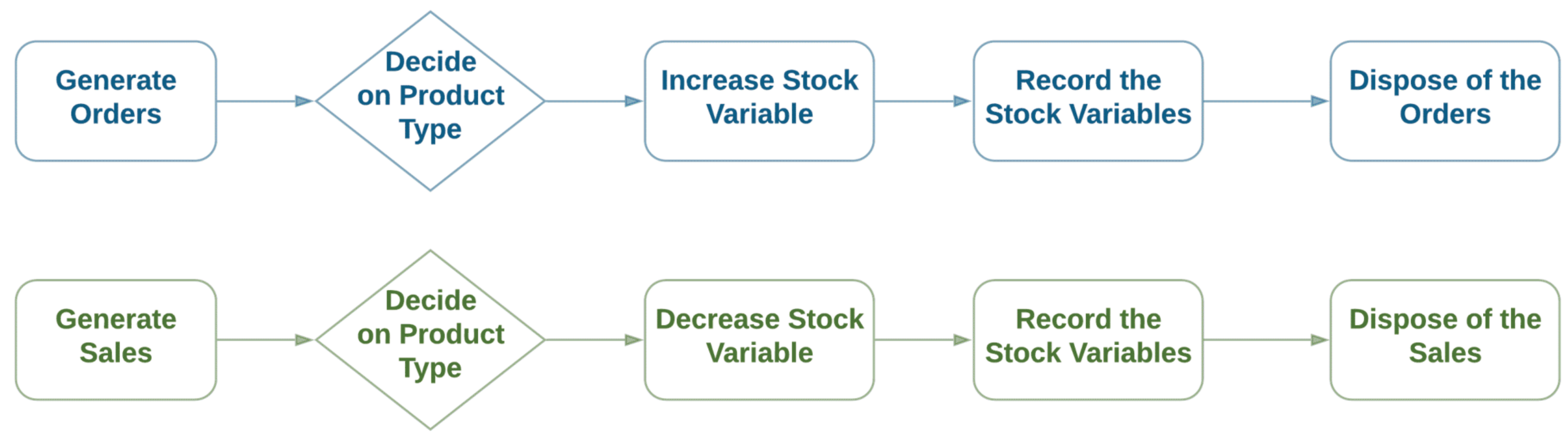

Figure 3. General View of System Simulation

The simulation model is prepared using Arena Simulation and it is divided into two parts: Sales and Orders. The model keeps track of stock variables for each product type and determines the amount of sale and order according to time with prepared schedules that considers seasonality for demand. The first part of the simulation model is Orders that starts with a create module to generate Order entities according to scheduled distributions. Then the decide module divides the orders created to product types and assigns corresponding stock variables to increase with every product type that passes through the assign module. After the stock variable is updated it is recorded and the entities created are disposed of. The Sales part is constructed in a similar matter which generates Sales entities and decreases the stock variables. The model ran for 12 hours per day and for a year with 30 iterations and the output is collected for every branch. After simulations 11 branches had out of stock problems and were selected for optimization.

Optimization Model:

Sets:

k = seasons
t = products

Data:

S_{kt} = weekly sale in product t on season k
N = max stock capacity
P = penalty for out - of - stock
L = distance for visit the branch
SC = storage cost of one product
B = cost of the gasoline
K = profit from one-unit product (PepsiCO)

Decision Variables:

X_{kt} = batch size of product t on in season k
Y_k = shipment frequency on season k
W_{kt} = over stock for product t on season k
O_{kt} = out of stock amount for product t on season k

Formulation (Model 1):

Objective Function:

$$X = \min x = \Sigma_{k,t}((O_{kt} * P + W_{kt} * SC) * C_1 + ((Y_k * L * B) - X_{kt} * K) * C_2)$$

The objective function consists of two objectives: reduce the out of stock and over stock costs in the branches while considering the cost of visit for each shipment and the profit Pepsi makes by selling beverages.

Constraints:

(1)	$X_{kt} * Y_k - W_{kt} + O_{kt}$	$=$	S_{kt}		for all k,t
(2)	$W_{kt} * O_{kt}$	$=$	0		for all k,t
(3)	$\Sigma_t(X_{kt} + W_{kt})$	$\leq$	N		for all k
(4)	X_{kt}	$\geq$	42		for all k,t
(5)	$2 \geq Y_k$	$\geq$	1		for all k
(6)	$W_{kt}, O_{kt}, X_{kt}, Y_k$	$\geq$	$0,$	integer	for all k,t

Constraint 1 is used to assign out of stock variable O_{kt} and over stock variable W_{kt} according to weekly sales and orders.
Constraint 2 is used to define the relation between O_{kt} and W_{kt} that is if out of stock happens than for that week there should be no product left in the stock.
Constraint 3 is used to ensure that the products sent with each delivery does not exceed the capacity of the branch. For this the capacity is taken as the capacity of Pepsi coolers.
Constraint 4 gives a lover bound to the size of each shipment which was taken from Pepsi.
Constraint 5 also defines the bounds of the variable that is the number of visits for a week should be at least one and the upper bound is given as 2 times a week.
Constraint 6 is the non-negativity constraint and the variables used in this model will be integers, that makes the model a Mixed Integer Nonlinear model.

The first model is used to try out the scenarios and collect the results of possible meanwhile a model that decides on the capacity and the upper bound for shipment frequencies considering the cost of adding another cooler or making another visit to the branch is prepared. In this second model possible capacities and cooler cost is given as parameters and two additional variables are defined to decide on the possible capacities. Two constraints that controls the maximum shipment frequency and capacity are now replaced with the equations given below.

Data Added:

$N1$ = max stock capacity of one cooler
$N2$ = max stock capacity of two cooler
M = large number
CC = cost of adding a cooler (doubles if 2 coolers added)

Decision Variables Added:

A = 1 if N1 is chosen, 0 if N2 is chosen as capacity for
B = 1 if 2 is chosen, 0 if 3 is chosen as capacity for

Formulation (Model 2):

New Objective Function:

$$X = \min x = \Sigma_{k,t}((O_{kt} * P + W_{kt} * SC) * C_1 + ((Y_k * L * B) - X_{kt} * K) * C_2) + (1 - A) * CC) * C_2$$

Constraints Added:

(3.1)	$\Sigma_t (X_{kt} + W_{kt})$	$\leq$	$N1 + M * (1 - A)$		for all k
(3.2)	$\Sigma_t (X_{kt} + W_{kt})$	$\leq$	$N2 + M * A$		for all k
(5.1)	$2 + M * (1-B) \geq Y_k$	$\geq$	1		for all k
(5.2)	$3 + M * B \geq Y_k$	$\geq$	1		for all k
(7)	A, B		binary		

The binary variables A and B is used to decide which value will be used as capacity (3.1 & 3.2) or shipment bound (5.1 & 5.2) and it ensures that the two constraints are not active at the same time. For example, if the capacity is chosen as N1 the constraint that sets the capacity to N2 becomes redundant.

Optimization Scenarios:

Table 1. Optimization Scenarios

	Scenarios	Stock Capacity (N)	Max Visit Frequency
Model 1	1	370	2
	2	370	3
	3	787	2
	4	787	3
Model 2	5	Decides on the Values	

The scenarios are formed by changing two parameters. The first parameter is the maximum capacity of the branch which can be a cooler with one door or two doors.

Another scenario is to suggest to Pepsi to visit the most selling branches 3 times a week. The fifth and the last scenario was to see what the model would recommend between these four given situations. After obtaining the optimization results for the selected branches the best scenario was selected according to their objective function values and simulation was completed again to show the difference on the stock levels after optimization.

Results & Suggestions

After the simulations the scenarios were seem to improve the situation so recommended changes were suggested. An example for recommended batch sizes of Bahçelievler and the changes recommended for the shipment frequencies and order capacities are given in tables below.

Table 2. Suggested Batch Sizes for Bahçelievler

Bahçelievler								
S1 Nov/Dec/Jan	ITMango	ITPeach	ITLemon	ITWat	TMix	TPeach	TApricot	TCherry
pack 1 - 24	1	10	4	0	0	0	0	1
pack 2 - 12	0	1	0	0	1	1	0	0
pack 3 - 6	0	0	0	0	1	1	0	1
S2 Feb/Mar/Apr	ITMango	ITPeach	ITLemon	ITWat	TMix	TPeach	TApricot	TCherry
pack 1 - 24	0	7	2	0	0	0	0	0
pack 2 - 12	1	0	1	0	1	1	0	1
pack 3 - 6	1	0	1	0	0	0	0	1
S3 May/Sep/Oct	ITMango	ITPeach	ITLemon	ITWat	TMix	TPeach	TApricot	TCherry
pack 1 - 24	1	16	6	0	1	1	0	2
pack 2 - 12	1	0	1	0	0	0	0	0
pack 3 - 6	1	0	0	0	1	1	1	0
S4 June/July/Aug	ITMango	ITPeach	ITLemon	ITWat	TMix	TPeach	TApricot	TCherry
pack 1 - 24	1	13	5	0	1	1	0	1
pack 2 - 12	1	0	0	0	0	0	0	1
pack 3 - 6	0	1	1	0	0	0	1	tab

Table 3. Suggested Changes for Selected Branches

Branch:	Visit # season 1 Nov/Dec/Jan	Visit # season 2 Feb/Mar/Apr	Visit # season 3 May/Sep/Oct	Visit # season 4 June/July/Aug	Capacity
Bahçelievler	1	1	1	2	787
Balgat	1	1	1	2	370
Cebeci	1	1	1	2	370
Demetevler	1	1	1	2	370
Etlik	1	1	1	2	370
İvedik	1	1	1	1	787
Kızlarpınarı	1	1	1	2	370
Meşrutiyet	1	1	1	1	787
Ostim	1	1	1	2	370
Sakarya	1	1	2	3	370
Şaşmaz	1	1	1	2	370

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