An Optimization Approach for Assortment Planning

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Abstract

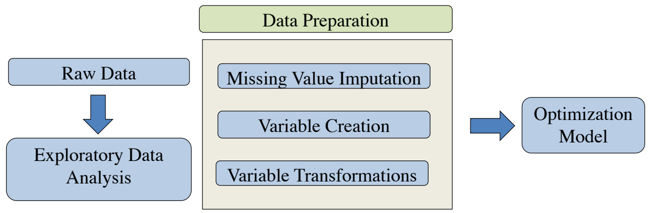
In this report, we are dealing with quintessential questions of supply chain management "What to stock?". Inventory management is the core of the supply chain that is associated with a significant percentage of cost. There is a trade-off between inventory cost and customer satisfaction as high inventory level will increase cost but will also increase service level (customer service level), and vice versa. Hence, firms aim to obtain a balance between the two so that they can maximize service level with minimum cost. This brings the idea of the assortment of inventories i.e. what combinations and quantities of SKU to be stocked so that customers can find the desirable SKUs. We have built an optimization model that maximizes profit as our objective function for the different assortment of SKU's for various stores with total space, total cost, and quantity of eligible SKUs in the assortment as decision variables. The model is built using Gurobi R.

Introduction

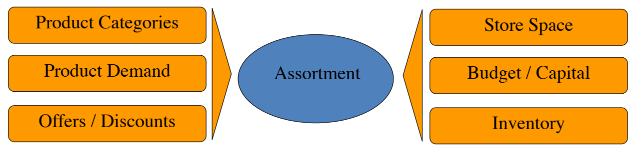
Assortment Planning: The retail sector is obsessed with targeting a multitude of issues such as customer targeting, segmentation, peer competition, pricing, location selection, and multichannel/Omni-channel strategies, etc. It is witnessed, however, that minimum importance has been given to one of the most significant strategies - assortment of SKUs. Proper assortment of SKUs based on customer requirements addresses significant underlying issues involved in supply chain such as proper product mix as desired by customers, variety of product mix, minimized lost sales, minimized excess inventory, the top line effects (increase in sales/profit margin/market shares), the bottom line effects (reduction in inventory costs, increase in productivity). A similar opportunity of optimizing various business objective functions like space, cost, and inventory arose with a firms focused on spares. We developed mathematical models to support and augment the efficiency of legacy heuristics that were followed retail locations selling spares.

Methodology

The data is provided by a national retail that sells spares and accessories in the United States. The data consists of 14,625 SKUs and 16 stores. The SKUs have different size and cost. Each store is divided into 4 MPOGs (planograms), and each MPOG has its own constraints of space and budget. Metrics like bundling, supersessions, exclusion, space, budget serve as constraints to define the criteria for SKUs to be in the assortment. Few additional variables were also considered to improve the accuracy of our model.



Model Building The objective of our optimization model is to maximize the profit. We have chosen multiple constraints like shelf space, MPOG size, total store budget, budget per MPOG, and minimum quantity required if a SKU is stocked. Our decision variables are price per SKU, space per SKU, and whether the SKU should be stocked or not (binary model). With this, we first created a prototype in excel on a small sample dataset, and later replicated the model to include all stores using the R.



Decision model

The optimization model was developed in excel solver first, and run for small number of SKUs (~100). It produced excellent results. As solver has a limit of ~200 for number of decision variables, our next step was to import the optimization model in Gurobi, and run it using R. Firstly, the file was imported in R. All the missing values were imputed. In gurobi, model$A is the linear constraint matrix, so subset was then converted into a matrix, and then transposed. Gurobi library was then imported in R, and all the constraints and values were specified in the model in the form of a vector or a matrix. In model$A component, all constraints were added in the form of a matrix. In model$obj component, objective function which is profit (price-cost) or profit per shelf space is added in the form of a vector. Model$vtype tells model that the variable type vector should be binary, integer or semi-integer.

Objective function

$$\text{Max profit} = \sum_{n=1}^{14625} (P_i - Ci) * xi * yi$$

P = Retail price
C = Cost
y = Minimum qty.
S= SKU space
B = SKU budget

Decision variables

x_i = 1, if SKU is included

x_i = 0, if SKU is not included

Constraints

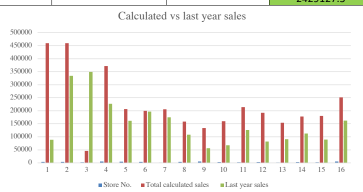
Store	$\sum_{n=1}^{14625} (S_i) * xi * yi$	=<	Space
Store Space	$\sum_{n=1}^{14625} (B_i) * xi * yi$	=<	Budget
Binary	x_i	=	0, 1
Non-negative	x_i	>=	0

Results

Decision model 1 – Maximizing profit- The total profit obtained for all 16 stores is mentioned in the table with maximizing profit as objective function. The total sales were also calculated for all stores.

Decision model 2 – Maximizing profit per shelf space- The total profit per shelf space obtained for stores was also calculated. The total calculated sales is mentioned in the table below.

	Objective Function - Profit	Objective Function -Profit per shelf space	Objective Function - Profit		
Store No.	Total calculated sales	Total Sales	Profit	Last year sales	Difference in sales
3571	459757.9	196241.2	154333.2	88995.4	370762.5
3813	459758.3	430972.1	307658.8	333954.6	125803.7
2584	46332.4	435525.4	311632.8	349484.6	-303152.2
5720	371622.1	347310.9	255522.7	226791.7	144830.4
5012	206758.6	193552.5	157260.0	161372.6	45386.0
4135	199636.6	187448.9	155337.9	197077.8	2558.8
1009	206037.5	192786.2	155638.3	175270.5	30767.0
3686	158253.9	147718.3	124454.7	108093.0	50160.9
5177	134092.2	124833.8	107993.7	56402.1	77690.2
3439	160226.7	149622.5	125327.3	67544.7	92682.0
2571	214275.4	200355.4	158976.5	126500.7	87774.7
3213	192427.8	179815.4	143330.9	82247.3	110180.5
1872	154198.7	143772.6	121499.6	90717.5	63481.2
3123	178158.5	166563.2	137259.7	112886.1	65272.4
2767	180087.8	168031.1	138988.3	89509.9	90577.9
5102	252078.0	236337.2	183079.3	162278.9	89799.1
				2429127.5	1054775.9



Conclusions

We have described the optimization model which has been built using various constraints, and representing the various assortment challenges for the retail store. The objective function of the model is to maximize the profit as well as maximizing profit per shelf space. Various constraints are used like shelf space, MPOG, total store budget, budget per MPOG, and minimum quantity required if a SKU is stocked. The model is first run on excel solver on a small scale, about 100 SKUs, and then imported to R, and run using powerful Gurobi package. With this model, we have successfully obtained our objective function profit for all the stores with all MPOGs. We have obtained binary results for about more than 14000 SKUs, and determined which SKUs to stock based on various constraints like cost, space, minimum quantity.

Acknowledgements

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