Application of Linear Programming for Optimizing mix type crackers packaging in Munchy Food Industries Sdn Bhd

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01. Introduction

Munchy Food Industries Sdn Bhd was started in 1991. It began in a small town of south Malaysia, and located at Batu Pahat for the first industry of Munchy's. The motivation for the invention of Munchy is due to a sibling, which are SK Tan and LK Tan. They successfully set up Munchy Food Industries that was their dream since they were small. The main products that Munchy's Industry manufactures are crackers and cookies. (Wikimedia Foundation, 2020)

The vision of Munchy is to be in the leading position in every country that they compete in. (*Munchy's Group, 2020*). Besides that, the mission of Munchy's Food Industries Sdn Bhd is to provide fun, cheeky, reasonable price and yummylicious biscuits and snacks for everybody around the world.(*Munchy's Group, 2020*). The Munchy's logo is in red, it is to reflect the company core values which are, 'Bold', 'Adventurous', 'Energetic', 'Playful', 'Ready to Go' and always immediately spring into action whenever there is an opportunity.

SK Tan and LK Tan do like to share Munchy's happiness with the world too. So, they decided to make an expansion for this company. The first destination of foreign expansion has been South Africa. Afterwards, they established a relationship and partnership with MNC which has a high reputation on producing chocolate. So, they will have the opportunities and be able to extend their scope of Munchy products by including chocolate wafers. (*Munchy's Group, 2020*)

In 1993, this was the year that Munchy's brand started to obtain popularity among biscuit lovers. During the crackers booming era, Munchy's reputation did help many people to satisfy their hunger and the market demand. The Munchy's was evolving from an Original Equipment Manufacturer to a household name around the world. After three years, in 1996, a Munchy's factory was built in Johor, Malaysia, with 120,000 sq ft (11,000 m2) of real estate and fully automated wafer technology. By having this factory, three new brands of products were launched which are Munchini, Lexus Biscuits and Muzic Wafers.

In 1997, Munchworld Marketing Sdn Bhd was set up as the Munchy's marketing arm and sole worldwide distributor. This entity was set up to spearhead Munchy's branding, advertising, promotions, marketing, distribution and events. (Wikimedia Foundation, 2020)

Nowadays, Muncyh's has gained a lot of awards from the world for example in 2006, the Munchy's was recorded in Malaysia Book of Records as 'Largest Wafer Manufacturer in 2005'. Munchy's won the Biscuits or cookies category in gold from the Reader's Digest Trusted Brand started from 2014 until 2017. In 2017, Munchy's got an award which is Giant Family's Choice Award and The BrandLaureate World Halal BestBrands Awards in 2018. The World Branding Awards is the award that sees the best brands from the 318 brands in 41 countries to recognise their work and achievements and the Munchy's get this award in 2019 and 2020. (*Munchy's Group, 2020*).

Moreover, Munchy's products are available in over 60 countries such as Bangladesh, Hong Kong, South Korean, Taiwan, Singapore, United Kingdom, Malaysia and many more. (Wikimedia Foundation, 2020). Therefore, the Munchy's crackers are easy to find in most of the retail outlets and supermarkets. Obviously, it has become one of the most favourite crackers and cookies brands among us.

The major brands for Munchy's are Lexus, Oat Krunch, Muzic, Choc-O, Munchy's Crackers and Captain Munch. These brands of crackers do provide a great deal for Munchy's such as Lexus Chocolate Cream Sandwich Calcium Cracker, Choc Sandwich Cracker, Oat Krunch Dark Chocolate, Muzic Bites Chocolate Wafer and Munchy's Cream Crackers. (*Munchy's Group, 2020*). This is because all of the biscuits sachets come in simple, convenient and easy to be open. (Finno Lux, 2019). Apart from this, Munchy's plans to provide the assorted biscuits, which contain the various types of small package biscuits inside a big package.

The purpose of this plan is to let everyone have a different flavour of Munchy's cracker at any time, anywhere and any place. However, each type of different crackers in Munchy's are different in cost, weight and size. Munchy's wishes the mix package will have a fair and reasonable price for the customer and earn an optimal profit from this product.

In this case study, linear programming will be applied for optimizing mix type crackers packaging in Munchy Food Industries Sdn Bhd.

02. Problem Statement

Due to the tiredness and weary of the taste of customers by having 10-20 sachets of the same flavour biscuit in a package. By uphold the basic spirit of concern about all the customers, Munchy plans to launch a new mix type crackers package product and named it as TopMix Supreme. TopMix Supreme will assorted with different sachets of biscuit to ensure that customers are able to taste different types of crackers in a package. To sell TopMix Supreme at a reasonable price and obtain the highest profit, Munchy cannot make decisions wisely on assorting the quantity of different sachets of crackers in the new package. This may cause the available resources not utilised in a proper way and the profit will not be optimized.

03. Objective

- To maximize the profit by assorting the quantity of every sachet of crackers appropriately in the TopMix Supreme package.
- To utilize all the available ideal volume and mass of the TopMix Supreme package.
- To fulfill the policy from the management team for assorting the quantity of crackers.

To achieve all the objectives, Linear Programming may be one of the suitable and appropriate methods to be applied. Linear Programming is one of the mathematical programming that can optimize problems where the objective functions and constraints in a linear mathematical relationship. Thus, this method will be able to find out the ideal quantity of different sachets of crackers to assort in the TopMix Supreme, at the same time fulfill all the constraints or policy that will affect the quantity of distribution too.

By applying Linear Programming into this production, it allows Munchy to have an overview for their financial situation so that Munchy will be able to take necessary steps and make a strategic plan to manage their business and this product. On the other hand, this method did provide a forecast about the profit of this production for Munchy too.

04. Methodology

The data for this research project was collected from Munchy's Food Industries. The data consists of the ideal volume, weight of TopMix Supreme Package and the total amount of sachet of crackers in it. The crackers that are considered to be assorted in TopMix Supreme are Lexus Chocolate Cream Sandwich Calcium Cracker, Lexus Chocolate Coated Cream Biscuit, Choc Sandwich Cracker, Butter Sandwich Cracker and Wheat Cracker. Besides that, the data below consist of the volume, weight and profit of every type of cracker per sachet too. Munchy Company wishes that at least one sachet of every type of cracker will be assorted in the TopMix Supreme but not repeat more than 4sachets. Moreover, the total crackers must not exceed more than 18sachets.

Assumptions

- It is assumed that the ideal volume and mass of TopMix Supreme obtained from the previous research is optimal which had considered the problems of size, cost and bearing weight of shelf rack and transportation for delivery.

- It is assumed that at least one of every type of cracker considered will be assorted in TopMix Supreme and not repeat more than 4sachets.

- It is assumed that the volume and mass of every different sachet of cracker (Lexus Chocolate Cream Sandwich Calcium Cracker, Lexus Chocolate Coated Cream Biscuit, Choc Sandwich Cracker, Butter Sandwich Cracker and Wheat Cracker) was aid optimal production, at the same time maximise the profits for Munchy Food Industries.

05. Dataset

- **Volume**

Ideal volume of TopMix Supreme Package available = $2565cm^3$

A sachet of Lexus Chocolate Cream Sandwich Calcium Cracker = $130\,cm^3$

A sachet of Lexus Chocolate Coated Cream Biscuit = $78cm^3$

A sachet of Choc Sandwich Cracker = $195cm^3$

A sachet of Butter Sandwich Cracker = $195cm^3$

A sachet of Wheat Cracker = $171.6cm^3$

- **Mass**

Ideal mass of TopMix Supreme Package available = 500g

A sachet of Lexus Chocolate Cream Sandwich Calcium Cracker = 19g

A sachet of Lexus Chocolate Coated Cream Biscuit = 20g

A sachet of Choc Sandwich Cracker = 43g

A sachet of Butter Sandwich Cracker = 45g

A sachet of Wheat Cracker = 23g

- **Number of sachets in a package**

Total number of sachets in TopMix Supreme $\leq$ 18sachets

Every type of crackers cannot repeat more than 4sachets

At least one sachet of every type of cracker assorted in TopMix Supreme.

- **Profit of Product**

Products	Average Cost Per Sachet (RM)	Average Price Per Sachet (RM)	Profit (RM)
Lexus Chocolate Cream Sandwich Calcium Cracker	0.26	0.48	0.22
Lexus Chocolate Coated Cream Biscuit	0.27	0.43	0.16
Choc Sandwich Cracker	0.37	0.60	0.23
Butter Sandwich Cracker	0.35	0.60	0.25
Wheat Cracker	0.14	0.30	0.16

06. <u>Model Formulation</u>

Let x_1 = the quantity of Lexus Chocolate Cream Sandwich Calcium Cracker

Let x_2 = the quantity of Lexus Chocolate Coated Cream Biscuit

Let x_3 = the quantity of Lexus Choc Sandwich Cracker

Let x_4 = the quantity of Butter Sandwich Cracker

Let x_5 = the quantity of Wheat Cracker

Let Z = Total profit of TopMix Supreme

Max , $Z = 0.22x_1 + 0.16x_2 + 0.23x_3 + 0.25x_4 + 0.16x_5$

Subject to

$130x_1 + 78x_2 + 195x_3 + 195x_4 + 171.6x_5 \leq 2565$

$19x_1 + 20x_2 + 43x_3 + 45x_4 + 23x_5 \leq 500$

$x_1 + x_2 + x_3 + x_4 + x_5 \leq 18$

$x_1, x_2, x_3, x_4, x_5 \geq 1$

$x_1, x_2, x_3, x_4, x_5 \leq 4$

The result will be obtained by using Excel Solver.

	A	B	C	D	E	F	G	H	I
1		x1	x2	x3	x4	x5			
2	**Number to make**	4	4	2.1506	4	3.10975			
3									
4	**Constraint**	**x1**	**x2**	**x3**	**x4**	**x5**	**Used**	**Sign**	**Available**
5	**Volume**	130	78	195	195	171.6	2565	<=	2565
6	**Mass**	19	20	43	45	23	500	<=	500
7	**Sachet**	1	1	1	1	1	17.26034971	<=	18
8	**maximum x1**	1	0	0	0	0	4	<=	4
9	**maximum x2**	0	1	0	0	0	4	<=	4
10	**maximum x3**	0	0	1	0	0	2.15059783	<=	4
11	**maximum x4**	0	0	0	1	0	4	<=	4
12	**maximum x5**	0	0	0	0	1	3.109751883	<=	4
13	**minimum x1**	1	0	0	0	0	4	>=	1
14	**minimum x2**	0	1	0	0	0	4	>=	1
15	**minimum x3**	0	0	1	0	0	2.15059783	>=	1
16	**minimum x4**	0	0	0	1	0	4	>=	1
17	**minimum x5**	0	0	0	0	1	3.109751883	>=	1
18									
19							**Total Profit**		
20	**Unit Profit**	0.22	0.16	0.23	0.25	0.16	3.512197802		

Figure 1 : Excel Solver Model and optimal result

07. Result, Discussion and Interpretation

- **Answer Report**

Objective Cell (Max)

Cell	Name	Original Value	Final Value
$G$20	Unit Profit Total Profit	0.000000000	3.512197802

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$B$2	Number to make x1	0	4	Contin
$C$2	Number to make x2	0	4	Contin
$D$2	Number to make x3	0.0000	2.1506	Contin
$E$2	Number to make x4	0	4	Contin
$F$2	Number to make x5	0	3.109751883	Contin

Figure 2 : Optimal Solution

From the Objective Cell(Max) table of this answer report, it shows the final maximum profit is RM3.52 (2d.p.). Besides that through Variable Cells table, we can observe that the maximum 4 sachets of Lexus Chocolate Cream Sandwich Calcium Cracker(x_1), Lexus Chocolate Coated Cream Biscuit(x_2) and Butter Sandwich Cracker(x_4) can all be assorted in TopMix Supreme, while only 2.15 sachets of Lexus Choc Sandwich Cracker(x_3) and 3.11 sachets of Wheat Cracker(x_5) can be assorted in the package.

From the result obtained, this mean that Munchy's have to produce those crackers in the ratio of 4: 4: 2.15: 4: 3.11 for $x_1 : x_2 : x_3 : x_4 : x_5$. So, it will provide a sufficient sachets of crackers for TopMix Supreme production. Moreover, Munchy will ensure the crackers stock level for TopMix Supreme will be stored in this ratio too to prevent the lackness of crackers or over store the unnecessary crackers.

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$G$13	minimum x1 Used	4	$G$13>=$I$13	Not Binding	3
$G$14	minimum x2 Used	4	$G$14>=$I$14	Not Binding	3
$G$15	minimum x3 Used	2.15059783	$G$15>=$I$15	Not Binding	1.15059783
$G$16	minimum x4 Used	4	$G$16>=$I$16	Not Binding	3
$G$17	minimum x5 Used	3.109751883	$G$17>=$I$17	Not Binding	2.109751883
$G$5	Volume Used	2565	$G$5<=$I$5	Binding	0
$G$6	Mass Used	500	$G$6<=$I$6	Binding	0
$G$7	Sachet Used	17.26034971	$G$7<=$I$7	Not Binding	0.739650287
$G$8	maximum x1 Used	4	$G$8<=$I$8	Binding	0
$G$9	maximum x2 Used	4	$G$9<=$I$9	Binding	0
$G$10	maximum x3 Used	2.15059783	$G$10<=$I$10	Not Binding	1.84940217
$G$11	maximum x4 Used	4	$G$11<=$I$11	Binding	0
$G$12	maximum x5 Used	3.109751883	$G$12<=$I$12	Not Binding	0.890248117

Figure 3 : Constraints table of answer report

As can be seen from figure 3, the status of constraints can be indicated into binding or not binding. Binding constraint has 0 slack variable and it is used to solve for the optimal point. For this case, volume, mass, maximum of x_1, x_2 and x_4 are binding constraints. The resources available are all fully utilized. While the total sachets allowed to assort for TopMix supreme are not utilized and the slack value is around 0.74. The allowed repeat sachets for x_3 and x_5 are not fully utilized too and the slack values are around 1.85 and 0.89 respectively.

- Sensitivity Report

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$B$2	Number to make x1	4	0	0.22	1E+30	0.094285714
$C$2	Number to make x2	4	0	0.16	1E+30	0.06
$D$2	Number to make x3	2.15059783	0	0.23	0.012771084	0.048181818
$E$2	Number to make x4	4	0	0.25	1E+30	0.014285714
$F$2	Number to make x5	3.109751883	0	0.16	0.0424	0.036976744

Figure 4 : Sensitivity for changing variables

From the report above, the reduced cost tends to be zero because all the final values for the changing variables are non-zero. The reduced cost only applies when the optimal value is zero. Reduced cost provides an estimate of how much the objective function will change if the variable is forced to assume some non-zero value.(Flylib.com, 2008). The allowable increase and decrease tell us how much the objective coefficients (unit profits) can be increased or decreased but not affecting the optimal solution for the changing variables.

Therefore, Munchy is able to determine whether they like to increase the unit profit of crackers according to the allowable increase to further increase the total profit of TopMix Supreme production while not affecting the amount of those crackers to be assorted.

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$G$13	minimum x1 Used	4	0	1	3	1E+30
$G$14	minimum x2 Used	4	0	1	3	1E+30
$G$15	minimum x3 Used	2.15059783	0	1	1.15059783	1E+30
$G$16	minimum x4 Used	4	0	1	3	1E+30
$G$17	minimum x5 Used	3.109751883	0	1	2.109751883	1E+30
$G$5	Volume Used	2565	0.000549451	2565	59.91162791	141.9813953
$G$6	Mass Used	500	0.002857143	500	31.18764569	13.21128205
$G$7	Sachet Used	17.26034971	0	18	1E+30	0.739650287
$G$8	maximum x1 Used	4	0.094285714	4	2.898699892	1.36668435
$G$9	maximum x2 Used	4	0.06	4	1.187923188	3
$G$10	maximum x3 Used	2.15059783	0	4	1E+30	1.84940217
$G$11	maximum x4 Used	4	0.014285714	4	1.028606735	1.653320976
$G$12	maximum x5 Used	3.109751883	0	4	1E+30	0.890248117

Figure 5 : Sensitivity for constraints

This table shows the final value of resources used in the third column. As can be observed that, shadow price is only available for the constraints of volume, mass, maximum of x_1, x_2 and x_4. This is because four of these constraints are in the binding status. Shadow price tells us how much the optimal solution can be increased or decreased if we change the RHS values by one unit.(Excel Easy, 2010). For example of the constraints of mass, if the available mass on RHS is increased by 1g, the total profit will be increased by RM0.0028 too.

For the column of allowable increase and decrease, it is referred for the RHS value. For a non binding constraint with the sign of $\geq$, if the RHS value increases according to the allowable increase value, the final value will not be affected. For a non binding constraint with the sign of $\leq$, if the RHS value decreases according to the allowable decrease value, the final will not be affected too.

Through this report, it allows Munchy to determine whether it is necessary to redesign the policy for TopMix Supreme production.

- Limit Report

Cell	Objective Name	Value
$G$20	Unit Profit Total Profit	3.512197802

Cell	Variable Name	Value	Lower Limit	Objective Result	Upper Limit	Objective Result
$B$2	Number to make x1	4	1	2.852197802	4	3.512197802
$C$2	Number to make x2	4	1	3.032197802	4	3.512197802
$D$2	Number to make x3	2.1506	1.0000	3.2476	2.1506	3.5122
$E$2	Number to make x4	4	1	2.762197802	4	3.512197802
$F$2	Number to make x5	3.109751883	1	3.174637501	3.109751883	3.512197802

Figure 6: Limits Report

From the figure 6 above, it shows the range of objective results between a changing variable on lower limit and upper limit while the other changing variables remain constant. For an example of Lexus Chocolate Cream Sandwich Calcium Cracker (x_1), when x_1 is equal to 1 which is on a lower limit, the objective result is RM 2.85(2d.p) but when it is on upper limit that is equal to 4, the objective result will increase to RM 3.51(2d.p). This means that the amount of cracker x_1 can be assorted in TopMix Supreme is in the range from 1 to 4 sachets and the profit will be from RM 2.85 to RM 3.51 respectively.

This report will indicate that the company production should take which product the most care while the other products take lesser care accordingly. It is to reduce and minimize the loss of profit whenever an unexpected bad circumstance happens. As can be see, on the lower limit of x_4, it has the lowest objective result compared to the other. This shows that Munchy has to take the most care on the production of cracker x_4. Thus, it will ensure the production of x_4 will be run smoothly and prevented making the highest loss compared to the other cracker whenever there is an unexpected problem on producing the cracker.

08. Limitation and Recommendation

Through this case study, we understand that Linear Programming consists of some limitation which caused us to face a problem while doing the analysis and interpreting the result. The limitation that we found and observed is Linear Programming cannot obtain an integer optimal solution for us. For this case, suppose we have to obtain an integer for the changing variable which are x_1, x_2, x_3, x_4 and x_5 but at the end this method provided us with a decimal solution which is not realistic to this circumstance. This is not the result that we expect to be obtained because crackers are produced in sachet or pack. So, it is impossible to assort a fraction or rational number of packs of crackers in the TopMix Supreme. In the end, it will also show us a wrong result for the objective function. This may cause Munchy to make a wrong decision for their business strategies and plans.

By having some research, we found that Integer Linear Programming may be the more suitable and appropriate method to be applied in this type of case. For Integer Linear Programming, there are three approaches that can be used, which are enumeration technique, cutting-plane technique and group-theoretic technique. (Bradley, Hax, and Magnanti. 1977). Undeniable, simplex method is the fastest way to solve linear problems but in this case three approaches of Integer Linear Programming should be applied instead of simplex method. The three stated techniques will give an integer for the optimal results which are realistic in this circumstance and the solution would be what we expect to be obtained too.

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10. Appendices

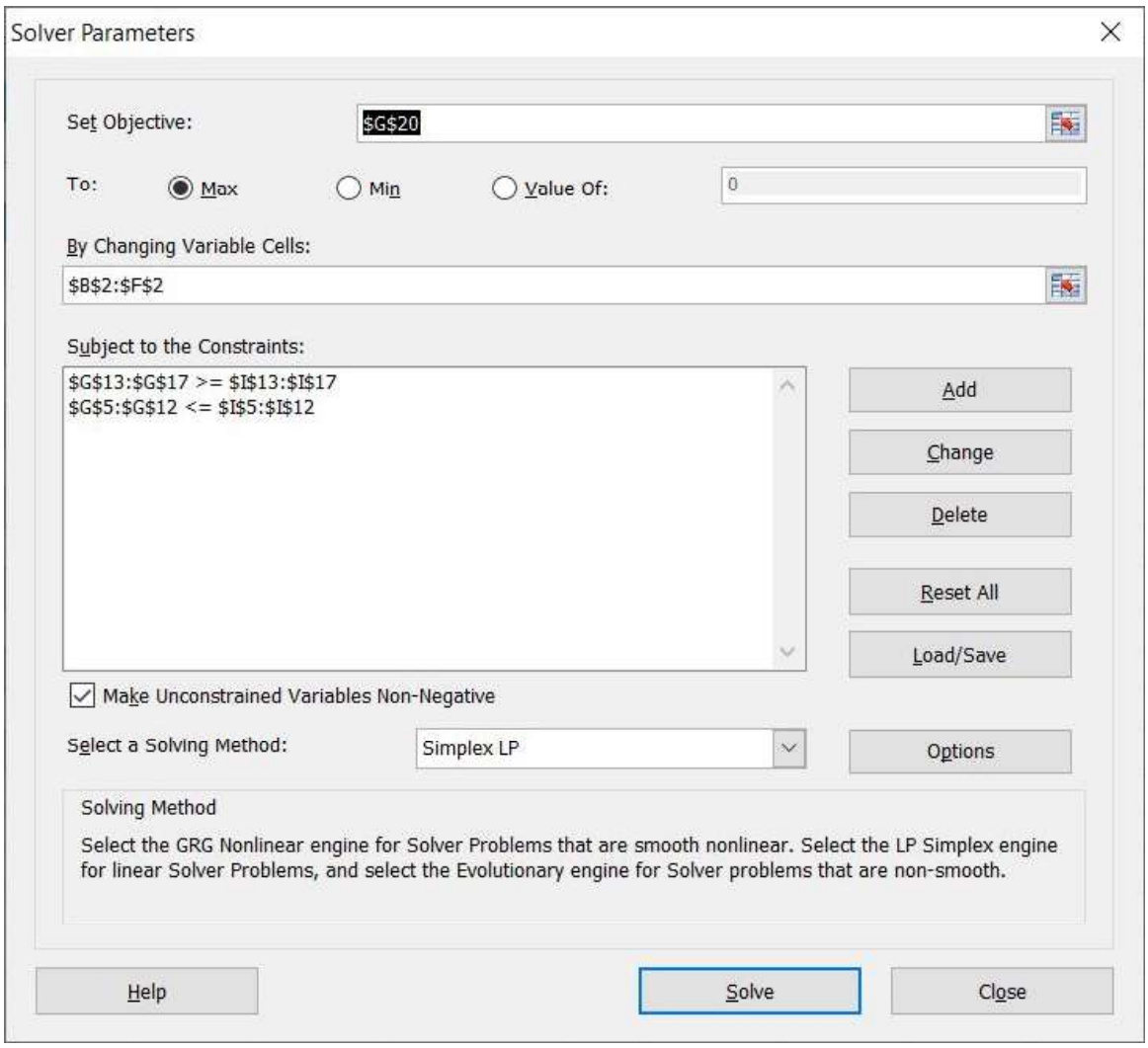

Figure 7 : Setting of formulas and cells for Excel Solver Parameters.