Hershey's Production & Organic Cocoa:

An Operational Analysis of Kisses & Hugs

by

Team 8: Alisha Barker, Jake Beder, Taylor Corbalis,
Elijah Raffo, Johnny Whitaker

Executive Summary

Group 8 has come together to optimize the amount of Hershey's Kisses and Hugs that we produce and sell for a profit given operational constraints. In order to do this, we looked at the production process and supply chain of Hershey's chocolate. We also looked into the machine hours of how long it takes to make Hershey's chocolate. In doing so, we saw that Hershey's gets a lot of its cacao beans from West Africa, and they get a multitude of other ingredients from South America, New Zealand, and North America. These ingredients are combined to create milk chocolate, which is 11% cocoa. With their current formula, they can make about 70 million kisses per day and it takes about 16 ½ machine hours for a batch to be made. We also found constraints that needed to be set, such as demand for the Hershey's Kisses and Hugs, machine hours (since Hershey's can only produce so much so quickly), labor hours, the amount of cocoa needed to meet demand levels, and the amount of milk needed to meet demand levels. We also took into account the amount of cocoa needed to be ordered to preserve the financial efficacy of foreign suppliers as well as the amount of milk that needed to be ordered to the financial efficacy of the milk suppliers. Finally, we considered Hershey's goal of using 100% organic cocoa.

After our research, our group set out to try and find how Hershey's could maximize the monthly profit that Hershey's receives from Kisses and Hugs with these given constraints. To do this, we created a linear program with three categories of variables: Xi, Yi, and Zi. These categories are further broken down into decision variables to help us get reliable results. We applied our constraints and ran the solver to generate an output. We saw that Hershey's would still make a profit even if they switched to 100% organic chocolate, but it would be a smaller profit than if they had not used organic cocoa (about $1.7 million less). That being said, this is not a large loss, and there are good implications that can come with using organic chocolate, since many people want to see their consumables being made organically. We recommend that the Hershey Company attempts to find multiple ways to save costs, such as in labor and machine hours, to try to absorb some of the cost that will come with our given constraints. The current solver can be changed if constraints change over time, so that it could still reflect current results. It can also be expanded to work with other items that Hershey's sells as well.

Scope

Our goal in this project was to maximize the monthly profit of the Hershey's Kiss department given the weekly operational constraints. First, we learned how the Hershey Company attains its cocoa and about Hershey's chocolate making process. We defined each part of the process involved in our linear program as variables to determine how the company incurs expenses as well as gains revenue. We also explained each constraint that is involved in operations, including cocoa, milk, machine hours, labor and demand. With keeping the constraints in mind, the group also wanted to be aware of the use of organic and nonorganic cocoa since Hershey's goal is to be sourcing 100% certified and sustainable cocoa by 2020.

Problem Description

The overall chocolate making process for Hershey's begins with receiving the cacao fruit from West Africa and letting them ferment for about a week and a half to become cacao beans. Those beans are then roasted to bring out the chocolate flavor and to loosen the shell from center of the bean. After being roasted the beans are then winnowed. Winnowing is the process of fully removing the shell and what small pieces of the bean that are left are the nibs that make the chocolate. Once the nibs are grounded down, milk and sugar are added to make chocolate crumb. Cocoa butter is added to make the crumb smooth. To fully incorporate the ground crumb and additional cocoa butter, the two are intensely mixed together during a process called conching. The mixture is then slowly heated while being stirred consistently to refine its taste and texture. After being tempered, the mixture is poured into vibrating molds to ensure that no air bubbles are captured in the chocolate and is sent through a cooling tunnel. Finally, the chocolate is packaged and distributed out.

The part of the project that our group was concerned about was how to maximize profit through the chocolate making process, while keeping in mind the costs of production and ingredients and reducing waste. The main challenge was finding accurate numbers for the cost of production. Most were an educated guess based off the research that had been done about the chocolate making process. The solver however was built so those numbers could change if more accurate costs were found. Another challenge that had to be addressed was deciding on what products to consider when working on the project. The group came to the conclusion of just focusing on

Kisses and Hugs. The difference between Kisses and Hugs is that Kisses are completely milk chocolate, while Hugs are a mixture of white and milk chocolate.

We considered the domestic production managers and distribution managers to be people that are directly involved and concerned about the chocolate making process. These managers would be the decision makers as to what hours the machines are operating and the amount of ingredients that go into each batch. As for the time horizon of this project, Hershey's is committed to sourcing 100% certified and sustainable cocoa by 2020. Keeping the solver in mind it's capable of manipulating many variables, including organic, so the project could technically go beyond 2020.

Objective Function and Decision Variables

The objective function is constructed to maximize profit, determined by summing the products of units produced and stored as well as the respective cost and revenue contributions to the Hershey Company. A list of the included decision variables can be found in Appendix A.

Defining Constraints

Demand

One constraint was the demand for Kisses accounted for the weekly demand in weeks 1-4 respectively. This varied by week to simulate realistic commercial variability of ordering for sales efficacy of vendors.

Similarly, the other constraint was the demand constraint for Hugs family packs in weeks 1-4 respectively. This varied by week to simulate realistic commercial variability of ordering for sales efficacy of vendors. Total demand for both products was taken from the calculation of estimated total production capacity then divided proportionally based on the number of products carried by Hershey's which feature the respective products resulting in 95% of demand attributed to Kisses and 5% to Hugs.

The overall demand for milk chocolate is the calculation of the amount of milk chocolate needed to meet the demands of factory production. This is constrained to equal zero to prevent waste.

Machine Hours

Machine Hours is the constraint for the availability of machine hours for processing and packaging both Hugs and Kisses. This is expressed as the aforementioned maximum weekly production capacity used for determining the maximum demand. Maximum demand is determined by calculating the amount of Kisses and Hugs per pound of milk chocolate using the reported statistic of 70 million Kisses produced per day and a calculation of the proportion of Hershey's products which our model accounts for. This allows us to determine that the portion of production we are examining is roughly 2.5% of the Hershey factory's total workload. Further correlations are shown by re-calculating using the reported statistic of the amount of milk brought into the production facility each day and the estimated proportional makeup of Hershey's milk chocolate (11% cocoa, 12% milk).

Machine hours reflect the total maximum capacity based on the supply of milk and cocoa. Hugs require 10% more machine hours to roughly simulate the extra resources required to create the white chocolate "Hug". Machine hours were expressed in units of production to simplify equating to production. It is important to remember the process the cacao bean goes through as it is made into milk chocolate. It will be roasted for 35 minutes to bring out the flavor. Next it will be winnowed to pick out the nibs and then crushed into a powder. The powder is mixed with other ingredients, such as milk and sugar, and it is conched. In our case, we are making milk chocolate, which take up to 16 hours to complete, so the total process takes about 16 ½ hours. Finally, the chocolate can be poured into molds and cooled. This does not take very long, though.

Labor

The constraint for labor reflects the capacity of production workers to intake raw cocoa in pounds. This was calculated using estimated statistics then converted into units of production to simplify equating to production.

Cocoa

Milk chocolate contains so much milk and sugar that its percentage of true cacao may be as low as 10 percent, the minimum required by the FDA for calling it "chocolate" on the label.

Hershey's milk chocolate contains about 11 percent cacao. In contrast, a serious dark chocolate bar will contain anywhere from 65 percent to 85 percent cacao.

One of constraints for cocoa was a calculation of the amount of cocoa needed to meet the demands of factory production. This was constrained to equal zero so that no cocoa was wasted. Another constraint for cocoa was the minimum and maximum order of cocoa necessary to preserve the financial efficacy of foreign suppliers in South America and Africa and to balance out the amount of milk brought into the production facility. This was calculated by multiplying the total amount of milk chocolate to be produced by cocoa’s proportional presence in the milk chocolate (11%).

Milk

Hershey’s milk chocolate is made from hundreds of thousands of gallons of fresh milk delivered daily from farms within 200 miles of the factory in Pennsylvania. Our goal was to order an amount of milk that would meet the demand for factory production. This was constrained to equal zero so that no milk was wasted in production. The other constraint for milk was the minimum and maximum order of milk required to produce enough to meet a tolerable level of product demand and to preserve the financial efficacy of the dairy farms from where the milk is locally sourced, which are very dependent on the Hershey Company’s business. The supply constraint was calculated using the reported statistic that between 300,000 and 350,000 gallons of milk are delivered to the factory for production each day, converted into pounds (one gallon of milk is approximately 8.6 pounds).

Goal and Value Proposition

Our goal is to maximize the profit that Hershey’s receives from Kisses and Hugs. The proposition to the company is that we can give Hershey’s a good opportunity to maximize their revenue and profit as they work to achieve 100% organic cocoa among other constraints. We will explain how our solver can achieve this in the next sections.

Linear Program Formulation

Our group decided on 11 decision variables grouped into three categories: Xi, Yi, Zi. The Xi category has two variables: Hugs and Kisses. Hugs and Kisses are products the market demands and are measured in total units produced. The Yi category has four variables: organic cocoa, non-organic cocoa, milk, and milk chocolate. These decision variables are supplies used to produce the product of Hugs and Kisses, and are measured in total pounds ordered. The Zi category is the carry over variable, and comprises of five groups: Kisses, Hugs, cocoa, milk, and milk chocolate. These variables each play a role in one week the product mix planning. Furthermore, each variable has 4 iterations because we created a multi-period production planning model.

We created our decision variables by analyzing the production process of milk chocolate. First, cocoa [organic and non-organic] and milk arrive to the facilities. These supplies are used to create milk chocolate. Any leftover milk or cocoa is stored for use in the next weeks production of milk chocolate production. Second, milk chocolate is produced for which is used to produce Hugs and Kisses. Any milk chocolate not used in production can carry over into the following week. The final step in the production process is for a machine to extrude and create the iconic Kisses and Hugs shape. Any Kisses or Hugs not delivered to a final consumer can be stored and delivered the next week.

Our linear program was designed for one goal to maximize the monthly profit of the Hershey's chocolate making process for Kisses and Hugs. Our maximization equation can be described by this formula:

$$= \sum_{\{Week\}\, i=1}^{4} S_{i,x}X_i + S_{i,y}Y_i + S_{i,z}Z_i$$

- Si = Revenue or Loss the of each variable
- Xi = Output of products for market (unit)
- Yi = Inbound material ordered (pound)
- Zi = Carry Over Supply (unit or pound)

Si for Xi would be positive because we receive revenue from sales of Kisses and Hugs. Si for Yi would be negative because we are buying supplies for production. Si for Zi would be negative because we incur a cost when storing goods for next week's production cycle.

Constraints and Conversions

Our first constraint is that the ratio between the weekly supplied organic cocoa and non-organic cocoa must be 80%. Mathematically for the week: Organic Cocoa = 0.80 * (Organic Cocoa + Non-Organic Cocoa).

Our second constraint is a minimum and maximum weekly supply of cocoa and milk to our department. We set a minimum and maximum constraint to our model to mimic minimum and maximum orders that are often defined by suppliers. We decided that the inbound supply of cocoa and milk happens once at each beginning of a week. One supply constraint is that the minimum order in pounds of milk and cocoa per week must be more than or equal to our supply constraint. Another constraint is that the maximum order in pounds of milk and cocoa per week must be less than or equal to our supply constraint. Mathematically for the week: Organic Cocoa + Non-Organic Cocoa <= Upper Supply Constraint or Organic Cocoa + Non-Organic Cocoa >= Lower Supply Constraint. This math formula was also used to derive the minimum and maximum weekly supply of milk.

Mathematically we derive the milk supply constraint as: (350,000 [Upper] or 300,000 [Lower]) * .025 * 8.6 * 7 = Milk Supply Constraint. As described above, {350K/300K} is the reported daily inbound gallons of milk to the Hershey's company. {0.025} is the estimated proportion of material that our department uses. {8.6} is the researched gallon to pound conversion factor, and our company is open {7} days a week. For cocoa we set the inbound supply proportional to the upper/lower supply constraint of milk. Specifically, we estimated the total possible milk chocolate that can be produced by the inbound milk and multiply that value by the proportion of cocoa that is in milk chocolate. Mathematically the cocoa supply constraint is: (([Upper] or [Lower] Milk Supply Constraint) / 0.12) *0.11 = ([Upper] or [Lower]) Cocoa Supply Constraint.

Another constraint in our model is the demand, or processing of, of milk and cocoa. Milk chocolate is made from cocoa and milk; therefore, milk and cocoa are demanded by milk chocolate. We also assume that we cannot make any more milk chocolate than is available from the materials we have. Whatever supplies of milk and cocoa are not demanded will be moved to the next week as carry over material. Mathematically the weekly demand constraint of cocoa and milk is: ((inbound supply of cocoa or milk) + (previous weeks carry over supply of cocoa or milk) – (current weeks carry over supply of cocoa or milk)) – (percent of milk chocolate * (current weeks milk chocolate production + current weeks carry over milk chocolate production)) = 0.

After we produce a bunch of milk chocolate it is supplied to create Kisses and Hugs. We assume that any milk chocolate not used to produce Kisses and Hugs is carried over to the next week. Mathematically the supply of milk chocolate is defined by: (previous weeks carry over milk chocolate production + current weeks milk chocolate production – current weeks carry over milk chocolate production) – (((weekly demand of Kisses + weekly carry over of Kisses) / Kisses conversion factor) + ((weekly demand of Hugs + weekly carry over of Hugs) / Hugs conversion factor)) = 0. We use a {Kisses conversion factor} because milk chocolate is measured in pounds and Kisses/Hugs are measured per unit.

Our {Kisses conversion factor} is 102. We first measured that there are 126 Kisses in a 19.75-ounce family pack. We then derived that 102 Kisses can be made from one pound of milk chocolate. The {Hug conversion factor} is 204. We assumed that half the amount of milk chocolate is in a Hug; therefore, the {Kiss conversion factor} * 2 = {Hug conversion factor}.

The most important constraint and one that impact the model the most is the Kiss and Hug demand. We simply say that we have estimated demands for Kisses and Hugs produced by the Hershey company, and we must meet those demand. Mathematically the weekly demand constraint is, (Kiss or Hugs) + (Carry Over Kiss or Hugs) = Weekly Demand. We assumed varying levels of demand over 4 weeks to see how our model responds and where it chooses to create carry over.

To add realism to our model we added in a labor hour constraint. The labor hour constraints scope is a measure of how many bags our current employee base can do for the moving of raw and completed goods. One labor hour constraint assumption is that employees move 50-pound bags of cocoa, kisses, and hugs around the facility. Mathematically our weekly labor hour constraint is: ((inbound supply of cocoa) / 50) + ((total production of Kisses and Hugs) / 50 * Kiss conversion factor) <= Labor Pounds.

Our labor pound constraint is an assumption built upon the fictitious information that we have 11 employees, who can move 60 bags per hour, 24 hours in day, 7 days a week. This is a fictitious assumption that factors in machinery us, teamwork, bulk moving of goods, and travel time.

To add more realism to the model we factored in a machine hour constraint. We researched that 70 million kisses are produced daily at the Hershey's factory. Mathematically we said: (weekly Kiss production + (Hug machine hour conversion factor * weekly Hug production)) <= (70 million * Days operating). Our Hugs machine hour conversion factor is 1.1 because we assume that it takes 10% more time to produce a Hug than a Kiss.

Our final constraint is that no variable can be negative because the only outbound variable is Kisses and Hugs.

Data Collection

Our data collection processes consisted of primarily only research. We researched how milk chocolate is produced in general, and uniquely to the Hershey's production process. We did not make assumptions about the ratio of milk and cocoa in the Hershey's recipe. We also did not assume how many Hershey's Kisses are produced daily at the factory. Our constraints relating to inbound supply, and the proportion our department used are estimates derived from research.

The reliability of our model is reasonable when looking at certain metrics. Because we guessed on all revenue and loss figures our model does not accurately predict monthly profit. However, our model does accurately reflect the production cycle of milk chocolate, and given our estimated constraints can reasonably predict whether a production can meet demand under the constraints we measured. We can also understand how profit will change as the ratio of organic to non-organic cocoa changes.

Running the Model

To run the model, navigate to the data “tab” within Excel, select solver, and run the optimization on Simplex LP. We use Simplex LP because this offers the best solution when looking at all options.

We also include an input sheet for the model. The metrics you can adjust on the input sheet is inbound supply of milk, organic to non-organic cocoa ratio, total operating time, percentage of milk and cocoa in milk chocolate, demand proportion, # of workers, and machine uptime. All these metrics play into our constraint and by adjusting them we can measure whether production can operate under the input assumptions. If the model cannot solve for your given assumption than you must adjust your assumptions to produce the specified Kisses and Hugs amount.

Optimal Solution

Currently, Hershey’s maintains organic cocoa as 60% of the total cocoa used in production. Our solution examined the profit estimate of the solver for the current proportion, for the 2020 goal of 100%, and for the midpoint of 80% ideally reached within at least six months. Pictured in Appendix B are the specific input variable values used in our optimal solution as well as the solution results.

For each 20% increase in the proportion of organic cocoa there is a loss of $888,094, with a total loss of over $1.7 million over the next 8 to 12 months. The majority of constraints were binding as we established our model based on precise production estimates, however Machine Hours (Appendix C) and Labor Hours (Appendix D) were the main opportunities for variability in refining the process and reducing costs.

Machine hours were underutilized three weeks out of the month, particularly in week 4 due to heavy carryover from week 2 and intense production from week 3. Labor hours were grossly underutilized throughout the month, though week 4 is again the most inefficient week. Although these constraints are based on estimates, they highlight the principle challenge of effectively combining flexibility in applying human capital and machine hours with recipes requiring stricter constraints.

Financial Impact

Relative to the size and financial resources of The Hershey Company, a $1.7 million controlled loss is a very minor liability. The potential goodwill and increased demand experienced for following through on such an audacious and socially conscious marketing maneuver could possibly mitigate a large share of the increased cost of production. However, our estimate accounts for 2.5% of total factory production, implying a total potential loss of over $850 million over 8 to 12 months; roughly 10% of the company's revenue for 2018. A loss of that size could be devastating to the goodwill built from pursuing 100% organic suppliers, should The Hershey Company find itself unprepared to absorb nearly a billion-dollar loss and be forced to desperate measures such as layoffs or shifting losses to their loyal suppliers.

Managerial Recommendations

Such a large increase in production costs will require an immense amount of intimate attention to the operational efficacy of production facilities. As such, in addition to the potential loss, our model demonstrates opportunities for mitigating loss and can track the effectiveness of new operational solutions in broad figures.

It is our recommendation to the production facility management that they utilize our model to identify cost-mitigating opportunities across the various constraints in attempt to find ways to save the over $1.7 million in increased production costs. We recommend beginning with Labor Hours and Machine Hours, by addressing the number of workers and machine uptime to ensure that the underutilization ceases. Reassigning employees to other departments or cross-training to increase effectiveness on various production tasks could reduce the current wasting of human resources. By adjusting machine uptime over 100% on the Input page, the purchase of new machinery or addition of machine hours from other production lines can be simulated. More pertinently, the reduction of machine uptime below 100% can simulate both potential repairs or being able to loan machine hours to other production tasks to reduce underutilization, particularly during week 4.

Once the model has been used to mimic or track the implementation of the more efficient labor and machine hours distributions, management should rerun the model to assess the new potential loss. By continuing to manipulate variables such as pricing, demand figures, and proportion of total facility supply of Milk and Cocoa, the management can explore ideal solutions for absorbing the $1.7 million loss. Once simulated in this model, similar solutions can be crafted to incorporate the full scope of production and determine a company-wide strategy to mitigate or prevent entirely the near $1 billion potential loss by 2020.

Appendix

Appendix A

Ki (1-4): The amount of Hershey's Kisses produced in weeks 1 through 4 respectively

CaK (1-4): The amount of Hershey's Kisses produced in weeks 1 through 4 respectively, which exceeds demand for the week and are stored to be used to meet a later week's demand (ex/ production for week 2 is K2 + CaK1 - CaK2).

H (1-4): The amount of Hershey's Hugs produced in weeks 1 through 4 respectively.

CaH (1-4): The amount of Hershey's Hugs produced in weeks 1 through 4 respectively, which exceeds demand for the week and are stored to be used to meet a later week's demand.

MC (1-4): The amount of milk chocolate in pounds to be produced in weeks 1 through 4 respectively.

CaMC (1-4): The amount of milk chocolate in pounds to be produced in weeks 1 through 4 respectively, which exceeds demand for the week and is to be stored to be used in a later week's production.

OrgCocoa (1-4): The amount of organic cocoa beans in pounds to be purchased and imported in weeks 1 through 4 respectively. Organic cocoa must compose at least a set percentage of entire cocoa supply; currently at 60% for the company but can be modified manually in solver.

NonOrgCocoa (1-4): The amount of non-organic cocoa beans in pounds to be purchased and imported in weeks 1 through 4 respectively. Non-organic cocoa cannot compose more than (100% - Organic Proportion Minimum).

CaCocoa (1-4): The amount of organic and non-organic cocoa beans in pounds to be purchased in weeks 1 through 4 respectively, which exceeds demand for the week and is to be stored to be used in a later week's production.

ML (1-4): The amount of milk in pounds to be purchased in weeks 1 through 4 respectively.

CaML (1-4): The amount of milk in pounds to be purchased in weeks 1 through 4 respectively, which exceeds demand for the week and is to be stored to be used in a later week's production.

Appendix B

Input of Gross Daily Factors

Cocoa Organic Proportion		
80%		
Minimum Daily Milk Supply		
300,000	gallons	
Maximum Daily Milk Supply		
350,000	gallons	
Minimum Daily Cocoa Supply		
59,125	pounds	
Maximum Daily Cocoa Supply		
68,979	pounds	
Minimum Daily Milk Chocolate Production		
537,500	pounds	
Maximum Daily Milk Chocolate Production		
627,083	pounds	
Operating Hours per Day		
24		
Days Open per Week		
7		

Manually Adjustable Variable
Auto-Calculated Variable

% of Milk in MC
12%
% of Cocoa in MC
11%
of Workers
11
% of Machine Uptime
100%
Kisses Demand Proportion
95%
Hugs Demand Proportion
5%
Proportion of Total Production
2.5%

Total Profit	
$	**28,729,465**

Appendix C

Total Profit	**$**	**28,729,465**
Revenue	$	69,273,750.00
Costs	$	(40,544,284.87)
Profit at 60% Organic	**$**	**29,617,559.00**
Profit at 80% Organic	**$**	**28,729,465.00**
Loss from 60 to 80%	$	(888,094.00)
Profit at 100% Organic	**$**	**27,841,371.00**
Loss from 80 to 100%	$	(888,094.00)
Total Loss	$	(1,776,188.00)

Machine Hours	W1	**K+H**	418,582,500	≤	490,000,000
Machine Hours	W2	**K+H**	445,655,000	≤	490,000,000
Machine Hours	W3	**K+H**	490,000,000	≤	490,000,000
Machine Hours	W4	**K+H**	344,715,000	≤	490,000,000

Demand	W1	**Kiss**	395,675,000	=	395,675,000
Demand	W2	**Kiss**	325,850,000	=	325,850,000
Demand	W3	**Kiss**	558,600,000	=	558,600,000
Demand	W4	**Kiss**	325,850,000	=	325,850,000

Demand	W1	**Hug**	20,825,000	=	20,825,000
Demand	W2	**Hug**	17,150,000	=	17,150,000
Demand	W3	**Hug**	29,400,000	=	29,400,000
Demand	W4	**Hug**	17,150,000	=	17,150,000

Appendix D

Labor Hours	W1	**Cocoa + Demand**	90,953	≤	110,880
Labor Hours	W2	**Cocoa + Demand**	96,313	≤	110,880
Labor Hours	W3	**Cocoa + Demand**	106,568	≤	110,880
Labor Hours	W4	**Cocoa + Demand**	75,482	≤	110,880

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