CASE STUDY A

Linear Programming Utilization at Reliable Battery: Improving Acceptance of Quantitative Tools

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INTRODUCTION

Larry Miner, Production Manager, was sitting at his desk on Monday morning reviewing last week's production records for the special thermal battery line (or power supply unit). Thermal batteries are primary, reserve batteries which use electrolytes which are solid and nonconducting at ambient temperatures. An electrical or mechanical impulse activates an integral pyrotechnic heat source which melts the electrolyte and renders it conductive. Activation times are normally under one second and discharge lives range from a few seconds to one hour.

This week's output quantities were typical, but Larry believed that if he could build batteries at a more constant rate, the production operation could show dramatic increases in output efficiency. Besides, he hated being at the mercy of the Master Schedule, a document he seldom saw anyway until it was approved and finalized by top management. Larry realized although he carried the title of manager, he virtually had no power outside of his own production area and that the planning functions were determined by some nebulous group which appeared to be made up of the contract manager, two engineering managers, and the plant manager. Larry was given considerable authority in his internal scheduling and wide latitude in production operations so long as the proper quantities of the right batteries were fabricated according to the Master Schedule. Although Larry saw incentives to increase output efficiency and save labor man hours, he could only do this to a limited degree and only on a weekly basis. He was not given the opportunity to alter the schedule. For example, he did not have the authority to double production on one battery this week and build none the next.

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Larry Miner had been with Reliable—Battery Division for sixteen years, gradually working himself up from foreman, to production supervisor, to assistant production manager and for the past five months to production manager, replacing Ken Alford who had left the company to go into private business.

COMPANY HISTORY

Reliable Products, Inc., an Illinois based diversified company, has been in business since 1899. The company operates sixteen plants all located in the Ohio Valley area, and each engages in producing specialized products ranging from plastic hoses and metal office furniture to commercial chemicals and special-purpose batteries. The Battery Division, located in a small town about 70 miles southeast of St. Louis, began operating in 1951 as a manufacturer of batteries used for mobile radio communications for the Army and Marine Corps. The division had its ups and downs in the 1950's due to its dependence on large governmental contracts. In the early 1960's the division increased operations in the aerospace battery business. Increasing federal funding of NASA, coupled with the Vietnam conflict, provided sufficient demand to allow the Battery Division to increase in size and to largely avoid large sales fluctuations.

At present, with about 400 employees, the division manufactures a broad line of special-purpose batteries for the federal government agencies and branches—primarily NASA, DOD (Department of Defense), and DOE (Department of Energy). More than 95% of their sales are to government prime contractors and subcontractors (including large aerospace firms such as Boeing, General Dynamics, Raytheon, Grumman, Lockheed, McDonnell Douglas, and others).

DEVELOPMENT OF A PRELIMINARY MODEL

Larry Miner was pursuing an MBA (evening program) at nearby Southeastern Illinois University. He was taking an operations management course in which he had been exposed to linear programming. He was taking the class with another Battery Division employee, Gary Smith, a young, aggressive Contract Administrator who had been with the company only nineteen months.

Based on some inputs Gary had developed from the pricing and cost side and largely based on historical production and quality control records which Larry had readily available from within his department, he developed an LP model for one of the six main production areas of the plant. As part of the model development process, product profit rates were converted in the form of an objective function and the product resource requirements and limitations were transformed into a set of constraining equations.

OBJECTIVE FUNCTION

The company's objective, as perceived by Larry, is to obtain the maximum profit from sales of four power supply units (PSU). The estimated profit contributions are determined by deducting costs from selling prices. Pertinent costs include material costs, labor, and overhead items. Reject/attrition rates were accounted for in the calculations. Profit contributions of the four units vary widely because of the differences in physical size, power rating, and special application, and are shown below in Table 1 (cost calculations appear in Table 3).

TABLE 1 Profit Contributions

	Power Supply Units (PSU)			
	Type I	*Type II*	*Type III*	*Type IV*
Selling Price	$84.00	$160.00	$3,200.00	$280.00
Variable Costs	75.00	142.25	2,749.00	249.25
Profit Contribution	$ 9.00	$ 17.75	$ 451.00	$ 30.75

Thus, maximization of average daily profit is:

$$9X_1 + 17.75X_2 + 451X_3 + 30.75X_4 \quad (1)$$

where X_j represents the average daily production of Type j PSU.

CONSTRAINING EQUATIONS

At present, demand exceeds production capacity for producing power supply units, which are sold to federal government agencies and industrial companies. Limiting resources include labor (manufacturing, technical, engineering, and administration), equipment, machinery, working area, raw chemicals, purchased parts, and raw materials.

The constraining equations (2) through (8) respectively represent daily build capacity, availability of raw material processing machines, power supply test equipment, stacking and potting molds, vacuum drying ovens, x-ray inspection machines, and final inspection capacity. In formulating these equations, numerous assumptions were made. These underlying assumptions included: (1) no restrictions existed on supplies of raw chemicals and materials, nor on purchase parts; (2) equipment set-up and down-time were accounted for; (3) no improvement (learning) curve on labor was applicable; (4) wear and tear on equipment was the same per direct labor hour for all power supply units; (5) reject/attrition rates for PSU were included; and (6) an eight-hour shift per work day was common practice (less breaks and clean-up time allowance). Additional costs, direct and indirect labor, or other internal or external factors did not impose any restrictions on the product mix. Table 2 shows a summary of resource utilization and availability.

From past production records, the average maximum output of the power supply units is restricted to a combination of 100 Type I, 100 Type II, 20 Type III, or 50 Type IV power supply units. The daily building capacity for the PSU is expressed as:

$$\tfrac{1}{100}X_1 + \tfrac{1}{100}X_2 + \tfrac{1}{20}X_3 + \tfrac{1}{50}X_4 \leq 1 \quad (2)$$

Four blenders, each capable of producing 1600 grams of usable raw material per shift, are available. The relationship between government regulations regarding the raw material content (grams) of each power supply unit and the daily supply of raw material is specified as:

$$30X_1 + 50X_2 + 640X_3 + 125X_4 \leq 6400 \quad (3)$$

TABLE 2 Summary of Resource Utilization and Availability

Resource	Availability of Resource	Power Supply Unit Requirements			
		Type I	*Type II*	*Type III*	*Type IV*
Building Capacity[1]	1 day[2]	100 PSU/day	100 PSU/day	20 PSU/day	50 PSU/day
Raw Material Processing Machines	4 blenders[3]	30 grams/PSU	50 grams/PSU	640 grams/PSU	125 grams/PSU
Performance Testing (including setup time)	2 testers[4]	4 minutes/PSU	4 minutes/PSU	3⅓ hours/PSU	8 minutes/PSU
Stacking and Potting Molds	50 molds[5]	2 PSU/mold	2 PSU/mold	4 molds/PSU	1 PSU/mold
Vacuum Drying Ovens	17 ovens[6]	25 PSU/oven	10 PSU/oven	0.5 PSU/oven	5 PSU/oven
X-ray Inspection Machines	2 machines[7]	4 minutes/PSU	4 minutes/PSU	10 minutes/PSU	4 minutes/PSU
Final Inspection Capacity[8]	1 day	200 PSU/day	100 PSU/day	10 PSU/day	40 PSU/day

[1] The building capacity represents the maximum building rates when producing only one type of PSU at a time. It is reasonable to assume that a linear tradeoff exists among the production of power supply units.
[2] A day consists of one eight-hour shift which encompasses seven hours of working time, one-half hour for lunch, two-sixths hour for breaks, and one-sixth hour for clean-up time.
[3] Each blender can produce about 1600 grams of usable material per day.
[4] Each of the two power supply testing equipment is available seven hours per day.
[5] The process duration is such that each mold can be used only once per day.
[6] Each drying oven is tied up for most of the day and, hence, is available only once per day.
[7] Each x-ray machine can be used for only six and one-half hours per day.
[8] The final inspection capacity represents the maximum handling rates when only one type of PSU is inspected. Again, linear tradeoff among the inspection of PSU is a reasonable assumption.

Two power system testers are each used seven hours per day. Specified test times are considerably longer than the actual time because of necessary set-up procedures. These time estimates are based upon quality control records. The four power supply units testing requirements are four minutes, four minutes, 3⅓ hours, and eight minutes, respectively. The time (minutes per day) allotted for performance testing is expressed as follows:

$$4X_1 + 4X_2 + 200X_3 + 8X_4 \le 840 \qquad (4)$$

Each of the fifty stacking fixtures/potting molds can handle two Type I, two Type II, or one Type IV power supply units. The Type III unit requires four molds per PSU. The utilization of these molds is expressed below as:

$$\tfrac{1}{2}X_1 + \tfrac{1}{2}X_2 + 4X_3 + X_4 \le 50 \qquad (5)$$

Vacuum drying ovens are used for a minimum of five hours and thus cannot process more than one batch of power supply units per day. Each oven can contain 25 Type I, 10 Type II, 0.5 Type III, or 5 Type IV power supply units. The availability of these ovens is expressed in the following manner:

$$\frac{1}{25}X_1 + \frac{1}{10}X_2 + \frac{1}{.50}X_3 + \frac{1}{5}X_4 \leq 17 \qquad (6)$$

There are two x-ray machines, each used 6½ hours per day. The constraint expressing the relationship between x-ray time (minutes) required by each type of PSU and the time available is given as:

$$4X_1 + 4X_2 + 10X_3 + 4X_4 \leq 780 \qquad (7)$$

The last constraint indicates final inspection capacity. Based upon quality control data, the average maximum processing is limited to a combination of 200 Type I, 100 Type II, 10 Type III, or 40 Type IV power supply units. The daily inspection capacity is expressed as:

$$\frac{1}{200}X_1 + \frac{1}{100}X_2 + \frac{1}{10}X_3 + \frac{1}{40}X_4 \leq 1 \qquad (8)$$

PROBLEM SOLUTION

Solve the linear problem formulated. Show that an average daily profit of $2527 resulted.

a. Determine the optimal product mix.

b. Determine the nature and amount of excess resources.

c. Discuss the resoning of the Company for the excess resource.

SOLUTION ACCEPTANCE AND IMPLEMENTATION

After setting up and solving the problem with a linear programming routine, Larry realized that based on his model's assumptions he could offer a product mix that would generate more profits for the Battery Division. Waiting until he thought the time was right, he approached Ralph Thomas, the Contract Manager. Larry perceived Thomas to be the most powerful (next to Dennis Adams, Division General Manager) of the group that controlled the Master Schedule.

Larry entered Ralph's office and said, "Do you have a few minutes to discuss some ideas I have about battery scheduling for more labor efficiency?" Ralph said, "Sure, sit down Larry, would you like some coffee?" Larry responded, "No thanks, the doc said I should cut back."

Larry then briefly detailed his model as Ralph listened intently. Ralph commended, "Your ideas look good on paper, but they simply won't work. Your assumptions about linearity and so on might hold up, that's not the problem. The problem lies in established corporate-level policy. Reliable strictly believes the customer is always right. We go out of our way no matter what the short-term cost to satisfy the customer's immediate needs. Since this is a job order shop, we must prepare the Master Schedule in accordance with time, quantity, and quality demands of our customers. The top brass at corporate headquarters have been operating on that philosophy for years and they're not about to change. Imagine if we juggle things around here and say General Dynamics doesn't get batteries when they want them. We both know what will happen if they complain to the corporate office, or even to Dennis—I'll be in trouble, and your production people will be working around the clock until I'm bailed out. I realize that the present system may not be 100% efficient, but, it's the way we have to operate, period."

Larry temporarily dropped the subject until about a month later when one day after work he went to a farewell party for Bruce Phillopa, a production supervisor who was retiring. Over cocktails he was talking with Earl Carlson, Engineering Manager. Earl said, "I wish we could go with only one or two thermal batteries at a time (in production), sure would save us money, but Ralph's always muttering this 'the customer is always right' stuff and how over the long-run, customer relations pay off with optimal profits." Larry then told Earl about his model and explained how it could be operationalized to include other battery production lines as well. Larry said, "I'm sure we could make more money, I've got some figures to prove it."

The next day Larry explained to Earl the concept of his LP model. Earl expressed a keen interest in it and said he'd talk to Dennis Adams about it and try to arrange a meeting for Larry to explain his ideas to Adams, Thomas, Miller (the other Engineering Manager) and Black (controller).

Adams agreed to a meeting and Larry was given one week to prepare his presentation.

DISCUSSION QUESTIONS

1. What are main points Larry should emphasize in his oral presentation?
2. What presentation approaches can be used to help improve chances of acceptance for LP results?
3. If management rejects the proposal, what changes in the problem statement or techniques used in problem solving might be helpful in producing a compromise proposal?

TABLE 3 Computation of Costs of PSU

Cost Factors	Method of Costing	Type I PSU	Type II PSU	Type III PSU	Type IV PSU
Raw materials (with loss factor)	At cost	$ .70	$ .97	$ 60.62	$ 2.16
Purchase parts (with loss factor)	At cost	16.21	25.44	481.91	56.70
Interdivisional transfer	At cost	0	3.73	72.88	5.85
Direct salary labor	$9.39 per hour	4.70	9.39	150.24	15.02
Direct hourly labor	$5.65 per hour	18.08	34.58	686.48	57.35
G & A	23.0% of direct labor	5.24	10.11	192.45	16.65
Overhead	131.5% of direct labor	29.96	57.82	1,100.29	95.17
Consumable tooling	$.03 per direct labor	.11	.21	4.13	.35
		$75.00	$142.25	$2,749.00	$249.25
	Selling Price	$84.00	$160.00	$3,200.00	$280.00
	Cost	75.00	142.25	2,749.00	249.25
	Profit Contribution	$ 9.00	$ 17.75	$ 451.00	$ 30.75

Profit = Selling Price − Cost, where cost consists of materials, labor, and overhead items.