Staff Contribution 6-6

Miscellaneous Staff Contribution of the Department of Agricultural Economics

Purdue University
Lafayette, Indiana

For information concerning additional available publications write: Librarian, Department of Agricultural Economics

"UNIVAC" SAYS THUMBS UP -
A NEW WAY TO PICK A PROFITABLE LINE OF PRODUCTS

(Remarks by Charles E. French, Purdue University at
Milk Industry Foundation 49th Annual Convention,
Atlantic City, N.J.)

Modern management is a science. To continue to view it basically as an art invites trouble. I believe that it was Lord Kelvin, the man who developed our temperature scale, that once said, "If you can measure that of which you speak, and can express it by a number, you know something of your subject. But if you cannot measure it your knowledge is meager and unsatisfactory."

Thus, modern management has gone to extensive lengths to measure and to automatize. So-called electric brains typify this development. "Univac" is revered as the magical means by which guess work will be taken out of management. This, "Univac" cannot do. Yet it can do enough that we must sit up and take notice of it.

A Word About "Univac" Itself

An electric brain isn't a brain, it's a machine. You folks know well the limitations of machines. "Univac" has them. It can do only that which man is capable of telling it to do. Often the first time "Univac" solves a problem, it is easier to do it yourself than to tell "Univac" how to do it. However, it can do problems which man cannot reasonably do, merely because of their size. Also, once "Univac" is shown how to do a certain kind of problem it can do many more like it much more effectively than man. Its real effectiveness then is on large repetitive problems.

New mathematical methods have made "Univac" workable, and fortunately these new mathematical methods are not reserved for "Univac". Many of your problems can be solved by clerks with the very techniques of "Univac" but you don't need a $200,000 electric brain to do it. Thus, I want to show you how to use one of the most effective tools of "Univac" this afternoon. It is called linear programming. It proved itself in ship convoy planning during the war, the Berlin airlift, and this type of thing. Now, it is proving itself on business problems of nearly every type.

I want to illustrate the method for you, show you how to use it to decide what products a fluid milk plant should produce, and conclude by suggesting some problems which you can solve with this technique.

The Method Used by "Univac"

The products which you produce are influenced by many things. For example, you appreciate well that in many plants, it is not easy to say whether a plant should go 100% paper or not. Let us look at how such a problem is tackled by "Univac".

Problem I

First, let us take a very simple problem. Suppose:

1. We have these fixed items:

   a) Cold room space — 10000 sq. inches

   b) Machine capacity — 480 minutes running time

2. It takes this much of each to produce one unit of these products:

	Cold Room Space	Machine Time
a) Quart	30 sq. in.	2 min.
b) Half gallon	50 sq. in.	5 min.

3. Our selling prices less all costs except a charge for coldroom space and machine time are:

   a) Quart — 9 cents

   b) Half gallon — 17 cents

4. We can sell 1000 quart equivalents of the two together at these prices. Either can substitute for the other.

5. We want to know which of these to produce to get the greatest return considering our fixed resources in cold room space and machine time.

You look at this and obviously say, "Well, quarts net me 9 cents per quart equivalent and half gallons only 8½ cents per quart equivalent, so I will push quarts. The market will take 1000 quarts equivalents; have I machine time enough to produce this many? No, I can only go up to 240 quarts. This looks like a bottleneck. Would I do better on half gallons? No, I can produce only 96 half gallons. This would return me only $16.32; 240 quarts would return me $21.60. So I had better stick to quarts. I know that 240 quarts are the most I can produce. But, maybe I cannot produce even this many; have I cold room space enough to handle them? A quick check shows that I have enough to handle 333 quarts; so I am alright here. Thus, my answer - 240 quarts, no half gallons."

You went at this much as "Univac" would and it wasn't too difficult. You didn't have many products, machines, or selling prices to deal with. Its when you multiply each of these several times that "Univac" comes into its own.

Problem II

Now, let's take a little harder one and look at "Univac's" method a little more closely.

Suppose:

1. We have these fixed items

   a) Cold room space 52,000 sq. inches

   b) Quart machine time 360 minutes

   c) Half gallon machine time 360 minutes

2. It takes this much of each to produce one unit of these products:

	Cold Room Space	Quart Machine Time	Half Gallon Machine Time
a) Quart	8 sq. in.	.04 minutes	none
b) Half Gallon	5 sq. in.	none	.10 minutes

3. Our selling prices less all costs except a charge for the cold-room space and machine time are:

   a) Quart 25 cents

   b) Half Gallon 40 cents

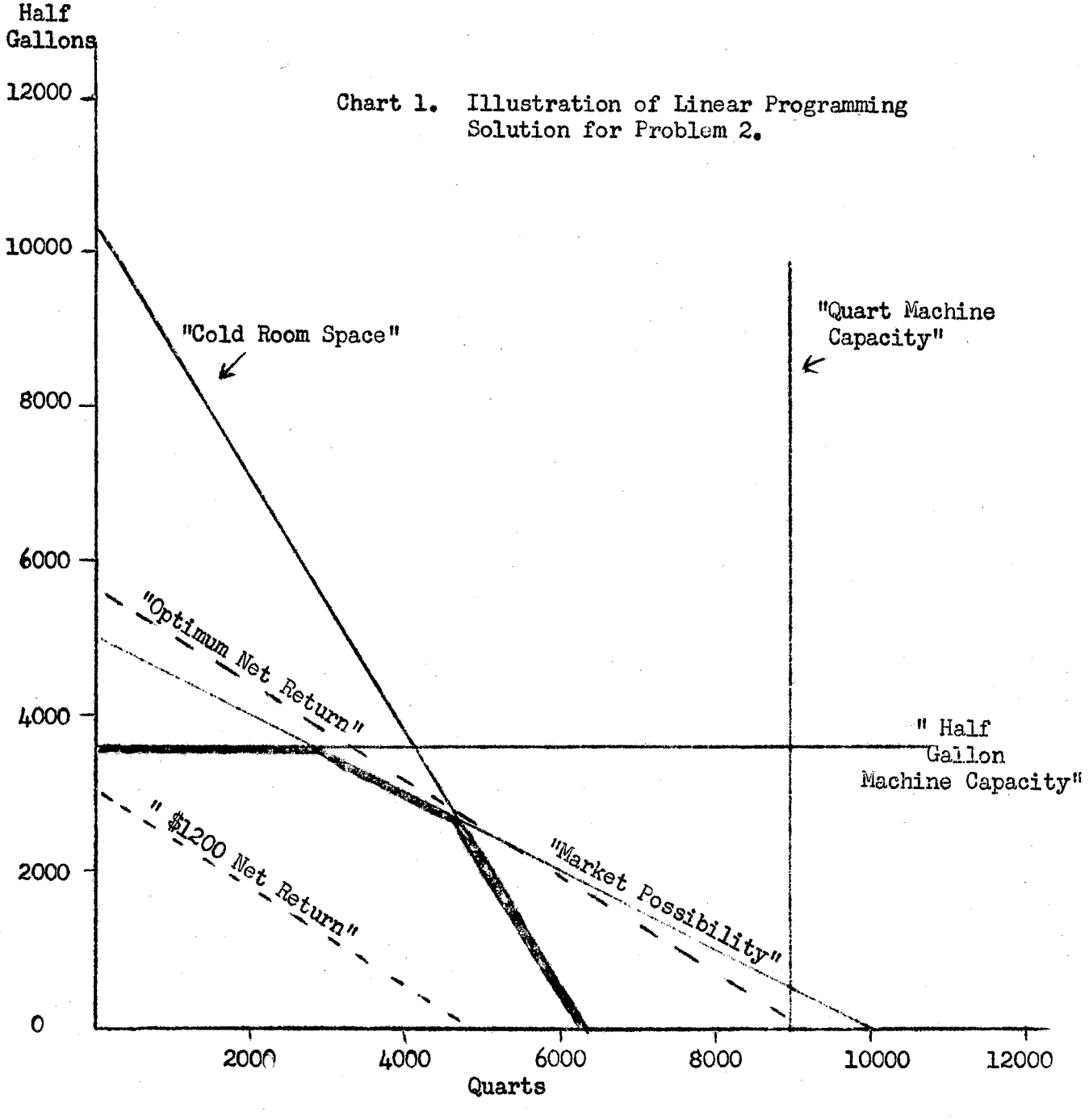
4. We can sell 10,000 quart equivalents of the two together at these prices. Either can substitute for the other.

5. We want to know how much of each to produce to get the greatest return.

This is a little hard to see so let us draw a picture of it. (Chart I) We know that we have capacity for only 3600 half gallons on the half gallon machine, so let's draw a line in to show that we must not produce more than 3600 half gallons. This line is labelled "half gallon machine capacity". The quart machine limits us to 9000 quarts so we draw that one in as the "quart machine capacity" line. Now we know that the market will take either 10,000 quarts or 5000 half gallons. If we draw a line connecting these, it will show all possible combinations of the two which we could produce and still not go over the 10,000 quart equivalent limit of the market. For example, one such combination would be 4000 half gallons and 2000 quarts. We call this the "market possibility" line. Now we have one other factor - cold room space. We have space for 10,400half gallons or 6500 quarts. If we draw a line between these points we have all possible combinations which the cold room can handle. One such combination would be 4000 half gallons and 4000 quarts. We call this the "cold room space" line. Now, you can see that we have a picture of what we can produce - any combination of quarts and half gallons below the heavy black line formed by these intersecting lines. The question is, which particular one? It's rather simple to find that one. All we need are the prices - factors we long ago found to be important in such a problem as this!

What are the relationships between our prices? All we need to determine this is to find how many of each we must sell to get a logical net return, say $1200. We can get that with 4800 quarts or 3000 half gallons. If we

Chart 1. Illustration of Linear Programming Solution for Problem 2.



draw a line between these two points we have all of the possible combinations of these products which will give us this return of $1200. This line is labelled "$1200 Net Return". Now, if we will draw a line parellel to this one at the highest point possible and yet touching the heavy line marking out our production possibilities, we can get our answer. Such a line labelled "optimum net return" should show that we should produce 2550 half gallons and 4900 quarts, for a net return of $2245. Thus, we produce at that level where this line touched our production possibility area. This is the most that we can possibly get under our conditions. It is the one best answer.

This technique is a useful one for simple problems involving only two products, but when you get more than two, you have trouble drawing pictures of them and need another system. If you remember just a little of your algebra, you can visualize how "Univac" handles that. It merely puts these ideas into mathematical equations. For example, this last problem should look like this:

Quarts Produced (Q)	½ Gallons Produced (H)	Market Not Used (M)	Cold Room Space Not Used (C)	Qt. Machine Time Not Used (M_1)	Half Gallon Machine Time Not Used (M_2)	
1Q	$\leq$ 2H	$\leq$ M				= 10,000 qt. equiv. (market)
8Q	$\leq$ 5H		$\leq$ C			= 52,000 sq. in. (cold room)
.04Q				$\leq$ M_1		= 360 minutes (qt. machine)
	.10H				$\leq$ M_2	= 360 minutes (½ gal. machine)
.25Q	$\leq$ $.40H					= MAXIMUM DOLLARS

Now by solving these mathematical formulas you get the answer we got before with the chart. If you had only two products involved you would probably use the chart. However, with equations such as these you can keep adding products and limiting factors and still make sense even though you cannot draw a graph of it. This is what "Univac" does. It can easily handle 50 to 100 products and 50 or more restricting factors. It is practical to work rather large scale problems of this type with a desk calculator. The method is quite simple and can be done by a competent clerk. I'll not outline that in detail. One good refernce on this is:
A. Charnes, et.al., "An Introduction to Linear Programming" available from John Wiley and Sons.

A Practical Problem

James C. Snyder and I applied these techniques to help one of our Indiana plant operators pick his best line of products. We were encouraged with the results.

This was a good plant, about 75,000 pounds per day volume, progressive, excellent accounts, and not a plant where you would expect to make a large saving. Yet, "Univac" showed where improvements could be made even under these conditions.

Certain types of specialized labor, machine capacities, cold room space, fat content of the milk, market potentials, and operating capital were the main items which were considered as possible limitations. The "Univac" was allowed to select among any products in the present line of products which included cottage cheese but not ice cream. The total problem as given to "Univac" involved 26 mathematical equations with 20 unknown factors in each equation.

Labor was allocated to the products by time study; space requirements were measured; actual machine capacities were determined; product formulas were used; a 15% increase in present sales was allowed on each product; and regular accounts were used to determine operating capital needs and unit selling prices.

Basically two types of answers were secured. First, we were given the line of products which would maximize returns to this plant (Table 1).

Best Line of Products, One Selected Fluid Milk Plant, Indiana

TABLE 1

Product	Available Market (units)	Best Line of Products (units)	Marginal Cost Above Net Selling Price (cents/unit)
Gal, glass, homo, whlse	229	-----	4.4
Pt., glass, homo, whlse	8500	8500	-----
½ pt, glass, homo, whlse	12700a/	12700	-----
½ gal., paper, homo, whlse	6738	5585	-----
Qt, paper, homo, whlse	5800	5800	-----
½ pt, paper, homo, whlse	12700a/	-----	.3
½ pt, glass, cof. cr., retail	400b/	400	-----
½ pt, glass, cof. cr., whlse	1800c/	1800	-----
½ pt, paper, cof. cr.,retail	400b/	-----	.3
½ pt, paper, cof. cr., whlse	1800c/	-----	.4
Qt, paper, but.milk, whlse	750	750	-----
Qt, glass, choc., retail	375	375	-----
½ pt, glass, choc, whlse	7800d/	4566	-----
Qt, paper, choc, whlse	1950d/	808	-----
½ pt, paper, choc, whlse	7800d/	-----	.4
½ gal, paper, low fat, whlse	463	463	-----
pt, paper, H & H, whlse	650	650	-----
12 oz.,cottage cheese, whlse	2920e/	1016	-----
2 lb, cottage cheese, whlse	730e/	-----	10.3
4 lb, cottage cheese, whlse	486e/	-----	16.6
Total net rev.	$5790.09		

a/ Market will take up to 3175 quart equivalents in glass or paper.
b/ Market will take up to 100 quart equivalents in glass or paper.
c/ Market will take up to 450 quart equivalents in glass or paper.
d/ Market will take up to 1950 quart equivalents in glass or paper.
e/ Market will take up to 2920 units 12 ounce, or 730 units 2 pound, or 486 units 4 pound, or some combination of these amounts.

With this, we also have some indication of the loss that would occur by switching products. This information is given by the factors labelled "marginal values" in Table 1. For example, if we produced one gallon jug, (which "Univac" said not to produce) total returns would be reduced 4.4 cents. Or if one unit of cottage cheese in our two-pound package were produced, total returns would be reduced 10.3 cents. These values are the minimum losses sustained. If you produce very many units of each, you will lose even more as you give up other things.

Secondly, we were told how much of each of our resources to use and how much of each we should leave unused (Table 2).

Best use of Resources, One Fluid Milk Plant, Indiana

TABLE 2

Limiting Factors	Available Quantity	Unused Quantity	Marginal Value
	(man minutes)		(cent/unit)
Labor			
Empty Bottle & Case	610	18	----
Process	1135	505	----
Fill & Wash	2670	276	----
Cold Room	2725	38	----
Delivery	20160	509	----
Machine Running Time			
Glass ½ pt-qt	480	---	31.1
Glass Gal	73	73	----
Paper ½pt-qt	480	264	----
Paper ½ Gal	480	247	----
Cott. Cheese	73	48	----
	(sq. in.)		
Cold Room	179130	29634	----
	(lbs.)		
Fat	2797	---	18.0
Skim	72795	---	3.3
Market	(qt.eq.)		
Qt G M R	8500	---	3.6
½pt Tot H W	3175	---	2.3
½ gal P H W	13476	2305	---
Qt P H W	5800	---	.4
½ pt Tot Ccr W	450	---	25.5
½pt Tot CCr R	100	---	35.3
Qt P BM W	750	---	3.1
Tot Ch. W.	1950	---	2.5
Qt. G Ch R	375	---	5.2
½pt P Lf W	926	---	.5
Pt P HH W	325	---	10.9
Variable Capital	90000(cents)	23205	
Total Net Rev.	$5790.09		

In this plant the factors that actually limited production turned out to be glass machine time and milk supply. Also many products pushed to the limit of their market. The marginal values in Table 2 tell how much another unit of these limiting factors would return us. For example, an additional unit of glass machine time would have been worth 31 cents to this plant. Another pound of fat would have been worth 18 cents over the present pay price and skim would have yielded 3.3 cents over present cost. Also, the value of an additional market outlet for each limited product was given. These values may go up as the organization is changed, but we have the minimum amounts which they would add to the net returns.

We were interested not only in this plant but in others that had other types of facilities and bottlenecks. Thus, we altered the amounts of labor, cold room space, capital, and such items available to this plant and tested the effects upon line of products. The results make it obvious why there is no clearcut general answer for such questions as paper vs. glass. The most profitable line of product depends upon the resources which the plant has to work with and the prices prevailing in the market.

Some of our general findings were:

1) Within a $50.00 range in daily net returns, considerable flexibility existed in choice of a line of products. Within reason it made sense to "meet competition" on certain new products entering the market.

2) There was some evidence that in the short run, firms can afford to spend sizeable amounts on increasing certain product sales. Marginal values for certain products were sizeable.

3) There was evidence that labor-machine balance and this type of thing were more important than line of product. For example, labor shortages suggested high priority for labor efficiency studies in specialty product processing and cold room product handling. The cottage cheese operation of the plant studied was remodelled to eliminate a processing labor bottleneck.

4) In all cases, restrictions of resource inputs reduced net returns out of proportion ot costs. For example, $2790.00 per additional square foot of cold room capacity, 59 percent return on borrowed working capital, and $7.80 per additional man-hour of plant labor were case answers which were all greatly out of proportion to costs.

5) Excess capacity costs dearly. For example, a 20 percent reduction in volume handled by this plant gave a marginal value for an additional hundredweight of milk, 34 percent above the actual buying price.

These facts suggest the importance of maintaining the proper balance of resource inputs and thus place a premium on the policy-making decisions of management. The need for more precise accounting, engineering and economic analysis techniques is evident.

For this particular plant the following restrictions suggested certain courses of action as follows:

1) Cold Room Limitations - Push large size and paper containers. Maintain specialty output (excepting low fat) at expense of homo.

2) Capital Limitations - Cut back on paper and low returns specialty (low fat and chocolate). Concentrate on products with relatively low container costs (4 pound cottage cheese). Push glass gallon for homo wholesale market.

3) Labor Limitations - In general, push paper products at expense of glass. For plant labor limitations, cut back high labor specialties - half and half and cottage cheese.

4) Fat and Skim Limitations - Reduce paper and half-gallon production. As milk supplies increase, push paper and cottage cheese production to market limit.

5) Butterfat Variations - Under low fat conditions, reduce coffee cream and half and half. Push cottage cheese. Trim homo back slightly. Under high fat conditions, push homo and all specialty (except low fat) to market limit. Reduce cottage cheese.

6) An Expanding Market - Push all specialty except low fat. As milk supply increases, follow suit with homo and cottage cheese.

7) Dual Operation - Push all-glass products where paper is not necessary for competitive reasons.

8) All Situations - Push quart homo retail and quart buttermilk wholesale.

9) Most Situations - Push half and half, buttermilk, and chocolate. Meet demand for homo. Balance fat-skim ratio with cottage cheese production.

Some Possible Problems

"Univac" can be used effectively on many plant problems. Let me mention a few possible applications:

1) What products to produce, 2) What processes and machines to use, 3) Labor scheduling and control, 4) Where to ship and where to produce in multiple firm operations, 5) Route scheduling, 6) Incentive wages and route commissions, 7) Seasonal production plans, 8) Ice cream, cheese or other product mix problems, 9) Number of bottling days, 10) Inventory, 11) Plant location, and 12) Farm bulk pick-up.

"Univac" is another machine - a fascinating and powerful one. The methods it uses are practical, flexible, and understandable. They will continue to be used. You had better take a look at them; your competitor will.