Determining corrugator performance with different numbers of roll-stock sizes available for scheduling

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ABSTRACT: Computer corrugator scheduling has come of age during the last decade. With the availability of good scheduling programs, it is possible to simulate different corrugator conditions and to construct models. The purpose here is to determine corrugator performance when operating with a different number of roll sizes available for scheduling. Data are presented on number of changes, running speed, widths, side trims, and costs when reducing the number of sizes available for scheduling from 10 to four.

KEYWORDS: Computers, corrugating machines, dimensions, models, performance, rolls, scheduling, simulation.

Fourteen sets of items were computer scheduled on an 87-in. corrugator using 10 sizes, nine sizes, eight sizes, and four sizes. The sizes were 87, 85, 83, 81, 79, 77, 75, 73, 71, and 69 in. for the 10-size run. The 69-in. was dropped for the nine-size run. The 69-in. and 71-in. were dropped for the eight-size run, and we used the 87-, 85-, 83-, and 81-in. for the four-size run.

We used the Corr-Trim computer program by Corrugated Technology, Inc. of San Diego, CA. This program has three different solutions available in one package: the first uses linear programming to deal with difficult trim problems by generating complex order splits, the second generates combinations sequentially in much the same way it would be done manually, and the third generates a large set of possible setups and selects which will be used based on cost minimization using a set partitioning algorithm. All 14 sets were run on all three programs, and final schedule selections for the study were based on least cost, if they also attained over 100% completion of items. A minimum of 294 computer runs were made on Corr-Trim (14 sets x 3 solutions x 7 different roll size combinations).

Product mix used

The 14 sets of items were selected to reflect a general 200-lb C-flute mix (42–26–42). The exception was that pretrimmed items were excluded. Pretrimmed items are defined as long-run, fast-delivery items that are always trimmed and run by themselves out of one constant roll size. Soap, tissue, can, and glass business (national accounts) fall into the pretrimmed category.

The 14 sets (180 items with 3400 ft^2 x 1000) were selected to reflect some short runs and some long runs. Also included were some sets with a fairly large number of items and some sets with a small number of items. Schedules were to be completed between 95% minimum and 110% maximum, with no blank-flap shying, a maximum of five out, and a minimum trim of 1 in.

The question arises: Do these 14 sets represent general 200-lb C business? Seasoned corrugator schedulers contend that there is no meaningful average with combination trimming. Individual items repeat, but they do not repeat at the same time as other repeaters. General pools of items are almost random if the pools are large enough. Every pool of items is a different scheduling challenge.

Table I presents a brief profile of the 14 sets.

Corrugator configuration

The following corrugator was selected to determine productivity and costs on the 200-lb C product mix: an 87-in., 575 ft/min B- and C-flute with singleface and double-back automatic splicers, 200-automatic-order-change slitter with manual head setting, electric double-cutoff knife, and double-down stackers. This corrugator configuration is not applicable to a vin-

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I. Profile of the 14 sets

	Minimum	Average	Maximum
Number of items/set	5	12.9	23
Number of blanks/set	5,300	25,694	61,760
1000 ft²/set	65	242	778
Average set			
lineal ft/item, 1 out	2,970	8,726	29,001
Average blank ft²	. . .	9.4	. . .

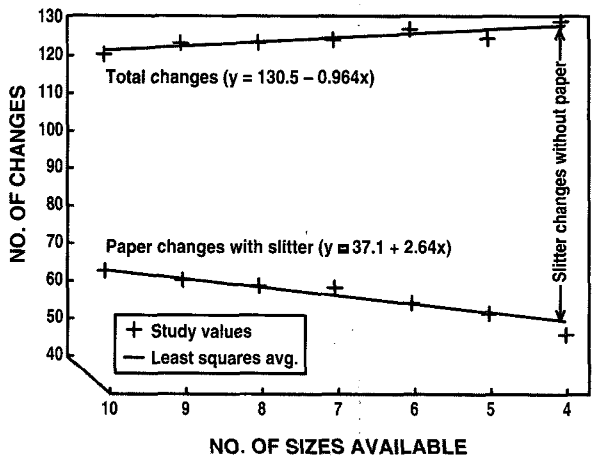
II. Approximate product mix

Weight, lb	125	175	200	275	350	DW
Percent	10	10	48	17	5	10

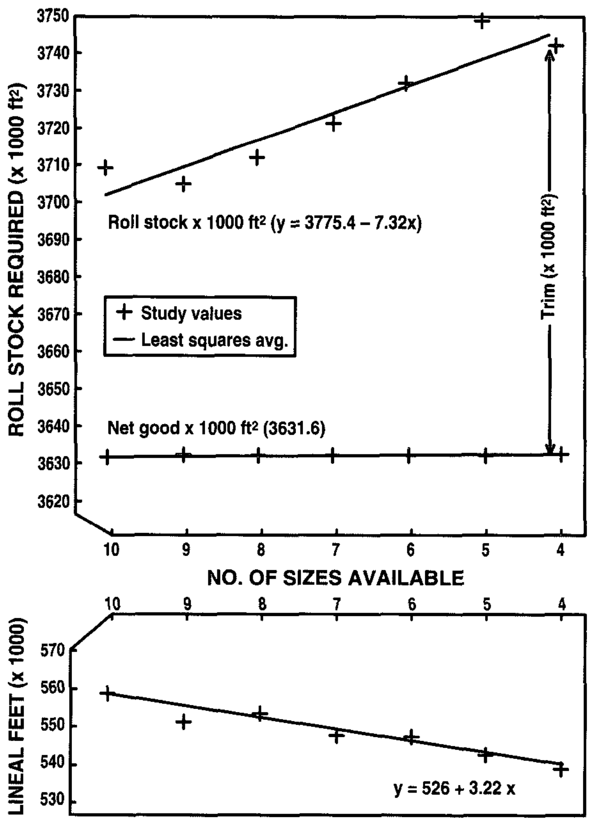
This equals 138 lb/1000 ft² of liner and medium.

DW = double wall.

1. Number of changes



2. Volume studies

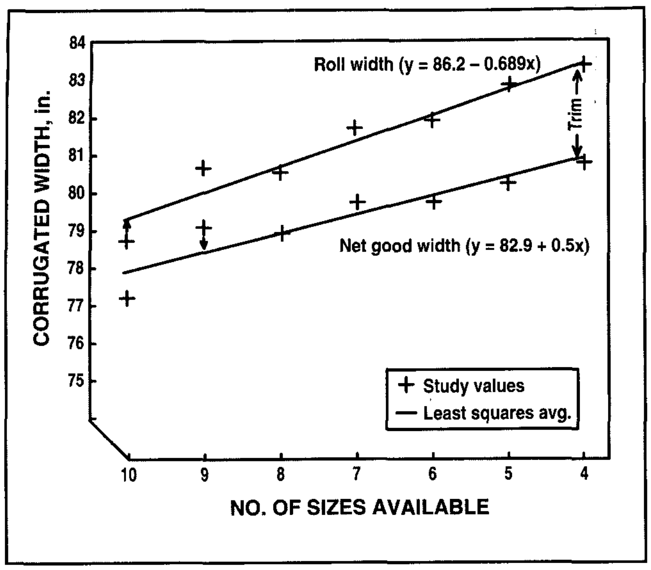


tage, bare-bones 63-in. machine or a modern 1000 ft/min machine. The corrugator chosen was a modernized, older 87-in. machine.

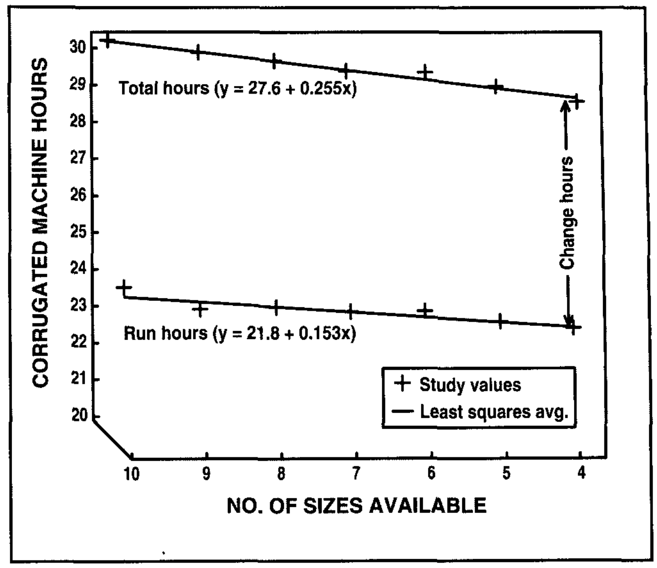
Detail of data

Corr-Trim did a good job of scheduling and all runs selected for the study were feasible. The average overrun in the selected sample was 107%, with a range of 104% to 109%. To prevent any volume bias in the data, all lineal feet, 1000 ft² rollstock, 1000 ft² trim, and net good 1000 ft² were

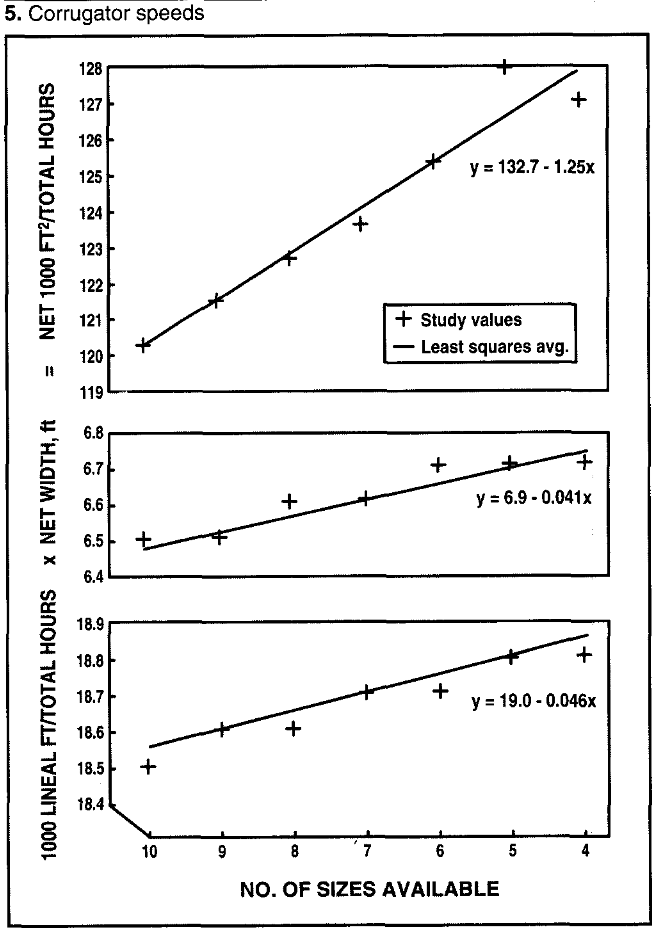
3. Corrugator widths



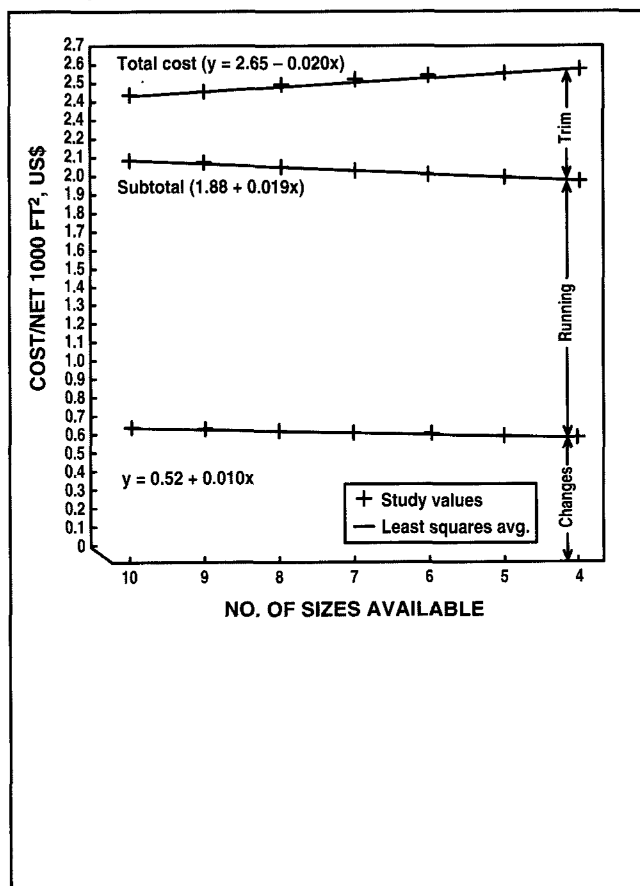
4. Corrugator machine hours



5. Corrugator speeds



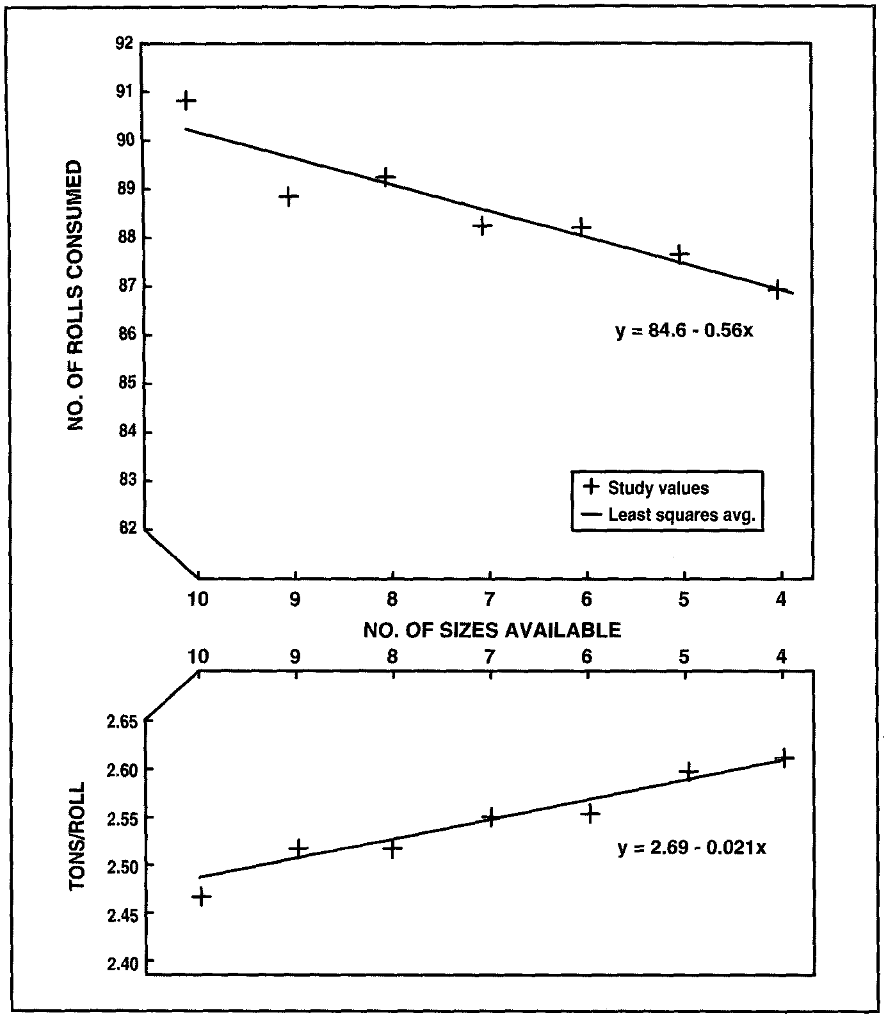
6. Corrugator costs per net 1000 ft²



adjusted to a 107% overrun basis. All data is in graphical and tabular form. Actual study values are shown with an appropriate least squares average trend line. Here is the way the detail data is shown by number of roll sizes available for scheduling:

- Changes: paper with slitter, slitter without paper, and total runs

7. Roll tonnage



III. Annual variable costs (US$) per net 1000 ft^2

	No. of sizes available							
	10	*9*	*8*	*7*	*6*	*5*	*4*	*4–10*
Changes	0.63	0.62	0.61	0.60	0.59	0.58	0.57	-0.06
Running	1.52	1.51	1.50	1.49	1.48	1.47	1.46	-0.06
Subtotal	2.15	2.13	2.11	2.09	2.07	2.05	2.03	-0.12
Trim	0.43	0.48	0.53	0.57	0.62	0.66	0.70	+0.27
Total	2.58	2.61	2.64	2.66	2.69	2.71	2.73	+0.15

- Volumes: roll stock/1000 ft^2, trim/1000 ft^2, net good/1000 ft^2, and 1000 lineal feet
- Corrugator run widths in inches: roll stock, trim, net good, and percent trim
- Corrugator hours: changes, running, and total hours
- Corrugator speeds: lineal/total hour and net 1000 ft^2/total hour
- Summary and corrugator costs of the seven different combinations of sizes
- Number of consumed rolls and tonnage as number of sizes increase.

Changes required

In moving from 10 sizes to four sizes, 16 paper changes with a slitter are eliminated (**Fig. 1**). As might be expected, the number of pure slitter changes increases; they go up by 22. The net effect is that the total number of runs increases by six.

Volume produced

Roll stock required increased 43.9 x 1000 ft^2 in moving from 10 to four sizes (**Fig. 2**). Trim exploded from 70.6 x 1000 ft^2 to 114.5 x 1000 ft^2—a 62% increase. Lineal feet decreased as shown and will be explained in the next section.

Corrugator running widths

Due to the reduction in number of sizes from 10 to four, progressively eliminating the narrow widths, roll stock width increased 4.1 in. (**Fig. 3**). Trim increased 1.1 in. or 1.8–3.0%. Net good width increased 3.0 in., which explains the decrease in lineal feet shown in Fig. 2.

Corrugator hours

The 10 to four size decrease resulted in 0.9 fewer running hours and 0.7 fewer change hours for a total of 1.6 fewer machine hours (**Fig. 4**).

Corrugator speeds

Figure 5 ties all the production study results together. A thousand lineal feet per hour increased 1.6% due to the reduction of running and change hours. The net good width (excluding trim) increased 3.1%, while net square feet per hour increased 4.7%.

IV. Annual variable costs (US$) with 500,000 ft² x 1000

	No. of sizes available							
	10	9	8	7	6	5	4	4–10
Changes	315,000	310,000	305,000	300,000	295,000	290,000	285,000	–30,000
Running	760,000	755,000	750,000	745,000	740,000	735,000	730,000	–30,000
Subtotal	1,075,000	1,065,000	1,055,000	1,045,000	1,035,000	1,025,000	1,010,000	–60,000
Trim	215,000	240,000	265,000	285,000	310,000	330,000	350,000	+135,000
Total	1,290,000	1,305,000	1,320,000	1,330,000	1,345,000	1,355,000	1,365,000	+75,000
Four other sizes	75,000	60,000	45,000	35,000	20,000	10,000	...	...
Annual machine hours	4,340	4,296	4,155	4,212	4,170	4,143	4,101	...

Summary and total corrugator cost/net 1000 ft²

Figure 6 breaks down the total corrugator cost/net 1000 ft². The following amounts were used to figure costs for hours and for trim:

- Paper with a slitter US$ 17.88 + US$ 9.21 = $27.09
- Slitter without paper = US$ 9.21.

Running cost was US$ 225/h. This is a selected variable cost. It is not applicable to operating statements or price-estimating manuals. The costs used were selected to reflect only those costs that are variable due to scheduling differences. Here are the components:

- Direct labor: 6 people per shift
- Indirect labor: 3.2 people per shift
- Repair labor: 1 person 50% to corrugator/shift
- Shift premium: standard calculation for second shift
- Overtime premium: standard calculation factored
- Payroll taxes and insurance: standard calculation
- Power costs: assumed plant cost factored for corrugator
- Fuel and boiler: assumed plant cost factored for corrugator
- Repair material: assumed costs factored.

The rates used to assign these dollar amounts represent general industry average costs but are not applicable to any single corrugator location.

Trim costs for 200-lb C (42-26-42) are shown at current actual market price less baled waste credits:

liner (US$ 360/ton) + medium (US$ 319/ton) = US$ 347.50 avg. cost/ton

% 200-lb C = liner (69.5) + medium (30.5) – waste/ton (35.00) = US$312.50 plant cost of waste/ton

120.9 lb/1000 ft² x 2000
= 0.0605 tons/1000 ft²
= US$ 18.89/1000 ft²

US$ 18.89/1000 ft² + US$ 0.60 adhesive
= US$ 19.49 trim cost/1000 ft²

These costs were applied to quantities developed in Figs. 1–5. They are displayed in Fig. 6, which is a cost summary of the corrugator operations on 10 through four roll sizes available for scheduling.

In going from 10 to four sizes, change costs decrease US$ 0.06/1000 ft². This is due to the exchange of 16 paper changes for 22 pure slitter changes (Fig. 1).

Running costs also decrease US$ 0.06/1000 ft² (Fig. 5). Thousand square feet per hour increases due to an increase in net width (Fig. 3) and in lineal feet per hour (Figs. 4 and 5).

All told, there is a decrease in the cost of machine operation of US$ 0.12/1000 ft².

Trim changes are adverse as might be expected when going from 10 to four sizes. Inches increase from 1.4 to 2.5 (Fig. 3). Trim per 1000 ft² increases 62% (Fig. 2)! Even with roll stock width increases (Fig. 3), percent trim rises from 1.8% to 3.0%. The net effect is to increase costs/1000 ft² by US$ 0.23.

The bottom line is an increase of US$ 0.11/net 1000 ft² when going from 10 to four sizes.

If 10 sizes are the least expensive, why not 12? Problem is, how small can trim be in a general mix with no pretrimmed items? It is my opinion that 1.4 in. is the least that can be attained in a general mix. If that is true, let us extrapolate the costs of 12 sizes holding trim at US$ 0.38/1000 ft² (Fig. 6):

- Changes = US$ 0.64
- Running = US$ 1.47
- Trim = US$ 0.38
- Total = US$ 2.49 (the same cost as eight sizes).

I believe that the only way to further reduce trim is to take on long run, pretrimmed national accounts business run out of designer roll sizes that have only 0.75–1.0-in. trim. Costs would be reduced, but sometimes the selling price on this business is reduced more than the costs are reduced!

Let's look at the other end—four sizes. What would happen with three sizes? The problem is that, in some sets, the trim becomes too wide to go through the blower system to the baler. One thing to do is run the trim as a side piece for pads and partitions. Operators who have tried this find that the side pieces clutter up the warehouse waiting for orders, and ultimately a large portion ends up in the baler.

It would seem that 10 roll sizes are optimum for the corrugator operation. However, there are other factors that are adverse to an increasing number of roll sizes.

Figure 7 calculates the total number of rolls consumed and the weight per roll. It shows that the number of rolls increase as the number of sizes available increases. However, the tons per roll decrease as the sizes available increase. The net effect is a standoff in net tonnage required when trim tons are subtracted. This is confirmed by the calculations in Fig. 2.

An increase in the number of consumed rolls when going from four to 10 sizes does have an effect on the total operation:

1. Handling waste, thread and peel waste, and running splice waste increase with the necessity of handling, shafting, and running an increased number of consumed rolls. The quantity of waste increases, but this could be negated by the decreasing weight of the narrower rolls, i.e., more splices within a run but fewer square feet per splice.
2. The 4% increase in number of rolls required means more unloading, warehousing, and more service to the corrugator. Built into the US$ 225 variable cost per hour is a full one-shift unloading operation and a full two-shift roll servicing operation. This should be enough to handle a 4% increase, but if the operation is near or at capacity more unloading and service labor may be required.
3. The freight picture will change with more rail cars at smaller weights. This will affect freight costs when the number of rolls required to run a given volume is increased. It probably will be an adverse factor with a large number of sizes. I thought it would be misleading to include freight costs in the study because they represent such a large range of costs—some plants are next door to a mill while others obtain their stock from mills over 500 miles away.
4. Another adverse factor to a large number of sizes is the fact that the more sizes a given production quantity requires, the larger the basic inventory becomes. Several formulas available to measure the increase were applied to the four to 10 sizes. The results were rejected because they produced unreasonably high inventory increases. When number of sizes is increased, basic required inventory does increase because (a) a large number of sizes makes forecasting roll stock usage more difficult (and there is a tendency to order on the high side) and (b) a large number of sizes decreases individual size turnover, which increases the possibility of excess inventory. The outcome of this is a larger inventory capital investment and more warehouse space when going from four to 10 sizes.

The study was based on 180 items with 3400 ft^2 x 1000 of 200-lb C. **Table II** projects the cost to an annual volume of 500,000 ft^2 x 1000 with the product mix indicated.

Costs shown in Fig. 6 were adjusted upward as follows to reflect the total mix in Table II:

- Changes = +1.7%
- Running = +5.0%
- Trim = US$ 19.49/1000 ft^2 to US$ 22.27/1000 ft^2, or +14.3%.

Tables III and IV show the difference between four sizes and 10 sizes. It has been proposed, but not quantified, that the more sizes, the more additional freight and inventory costs. The figures at the bottom are the upper limits of additional freight and inventory costs that can be absorbed.

In summary, corrugator change and running costs decrease as the number of sizes decreases. However, trim costs become so large that the net effect is an increase in total cost as the number of sizes decrease (Fig. 6). From the corrugator's point of view, 10 sizes are optimum.

Tempering this is an increase in freight costs and inventory carrying costs with an increase in number of sizes. The corrugator would like a large number of sizes, but other plant costs are lower with a smaller number of sizes.

There is no universal optimum number of sizes; it is unique for each plant. I can only suggest that each plant determine its own optimum number of sizes using the methods outlined in this study. ■

Received for review July 1, 1992.

Accepted Aug. 3, 1992.