Standards and efficiencies for corrugated work centers

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ABSTRACT: TAPPI's earlier Productivity Surveys for the corrugated container industry (1970–89) produced benchmark efficiency percentages based on simplified time standards for setup and run time. These benchmarks were established without benefit of such statistical information as square footage, number of pieces or fed sheets, and setups. Changes in automation and mix of work have made these efficiency percentages obsolete. The new Productivity Survey eliminates time standards in favor of statistical data. This report discusses the use of statistical and computer techniques to provide meaningful measures of parameters governing corrugated container work centers. Using techniques of modern time study, productivity information can be enhanced with performance standards that reflect true skill and effort.

KEYWORDS: Corrugated boxes, efficiency, folder gluers, man/machine systems, productivity, standards, statistical analysis, surveys, work study.

TAPPI has conducted an annual survey on productivity since 1970. The Industrial Engineering Committee of the Corrugated Division initiated a program in 1968 that involved creating time standards for the various work centers in the industry. The first manual was published in 1970 *(1)*. Revised manuals were published in 1986, 1991, and 1992 *(2–4)*.

The original project, initiated by industrial engineer Les C. Wightman of the Hoerner Corp., was carried on for two decades by other industrial engineers. The early standards were based substantially on the experience of the Hoerner Corp. and Owens–Illinois. A group of companies applied these benchmarks to their production by work center, and the survey developed efficiencies based on all participating entries. This project made a vital contribution to our industry but gradually became outdated.

One problem of this survey was that efficiency percentages were the only analytical figures provided. For example, the 1983 TAPPI Productivity Survey showed an average efficiency of 72.5% on flexo folder–gluers in the size class "28 in. x 72 in." There was no information on machine specifications, mix-of-work specifications, production per man-hour, production per machine hour, average setup time, percent downtime, crew size, or other similar data. This lack of data became a serious criticism of the TAPPI survey.

The time standards for the flexo folder–gluers of the 28-in. x 72-in. class comprised only two numbers, one for setups and one for runs. These standards, shown in minutes and hours in **Table I**, were expressed in man-time only.

The criticism of these standards was that they were too crude. They address the two variables of setups and area without considering the third fundamental variable: the number of pieces. There is a difference between a 4-ft^2 box, a 14-ft^2 box, and other in-between sizes. Other conditions being equal, a given total averaging 4 ft^2 in box area is a more efficient performance than the same total square footage averaging 14 ft^2 in box area. Many more pieces are produced with the smaller unit square footage. Such size differen-

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In early 1991, the TAPPI Productivity Survey Subcommittee abandoned all references to time standards because of the confusion that had previously occurred. Nevertheless, there was general agreement that, some time in the future, pertinent standards should be reestablished.

Beginning in 1991, the TAPPI survey inserted a tremendous amount of statistical information that was of great interest to the corrugated community. In the latter 1980s, the survey did show some select information on production statistics, but it was spotty and not well reconciled with the standards. Meanwhile, the time standards had not been updated to reflect the effect of automation in the industry or the substantial changes in mix of work. Automated corrugators started to show efficiencies as high as 300%. Semiautomatic finishing often showed efficiencies as low as 30%. (All of the good shape boxes were now produced on flexo folder–gluers.) Recall that the performance efficiencies reflect skill and effort and that changes in method or automation or mix of work require changes in standards. Consequently, the wholesale abandonment of the standards and a reliance on structured statistical information were in order.

The statistical information in the revised TAPPI format involved reporting surface area produced (square feet or square meters), production (measured in pieces, fed sheets, or lineal feet or meters), setups, and complexity units. Actual time was reported in man-hours and machine hours, and the machine hours were broken down into run time, setup time, and down/cleanup time. A series of analytical calculations showed area and production per man-hour, per total machine hour, and per run machine hour. Average setup time was shown in minutes, and average downtime was shown as a percentage. Mix-of-work information showed average order size in area and in production units.

This information was well received by the corrugated community. One could now evaluate one's corrugator or flexo folder–gluer experience and compare that production within the company and with the industry as a whole.

I. Early time standards for the flexo folder-gluer

Description	Man-time per setup, min (h)	Man-time per 1000 ft², min (h)
1983 flexo folder-gluer	61.1 (1.018)	3.24 (0.054)

Base common denominators

The original TAPPI approach referenced the following four factors:

- Setups
- Area (square feet or square meters)
- Pieces, fed sheets, or lineal length (feet or meters)
- Basis weight.

Even this format was inconsistently used. For example, the area factor was often used on operations with no reference to a pieces factor, even though this factor obviously existed, as already discussed for the flexo folder–gluer. Setup standards were nonexistent on operations with short setups, though they again obviously existed. The same basis-weight correction factors were used on all converting operations, even though basis-weight increases had a much smaller effect on semiautomatic tapers than on printer–slotters. These factors are readily corrected in the computer environment. The basic statistics recently collected by TAPPI include production data on these four common denominators.

Basis weight

Two hundred-lb-test C-flute weighs 120 lb per thousand square feet (MSF). Because it is the most common grade, it should be considered a base reference for measuring the impact of basis weight in analyzing standards and efficiencies. Most industrial engineers observe that there is no increase in speed for grades that weigh less than 120 lb/MSF. On the other hand, there is a slowdown impact when the mix of work exceeds 120 lb/MSF. The impact of greater basis weight is 45% for a nonprefeeder flexo folder–gluer. For example, if the basis weight is 180 lb/MSF, this is a 50% increase beyond the base. Applying the 45% factor to the 50% increase, the result is an increase in the standard time of 22.5%.

The basis-weight factors vary with machines (such as a semiautomatic taper vs. a flexo folder–gluer), and they may differ for different specifications of the same machine (nonprefeeder flexo folder–gluer vs. prefeeder flexo folder–gluer).

Mix-of-work or complexity considerations

The purpose of any new standard is to energize the corrugated community on the benefits of the standard and to chart the technical approach to implementing the standard. Thus the definition of corrugated complexities beyond the four well-known common denominators (setups, area, pieces, basis weight) is important.

By focusing solely on these four base common denominators, the original TAPPI standards failed to recognize the various complexities that exist throughout the industry. These complexities, more profound today than they were 25 years ago, can be identified as follows:

- Base crew definition
- Box shape or sheet shape
- Color and diecut stations

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- Box shape or sheet shape
- Color and diecut stations

II. 1983 vs. 1993 standards

Description	Machine time per setup, min (h)	Machine time per MSF, min (h)	Machine time per M pcs., min (h)
1983 actual standard	30.55 (0.5090)	1.62 (0.0270)	-
1993 average base std.	11.00 (0.1833)	1.15 (0.0191)	-
1993 actual base std.	11.00 (0.1833)	0.35 (0.0058)	4.30 (0.0717)

III. Typical cube boxes and shape penalty boxes

Cube boxes		Shape penalty boxes	
in.	mm	in.	mm
7 x 7 x 7	178 x 178 x 178	10 x 4 x 10	254 x 102 x 254
10 x 10 x 10	254 x 254 x 254	15 x 5 x 15	381 x 127 x 381
13 x 13 x 13	330 x 330 x 330	19.5 x 6.5 x 19.5	495 x 165 x 495

IV. Standards for a 28 in. x 72 in. flexo folder-gluer

Description[a]	Setup, min (h)	Per M ft^2, min (h)	Per M fed pcs., min(h)
Base standard	11.00 (0.1833)	0.35 (0.0058)	4.30 (0.0717)
Single-box shape, upfold	-	0.05 (0.0008)	0.15 (0.0025)
Double-box shape, upfold	-	0.10 (0.0017)	0.25 (0.0042)
Each color or diecut station	5.50 (0.0917)	-	0.35 (0.0058)
Feeder's helper, > 95 united in.	-	-	3.50 (0.0583)
Each print complexity	2.00 (0.0333)	-	0.75 (0.0125)

[a]Conditions: Two-man base crew, return conveyor, upfold method, no prefeeder, computerized setup, lead edge feeder, load former

- Specification complexities
- Crew additions (e.g., a feeder's helper required on large sheets)
- Multiple outs
- Machine limitations.

Beginning with the 1991 TAPPI survey, the concept of "unit complexities" was introduced. The survey asked for an input of printing color stations and diecut stations used on a work center, since it was clear that multiple-color jobs or diecutting in addition to printing required more time. The survey requested the number of color and diecut stations used in addition to the number of setups. The term "unit complexities" refers to other types of complexities on other operations.

Base crew and machine- vs. man-time standards

The base crew on flexo folder–gluers with sizes up to 28 in. x 72 in. may be either two persons or three persons. The crew is often linked to the layout of the machine. In the straightaway layout, the feed section, printing section, folding section, and bundling and stacking-off are all in a straight line. The three-person crew consists of the feeder at the beginning, the operator stationed typically at the spiral or ejection section, and the stacker at the far end.

The alternate arrangement is to supply a return conveyor from the spiral or ejection point through the bundler and back to the ejection point for stacking off. This permits the operator to stack off the boxes while remaining "on top of" the machine controls to deal with jam-ups, etc. Consequently, this configuration requires only a base two-person crew.

There should be a different standard for a machine crewed with three people compared with one operated with two. The return-conveyor method, with its reduced base crew, is likely to be a lower-cost alternative in most situations. However, conditions will vary from plant to plant. Whatever difference exists in production opportunity is beyond the control of the crew; therefore a different standard may be required. The original TAPPI standards were manhour-oriented only, and therefore blurred this distinction.

Example: Comparison of 1983 and 1993 standards for 28-in. x 72-in. flexo folder–gluer. It is pertinent to compare the old generalized standards of 1983 with the modern standards that reflect the many complexity parameters. These times are expressed in machine times for a two-person crew and are shown in **Table II**. Note the large difference in the setup standards and the run standards. The average base standard is calculated at 5.4 ft^2, the average size processed through this flexo folder–gluer. The last line features a footage and a pieces component.

The reduction in standard times is due in part to improvements that have been made this decade, permitting a lower time standard for the same skill and effort. However, the major difference is that the early standards were generalized. They included, but did not spell out, all of the complexity factors. The new base standards apply to the simplest condition or mix. The intent is to apply additional allowances to all the complexities being identified. This should provide a level of accuracy in standards and in efficiency measurement that was not previously possible.

Box shape or sheet shape

The dialogue in this description is specific to the flexo folder–gluer and to the size up to 28 in. in sheet width by 72 in. in sheet length. Obviously there are similar considerations on every corrugated work center.

The first complexity factor is box shape. For a given square footage, a cube box runs fastest, with other factors being equal. Consider a 7-in. x 7-in. x 7-in. box and compare it with a 10-in. x 4-in. x 10-in. box. Then consider a 10-in. x 10-in. x 10-in. box and compare it with a 15-in. x 5-in. x 15-in. box. Finally, consider a 13-in. x 13-in. x 13-in. box and compare it with a 19.5-in. x 6.5-in. x 19.5-in. box. Note that the first pair has the same blank size (15 in. x 30 in.) and the same square footage (3.125 ft^2). The same is true of the second pair (21-in. x 42-in. blank size and 6.125 ft^2) and the third pair (27-in. x 54-in. blank size and 10.125 ft^2). The cube box runs best, so we define the other shapes as requiring a box-shape allowance.

Most industrial engineers define a narrow-width allowance as one where the box length is 2.5 times or greater than the box width. Also, most engineers define a depth–width allowance as one where the box depth is 2.5 times or greater than the box width. Finally, most industrial engineers define a shallow-depth allowance as one where the box width is 2.5 times or greater than the box depth (as on a 13-in. x 13-in. x 5-in. box). **Table III** provides examples of cube boxes and "shape penalty" boxes.

Table IV shows the effect of various complexities on the standards for a 28-in. x 72-in. flexo folder–gluer. There is a time penalty for quality (square folding), defined as box length to box width, box depth to box width, or box width to box depth. There is a considerable penalty on upfold flexo folder–gluers, while there is a smaller effect with downfold units. Study the impact of the proposed box-shape standards on the suggested time values in **Tables V and VI.**

A box-shape allowance occurs on all operations involving panel folding. For example, it occurs and is a critical element on semiautomatic gluing, taping, and stitching. Other operations such as printer–slotters, slitters, etc., involve sheet-shape considerations but not box-shape considerations. The sheet-shape allowance is different from the box-shape allowance.

V. Standards for flexo folder-gluer base and box shape jobs

Box size, in.	Sheet size, in.	Sheet area, ft^2	Std. min per 1000	Prod/h, 100% eff.	Prod/h, 80% eff.
7 x 7 x 7	15 x 30	3.125	5.39	11,124	8,899
10 x 4 x 10	15 x 30	3.125	5.96	10,073	8,059
10 x 10 x 10	21 x 42	6.125	6.44	9,311	7,449
15 x 5 x 15	21 x 42	6.125	7.31	8,212	6,570
13 x 13 x 13	27 x 54	10.125	7.84	7,649	6,119
19.5 x 6.5 x 19.5	27 x 54	10.125	9.11	6,589	5,271

VI. Production example for flexo folder-gluer

Quantity	Colors	Box shape	Grade	Box size, in.	Sheet area, ft^2	Set-up, min	Run/M, min	Extended, min
5,000	1	-	200C	7 x 7 x 7	3.125	16.50	5.74	28.70
10,000	2	2	200C	10x4x10	3.125	22.00	6.66	66.60
5,000	1	-	200C	10x10x10	6.125	16.50	6.79	33.95
6,000	PL	2	200C	15x5x15	6.125	11.00	7.31	43.86
4,000	2	-	200C	13x13x13	10.125	22.00	8.54	34.16
11,000	1	2	200C	19.5 x 6.5 x 19.5	10.125	16.50	9.46	104.06
41,000	Totals					104.50		311.33

Total standard hours	6.93
Actual productive hours	7.50
Productive efficiency	92.41%
Actual total hours	8.00
Net efficiency	86.63%

Color and diecut stations

Consider the 200 flexo folder–gluer setups shown in **Table VII**. The color-complexity allowance is 5.5 min per station utilized, as seen in Table IV. The color stations add 1650 standard minutes to the time values for these 200 setups, as seen in Table VII.

Some engineers choose not to distinguish between the "plains" and the "one-colors," since both have some printing. By plain jobs, we mean stock boxes or boxes with the required certificate and box-number printing but with no customer plate printing. Stock dies, such as "This Side Up" and certificate printing, should be defined as plain. Setups are shorter, not only because of fewer dies, but also because any ink is used. Similarly, there is a small run increment for each color to monitor the quality on customer dies. If a flexo folder–gluer configuration contains a diecut station, it should be considered as a complexity when it is used (Table IV).

VII. Distribution of 200 flexo folder-gluer setups

	Setup	*Complexity units*	*Complexity setup, min*
	50 plains	0	0
	50 one-colors	50	275
	50 two-colors	100	550
	50 three-colors	150	825
Total	200	300	1650

VIII. Definition of united inches

English units			*SI units*		
Sheet width, in.	*Sheet length, in.*	*Sheet area, ft²*	*Sheet width, mm*	*Sheet length, mm*	*Sheet area, m²*
15	80	8.333	381	2032	0.774
20	75	10.417	508	1905	0.968
25	70	12.153	635	1778	1.129
30	65	13.542	762	1651	1.258
35	60	14.583	889	1524	1.355
40	55	15.278	1016	1397	1.419
45	50	15.625	1143	1270	1.452

Specification complexities

Specification complexities have much less effect on the flexo folder–gluer than they had on letterpress units. The following require some increase in setup time and some reduction in run speed:

- Close registration
- Each 100 in.^{2} of solid or block printing
- Fine legend or UPC printing
- Trapping
- Heavy lead-edge printing
- Halftones and complex graphics.

There are also diecut complexities that should be identified.

Crew additions

On a nonprefeeder flexo folder–gluer, the feeder needs a helper at some point. This point is sometimes defined as 12 ft^2, but this is not a technical answer. This point has also been defined as 70 in. in blank length (across the machine), but again this is no technical answer. When area alone is used to define the crossover point, there are obvious errors. Similarly, when blank length alone is used to define the crossover point, there can be errors. The best recommendation in determining this point is to use 95 united inches (sum of sheet width and sheet length). Obviously, in practice this is a guideline rather than a rigid practice.

Note the variation in sheet length and square feet for various sizes in the definition of united inches in **Table VIII**. This chart shows an 8.333-ft^2 box that is at the limit and another box at 15.625 ft^2 at the limit. Only the united-inch concept defines a technical guideline. The united-inch standard varies from machine to machine. A standard of 95 in. is appropriate for a printer–slotter or a flexo folder–gluer, and then only for a machine with no prefeeder (Table IV). A significantly higher figure would be used for a semiautomatic taper or a slitter.

In terms of efficiency skill and effort, the united-inch additional allowance should be applied as a standard where it is warranted, whether or not the crew uses a helper. If the crew uses an extra helper when it is not warranted, the actual time should be charged, but no penalty standard allowed. When the crew operates without an additional helper when it is warranted, the standard should be allowed. This application reflects true skill and effort.

Multiple outs

Machines such as printer–slotters and slitters process multiple outs, and this requires a standard to handle the complexity. The statistical method of treating this factor is to develop a standard time per thousand fed sheets (on the feed side of the machine) and another standard time per thousand removed sheets (at the take-off side of the machine). If the operation is a true multiple out, the standards will handle this factor automatically.

Machine limitations

There are specific limitations that can be handled as part of the machine specification, and these create complexity allowances. Skipfeed on a printer–slotter is an example of this. Another example is a shallow sheet passing through a printer–slotter (one that is not fully controlled as it transits from one machine section to another).

Task

In a high-task system *(5)*, 100% efficiency is very good, as would be a 100% grade on a school examination. In common low-task parlance, 100% is often used to mean the present average performance, typically mediocre, and the design of the system is to show improvement over time. Low-task performance is often observed to be 66.7% of high-task, as shown in **Table IX.**

The standards in the TAPPI Productivity Surveys from 1970–1989 were described in the manual as standards at low task. The standards were based on good performance at Hoerner and at Owens–Illinois. In general, the mix of work at these two companies was more simple than complex. In any case, the original standards were certainly not what is commonly understood as "low task," despite the definition in the productivity surveys. Most companies had efficiencies of 70–89%, and only a small group averaged 100% or better.

In other discussions at TAPPI, the standards have often been described as the performance of the top 15% of the companies. This would certainly be a high-task reference, and this orientation should be continued.

Standards expressed in minutes or hours

Both standard minutes and standard hours are used in the corrugated industry. Most industrial engineers prefer standard minutes because factory personnel find them easier to understand. It is easier to refer to a setup as 20.00 min rather than 0.333 hours. It is also easier to refer to a run speed at 6000/hour as 10.00 min/thousand rather than 0.1667 hours/thousand. In our documentation, both minutes and hours should be used.

Payroll time is universally expressed as actual hours worked. The computer system converts the standard minutes into standard hours for all summary reports.

Productive efficiency vs. net efficiency

In production, a distinction is made between productive work (both setups and runs) and nonproductive work, which comprises various classes of downtime and end-of-shift or end-of-day machine cleanup.

The extended productive work standards are divided by actual productive time to obtain productive efficiency. For example, if the crew "earns" 7.0 standard hours during a shift and the actual productive hours are 7.0, the productive efficiency is 100%. However, the actual payroll, including downtime and end-of-shift cleanup, may be 8.0 hours. Divide 7.0 earned hours by 8.0 worked hours, and the net efficiency is 87.5%. This device protects the crew on productive work performance, since the crew has no immediate control over downtime and machine cleanup. However, from a cost point of view, the company must pay for the extra hour. This is the rationale for the concept "net efficiency."

Application of modern time standards

The best application of modern time standards is at the local plant level. Note that it is possible to define not only the four basic common denominators, but also the several complexity parameters described in this article. Other considerations, such as base-crew concepts and machine limitations, are readily documented. The good news is that all of the arithmetic involved in these calculations can be transparent to the user, assuming the use of an up-to-date computer system. This means that all calculations concerning standards and efficiencies are done automatically in the computer environment.

There are various mechanisms for reporting production from the factory floor. Basic reporting involves: identifying the order; identifying the work centers and personnel; and identifying time changes in setups, runs, downtime, and cleanup. Much of this information is automatic in some plant environments.

IX. Task performance

Performance	High-task	Low-Task
Average incentive	100.0%	150.0%
Average day work	66.7%	100.0%

This report articulates the application of standards for one machine, a 28-in. x 72-in. flexo folder–gluer. However, there are similar considerations for all of the other direct-labor machines in the corrugated environment. There are also similar approaches for controlling the several indirect-labor work centers. The established science and art of Industrial Engineering studies should be respected, but it is different today than it was in the past. One should expect meaningful and accurate data without burdensome overhead for monitoring the results.

The TAPPI Productivity Survey has accomplished a great deal by reigniting an interest in efficiency considerations throughout the industry. This survey can evolve with enhancements each year to make it ever more useful to the corrugated community. Perhaps some of the described computer disciplines, which are readily used at the local level, might also be used in a similar international survey. In any event, the survey and the additional use of modern time standards should complement each other.

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