

**USING CYCLE TIME TO MEASURE PERFORMANCE
AND CONTROL COSTS IN FOCUSED FACTORIES**

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Abstract

In today's exceptionally competitive marketplace, manufacturers must fully satisfy their customer needs as cost efficiently as possible. To fulfill these dual, often competing, objectives, many companies have adopted a focused-factory configuration. In focused factories, unique products and/or processes are segregated and separately monitored, and the cycle times required to complete key bottleneck operations become critical indicators for performance evaluation and cost control. This paper describes how cycle time metrics in conjunction with traditional cost variance analysis can be used in a focused factory that includes production cells. It presents several general-purpose reports that could be prepared to identify cycle-time efficiency and non-value added cost. It then presents a detailed example showing how Parlec, Inc. a Fairport, NY tool-making company, actually employs cycle-time metrics for a variety of internal reporting purposes.

I. Introduction

Management has two distinct objectives in controlling manufacturing operations in focused factories. The first is to measure performance, typically by evaluating cycle time and capacity utilization relative to physical benchmarks or predetermined standards. The second is to control costs, usually by identifying and then eliminating inefficiencies relative to the plan or budget. Ideally, a firm's internal information system fulfills both objectives, although in large, diverse companies, performance measurement and cost control may engage different top managers and necessitate different responses. This paper will illustrate how cycle time metrics, in conjunction with traditional cost variance analysis, helps fulfill both dimensions of management control.

We initially discuss the reasons cycle time should be measured and describe its growing importance in focused factories that include production cells. We provide several hypothetical examples showing how cycle time metrics could be combined with accounting variances to produce cost control and performance evaluation reports. In the second half of the paper, we describe how Parlec, Inc., a Fairport, NY tool-making company measures and uses cycle time. We also provide examples of the actual cost control and performance reports that Parlec prepares on a regular basis.

II. Why Measure Cycle Time?

In the not too distant past, customers had to choose among a limited number of option packages if they wanted anything other than stock products. Customers may have preferred a different combination of accessories, but they understood that fully satisfying their preferences meant longer lead times and far higher prices. In today's marketplace, customers have innumerable sourcing opportunities and purchase channels, and as such, they increasingly expect manufacturers

to fulfill all of their needs on a timely basis. Manufacturers are keenly aware that to accomplish the dual pressures of meeting financial targets and maintaining loyal customers they must fully meet customer needs. In this environment, focused factories have replaced traditional assembly line manufacturing (Davis, 2000), and cycle time has become one of the most critical performance indicators.

Cycle time (CT) has been defined as “the length of time between starting and finishing the production of an order” (Brabazon, 1999, p.48). In a broad sense, CT incorporates four time elements that are often described as activities: 1) processing, 2) waiting, 3) moving, and 4) inspection. Although there is some debate about inspection,¹ processing is an activity that changes the composition of the product and thus adds value from the customer’s perspective. Clearly, the actual time to process an order must be monitored carefully, both to ensure efficient performance as well as to evaluate possible design changes in light of new materials and technology. Non-value adding (NVA) manufacturing costs derive from two main sources: 1) the costs directly associated with NVA activities like order expediting or defect correction, and 2) the excess costs associated with value-adding activities like processing. These latter NVA costs occur either by not reaching predetermined capacity levels, exceeding spending targets, or a combination of the two. In an era of build-to specifications, intense competition, and shrinking margins, measuring cycle time and reducing NVA costs have become important managerial focal points. As we will illustrate, measuring and evaluating actual processing time are key elements of Parlec’s information system.

III. Cycle Time, Focused Factories, and Cellular Manufacturing

In recent years, American manufacturers have responded to the dual pressures of reducing costs and meeting customer needs by adopting focused factories and cellular manufacturing. Focused factories are basically departments that have been separated for purposes of costing, headcount

and lead-time reduction, and for organizing support functions such as engineering and quality control. Whereas traditional manufacturing is often done on a continuous, assembly-line format, focused factories partition the shop floor into work centers and manufacturing cells, either on the basis of products or processes. A number of companies have adopted focused factories and promote their benefits on the company web sites. For example, Litton Guidance & Control Systems Division, a California defense contractor, reports that focused factories in conjunction with flexible hours, the Perfect Team concept, and pay for performance, enabled the company to realize a 9:1 dollar return on their investment in employee development, lower scrap rates, better yields, and reduced product costs (http://www.bmpcoe.org/bestpractices/internal/litg2/litg2_25.html). Artco-Bell Corporation, a Texas manufacturer of school furniture credits focused factories and JIT manufacturing for promoting improvements in process efficiencies and production output (http://www.midwestfolding.com/strategicpartners_one.html).

In focused factories that have highly diverse product lines and that utilize multiple and highly specialized production cells, a plant-wide, labor-based absorption rate usually provides little guidance for measuring cell performance and may actually distort cell costs, especially when cells are highly automated. However, the costs of creating individual cell overhead cost pools and absorption rates may not be beneficial, especially in small factories that produce relatively homogeneous products. In the case of Parlec, Inc. management determined that direct labor cost (i.e., the cost of machine operators and product assembles) would better serve as the basis for assigning plant overhead costs to manufacturing cells and work centers, and that a labor-based, plant-wide overhead rate would not be distortionary.

Clearly, alternatives to a single plant-wide allocation rate have been discussed widely in the literature. They include multiple allocations, cost pools, and cost drivers with Activity-Based Costing (ABC) (Cooper & Kaplan, 1992; Dhavale, 1992); the elimination of overhead allocations

in line with the Theory of Constraints (TOC) (Low, 1992); and more recently the integration of these two approaches (Coate & Frey, 1999; Cooper & Slagmulder, 1999). Proponents of ABC have argued that the benefits of more accurate product costs and the identification of cost reduction opportunities far exceed the costs of implementing and maintaining a complex cost accounting system. Those favoring TOC contend that the key issue for improving financial performance is the identification of bottleneck constraints and the subsequent increase in throughput rates and that all cost allocation procedures are essentially arbitrary and unreliable. Those supporting the integration of ABC and TOC believe that accurate costings and increased throughput rates are both critical and comprise interdependent dimensions of effective financial performance. In this regard, Spoede, Henke and Umble (1994, p. 43) have written that ABC has the potential “to generate the data necessary to support the Theory of Constraints management process.” In a later section of the paper we describe how Parlec, Inc. uses cycle time metrics to support the integration of ABC and TOC

IV. Using Cycle Time to Measure Performance

Initially, we lay out what a company might use cycle time metrics to measure and evaluate the performance of its production cells. Consider Acme Inc., a fictitious company that produces toasters and other counter-top consumer appliances in production cells. Like many firms that have adopted cellular manufacturing, Acme uses cycle time to assign conversion cost to output. For the purpose of our illustration, cycle time will be restricted to the processing activity. Assume that conversion cost in the toaster cell for 20X1 is completely fixed relative to output and is budgeted at \$1.56 million per annum.ⁱⁱ Total available cell time in the toaster cell is 4,160 hours (2 shifts * 8 hours * 5 days * 52 weeks) and conversion cost per hour is \$375.00 (\$1,560,000/4,160 hours) based practical capacity.ⁱⁱⁱ Thus, if 52,000 toasters are the expected (i.e., planned) level of

production for each shift per annum, planned average per-unit cycle time is 0.04 hours (4,160/104,000) and planned conversion cost per unit in the toaster cell is \$15 ($\$375.00 * 0.04$). Assume further that in Q1 each shift actually works 500 hours, day shift output 12,500 units, and night shift output is 13,750 units.

As mentioned, production cell performance is frequently evaluated according to cycle time efficiency relative to an external benchmark, although other measures of cycle time that identify non-processing NVA costs could be used.^{iv} For our example, assume that the physical benchmark for processing in toaster cells is 30 units per hour or 124,800 units per year (30 units * 4,160 hours) again computed at Acme's practical capacity (i.e. two 8-hour shifts). Thus, benchmark average per-unit cycle time is 0.033 hours (4,160/124,800) and projected annual cycle time efficiency is 83.3% (104,000/124,800). Note also that the benchmark conversion cost per unit rate is \$12.50 ($\$375.00 * .0333$).

Table 1 shows how actual and planned cycle time efficiency rates might be reported for each shift for the toaster cell during Q1, 20X1. The last column of the report reflects the financial impact of failing to achieve the benchmark level of cycle time efficiency by not working to Acme's practical capacity level of output and thereby burdening output with a higher-than-benchmark conversion cost rate. Note that this report could be used to evaluate cell performance, both on shift-to-shift or time-series basis relative to planned and external benchmarks. However, the report does not provide useful information for controlling cell costs. The next section of the paper provides a more detailed example that can be used for this purpose.

 Insert Table 1 about here

V. Using Cycle Time to Control Cell Costs

Many firms report using cycle time to measure performance and describe how reducing cycle time has helped them achieve better financial results. However to the best of our knowledge, no one has illustrated how cycle time could be incorporated with accounting variances to identify and measure non-value added costs. The current section of the paper illustrates this procedure in a general sense. The next section describes what Parlec, Inc. has done in this area. Table 2 presents a simplified budget report that separates capacity information from cost control information. It is based on the same data we used in our earlier example.

 Insert Table 2 about here

Notice that conversion cost charged (i.e., applied) to products is less than the cost incurred. NVA cost arises because the conversion cost rate is based on practical capacity and that level exceeds planned capacity. As noted earlier, expected average conversion cost at the budget is \$15.00 per unit ($\$1,560,000 / 104,000$ units); however at the benchmark, average unit cost is \$12.50 ($\$1,560,000 / 124,800$ units). Clearly, the higher unit cost at the budget represents the inability to meet benchmark throughput rates and, we believe, should be reported as an NVA cost. In our example, there are not enough units to be produced over which the cell's fixed costs can be spread. As a result, the average unit cost at the budget is higher than at practical capacity because the cost of *not* producing is being spread over the units that *are* produced. Therefore, one could argue that the benchmark \$12.50 per unit represents the cost at which there is no throughput inefficiency to burden the units at the planned level of production.

The cost at the benchmark can be perceived as the "true" or target cost at which units should be produced, given both current benchmark technology and Acme's current practical

capacity. Cost applied to output is \$375.00 conversion cost per hour (\$1.56 million/4,160 hours) times benchmark cycle time 0.0333 hours (4,160 hours/124,800 units), which is \$1,300,000 (104,000 units * 0.0333 hours per unit * \$375.00 cost per hour). The unapplied cost (\$260,000) represents the cost of underutilizing capacity rather than a cost of manufacturing products. Thus, the assumption in this report is that the inability to meet the benchmark output is not a true cost of production but rather a non-value added cost.

If cell technology is current and comparable to benchmark technology, then efforts at cost control by management would be misguided if they did *not* focus on capacity management, that is, by reducing cycle time and increasing throughput rates. On the other hand, if Acme's technology lags benchmark technology, then the non-value-added cost can be eliminated only by investments in additional technology and should not be attributed to cost control failures by operations managers.^v Based on this premise, cost reports should show \$12.50 rather than \$15.00 as the correct conversion cost for toasters. Thus, non-value added cost is not applied to products but is highlighted and remains unapplied in the cost center. When aggregated across the organization, non-value added cost provides powerful strategic information to evaluate operations.

The above assumptions can also be used to prepare year-end reports to evaluate cell performance. Suppose that 70,000 units are actually produced during the year. Both shifts operate continuously (i.e., 4,160 total hours) and conversion cost incurred is \$1.8 million, again assuming that all conversion costs are fixed relative to output. A year-end performance report is shown in Table 3.

Insert Table 3 about here

The \$240,000 variance for conversion cost incurred represents a spending variance. This is a 'true' spending variance that represents price changes, waste, and additional costs associated with utilizing cell resources. The \$425,000 variance in conversion cost absorbed (charged) to output represents the inability of operations to produce at planned output. This variance is the responsibility of operations managers who produced 70,000 units rather than the throughput plan of 104,000 units. Thus, the \$425,000 variance represents a 'volume variance', which is the increase in cell cost that could not be applied to products relative to the budget or plan ($\$12.50 * (104,000 \text{ units} - 70,000 \text{ units})$). Total non-value added cost has increased to \$925,000 which represents the combination of the 'volume' variance of \$685,000 ($12.50 * (124,800 - 70,000)$) and the \$240,000 spending variance. While the above examples describe the ways a company *might* report cycle-time internally, the next section describes how Parlec, Inc. actually incorporates cycle time metrics within its internal information system.

VI. Parlec, Inc.'s Cost & Control Reports^{vi}

Parlec, Inc. is a private, tool-making company with 2001 revenues of \$20.5M. Parlec uses 500 industrial distributors and a 250-page catalog to market its products to end customers that use CNC tool-cutting devices. Customers include the big-three domestic automakers and other major manufacturers like Boeing, John Deere, and Caterpillar. Parlec has six distinct product lines that range from the commodity-type toolholders that sell for as much as \$1,000 a unit, to multi-function workholding machines that sell for \$20,000 in a marketplace with only three primary competitors.

Parlec markets itself as a one-stop shop and is competitive in all six product-lines. It maintains over 6,000 active catalog part numbers and another 8,000 components. Eighty percent of Parlec's overall sales are made to stock catalog items, while the other 20% are "special" make-

to-order applications. Because the average lot size is 40 units, Parlec has frequent setups and large setup costs. The raw material component, chiefly bar stock, comprises about a third of manufacturing costs. The other two-thirds are labor and capital, the latter chiefly flexible CNC equipment.

Parlec currently employs 120 people in its Fairport, NY facility, 45 of which are classified as direct (i.e., machinists and assemblers), and another 20 directly support the manufacturing operation in the areas of engineering, quality, supervisory, or maintenance. Three of these employees are dedicated to quality control (QC) inspection, assistance, and auditing. Parlec has 40 distinct work centers, 10 of which are manufacturing cells comprised of two or three sequential machines. Each work center usually has one direct worker who also has inspection and quality responsibilities. Distributing these latter responsibilities to machine operators allowed Parlec to reduce its QC support staff from ten to three people.

In 2000, Parlec employed over 220 people and had revenues of \$24M, but like other precision toolmakers Parlec has been severely impacted by the recent economic downturn, although the company has been able to increase its market share in all six-product lines. Parlec continues to operate three shifts, in part, because the best (i.e., most flexible) operators prefer to work on the 3rd shift.

Parlec has five data-collection workstations that capture nearly 500 transactions per day. At each station, a barcode sheet captures data on time and attendance, set-up, job runs, scrap, and operation completion. Data is measured in “near-real time” and is posted every five minutes. Schedules for each work center are centrally posted and are updated daily, and individual job sheets list predetermined times for move hours, queue hours, and set-up hours for each job. The sheets also break down time on a per piece basis. Parlec assigns one of its better machine operators to create the standard cycle time per part, which is measured on a part-to-part basis.

Jay Nuccitelli, VP Operations, oversees manufacturing production, materials management, and plant maintenance. One of his most pressing concerns is training machine operators to become multi-skilled and certified in order to address bottleneck operations. Jay regularly monitors work center and production cell performance and continually seeks to reduce tooling and processing costs, especially in bottleneck centers. To accomplish these goals, Jay and other top executives converted Parlec into a focused-factory that isolates costs by product line. Because one of the six products is purchased, Parlec has five “focused factories” that Jay evaluates on two different tiers. The first tier is at the gross margin level, which is computed as revenues minus standard cost of goods sold. The second tier is the manufacturing margin, which basically measures actual expenses like direct labor cost, variable and fixed overhead expense, as well as manufacturing absorption and variances. The overall dollar amount left over after subtracting these expenses and corresponding overhead represents Parlec’s manufacturing margin (See Exhibit I).

 Insert Exhibit I about here

Parlec’s gross margin usually exceeds manufacturing margin because gross margin is calculated using ideal time and labor standards as well as ideal material allowances. The differences between gross margin and manufacturing margin indicates where Parlec is more or less efficient compared to plan. Exhibit I pinpoints labor cost inputs versus absorption outputs as well as variations in actual overhead expenses. Because Jay monitors daily the variance between production earned hours versus payroll hours, he always knows if Parlec is behind or ahead of the plan. For example, Parlec’s information system enables Jay to report that cycle time averages 4.2 minutes per piece in the C40 manufacturing cell of the toolholding focused factory.

A yearly sales forecast is made for each product, with budgeted sales broken down by unit for each line item. Since Parlec is not a seasonal business, the annual sales forecast is divided into 52 equal weekly buckets on a unit basis. The product-unit forecast generates a load profile for each work center that indicates how many actual hours are needed. The budget is prepared once a year and is monitored quarterly, although Jay examines work center performance on a daily basis. Parlec uses a SYMIX® enterprise resource system that incorporates forecasts and product standards. The SYMIX® system also permits users to load in efficiency and capacity utilization factors. Jay views the standard cost as what the product *should* cost based on optimal cycle times and actual labor rates, but recognizes that a variety of factors (QC training and other meetings, machine downtime, set-up delays, etc.) will lead to sub-optimal performance. He loads an 80% utilization factor for scheduling purposes only, but not for costing purposes – inventories, cost of goods sold, and gross margins are all computed according to ideal standards.

Thus for every earned hour at standard, Jay expects to use 1.25 actual hours of labor, but he does not burden inventory costs with excess or idle capacity.^{vii} Labor is applied on the basis of actual clock hours, which are compared to standard hours to monitor labor efficiency. Comparisons between earned and actual hours are made on a weekly, monthly and year-to-date basis. Jay used to monitor work center performance by units, but because Parlec’s product mix is so much more diverse, almost all of his monitoring efforts are on the basis of time (i.e., earned vs. actual hours, cycle time per unit, hours not applied, etc.). Parlec’s Earned Hours Report is presented in Exhibit II.

 Insert Exhibit II about here

Regarding Exhibit II, hours applied refers to the actual time clocked on a job by a machine operator. Hours earned refers to the time allowed by a predefined routing time standard. To illustrate: Assume job XYZ calls for 10 units with a part-to-part cycle time of 6 minutes per piece (assume zero set-up time for illustration purposes). Upon completion of the job, the system says it took the operator two hours to complete the job, i.e., the actual hours clocked by the operator. Thus the applied (clocked) hours would be two while the earned (allowed) hours would be one because the standard calls for one (6 minutes per unit times 10 units), and the efficiency for job XYZ would be 50 percent (applied hours / earned hours). Jay goes one step further and measures the efficiency for the five separate “factories” and the factory overall based on the ratio of actual payroll hours / earned hours. This latter ratio is more stringent because operators may have time during the day when they are not clocked on to jobs (company training, downtime, etc.). On an overall basis, which is Jay’s primary concern, this method of computing efficiency (payroll hours / earned hours) helps him spot areas to focus on and take corrective action. In Jay’s words, “every time Parlec earns an hour, it offsets an actual expense.” As a result of Parlec’s detailed internal reporting system Jay indicated that, “Parlec’s financial statements should be a verification of what we already know – and they are!”

We have included one other report that Parlec prepares on a regular basis even though it does not relate directly to either focused factories or cycle time. Exhibit III, Parlec’s Quality & Service Process Performance Index, illustrates the company’s balanced-scorecard, a performance-measurement scheme that has been widely promoted in the cost management literature. Parlec’s particular dimensions include quality, delivery, cost, service, technology, and management. What makes the report so informative is its ability to capture multiple dimensions of performance and to compute a composite rating of performance. The report clearly illustrates the importance Parlec

attaches to traditional cost variance analysis since each of the four subheadings in the cost category reflects budget-to-actual comparisons.

Insert Exhibit III about here

VII. Conclusions

The paper has presented hypothetical and real-world examples to illustrate how cycle time metrics can be used in focused factories that contain production cells. Cycle time has become one of the most critical indicators in competitive, manufacturing environments because it helps management focus on the two key factors in today’s marketplace – fully satisfying customer needs and conducting operations as cost efficiently as possible. We initially showed how cycle time rates can be computed at both practical and expected actual (planned) capacity levels, and how cycle time efficiency can be compared and analyzed on either inter-shift or time-series basis. Progress towards physical benchmarks (i.e., 95% of practical capacity or 80% of payroll hours) can then be effectively monitored and corrective actions (i.e., redesign product flows, introduce new technology, reduce capacity, etc.) can be undertaken. In conjunction with traditional accounting variances, conversion cost rates based on practical capacity and planned levels of output can be compared to generate a measurable amount of NVA cost. Identifying under-applied conversion cost as a NVA cost will accomplish two objectives: 1) it will not burden products with excess cost; and 2) it will direct management in its cost control efforts. In our opinion, cycle time in conjunction with accounting variances, are key metrics in production cell environments.

We described how Parlec, Inc. has been able to survive the current economic downturn by identifying bottleneck operations and reducing excess costs. For example, the decision to give machine operators quality-inspection responsibilities helped reduce dedicated quality staff by

nearly 70 percent. Parlec's information system clearly shows the importance of actual-to-plan comparisons and the relationship of earned-to-applied hours. Their use of the balanced scorecard also illustrates a multi-dimensional approach to performance measurement and should provide a clear pathway for Parlec to pursue as it both increases market share and regains profitability.

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ⁱ Some argue that inspection adds value because customers expect a fully functioning, quality product and inspection provides this guarantee. Others argue that defects should be designed out and inspection would be unnecessary.

ⁱⁱ Although the assumption of totally fixed costs is somewhat unrealistic, it is not completely unreasonable in highly automated cell environments.

ⁱⁱⁱ We promote the use of practical capacity as benchmarks for both measuring cell performance and controlling cell costs. See Maguire and Heath (1997) for an in-depth discussion about other measures of capacity.

^{iv} Brabazon (1999) describes a manufacturing cycle efficiency (MCE) ratio that compares processing time to the sum of all four time elements. Manufacturing efficiency improves as the MCE approaches 100%.

^v Note that non-value added cost does not represent the *opportunity* cost of lagging behind benchmark technology. That cost is the profit margin on lost sales.

^{vi} Data from Parlec, Inc. was obtained from Jay P. Nuccitelli VP Operations on December 11, 2001 during a 2-hour, on-site interview at Parlec's facilities and a number of follow-up discussions.

^{vii} Next year, for example, Parlec is planning for \$6.2M in labor and overhead, but the SYMIX® system is costed to absorb \$5.4M. The balance, \$.8M, is viewed as idle capacity and will not over-inflate inventory.