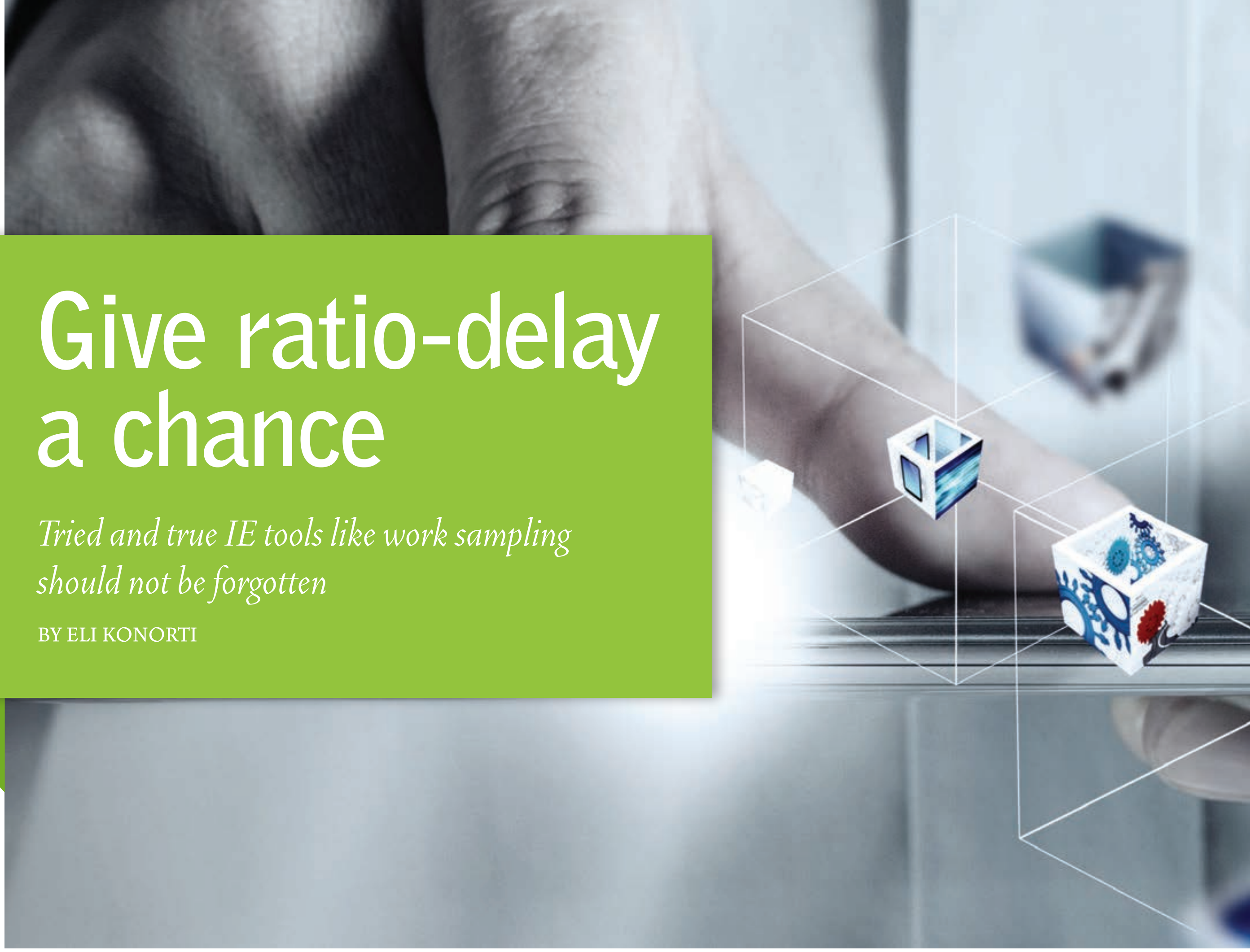


Give ratio-delay a chance

Tried and true IE tools like work sampling should not be forgotten

BY ELI KONORTI

THE INDUSTRIAL ENGINEERING FIELD CONTINUES TO introduce new tools and methodologies. However, we seem to forget simple yet powerful and proven tools such as work sampling, also known as ratio-delay. Work sampling has a much wider scope than just developing time standards for indirect labor. In fact, ratio-delay is an effective tool to determine direct labor productivity for shop floor activities. In the context of manufacturing operations, ratio-delay can determine productivity levels as a baseline that provides focus for new "industrial engineered" improvement initiatives – whether from a lean Six Sigma program or a complex re-engineering project.

Defining work and selection of work categories

When determining whether work is value added or not, it is helpful to define value added as an activity that transforms the shape of the product during the manufacturing process. For example, cutting vinyl profile used in window manufacturing to the correct length and creating a 45-degree angle at the end of the profile is value added because this work transforms the shape of the profile. On the other hand, transporting a part from one machine to the other does not change the shape of the transported part and hence adds no value to the product.

A second-level analysis of secondary work categories should include observing operators and asking them what specifically (i.e., individual tasks) they do throughout the day that either adds value or does not add value to the product. These types of activities include, but are not limited to, material handling, machine setup, receiving instructions from the supervisor and not being present at the workstation.

The focus of the improvement process will determine the level of detail required from the ratio-delay data. For example, management might be concerned about excessive time operators spend moving work-in-process from one machine to another, retrieving raw materials from the warehouse, or moving parts to a staging area or the warehouse. The data-gathering activity should reflect this concern.

If, on the other hand, management is more concerned with where the focus of the improvement should be, then a less detailed initial level of analysis is required. For example, should the improvement process focus on eliminating material handling time or reducing machine setups? The answer to such a question will guide the level of detail required for the ratio-delay study.

Many years of conducting such studies and experimenting

with a variety of primary and secondary categories has led to the conclusion that the more simple the approach, the less debate about the results. Ambiguity can be removed by drilling down further into additional categories such as the ones described previously. Figure 1 shows an idea of the primary and secondary categories used in studies.

Conducting the ratio-delay study

There are critical steps involved in initiating and executing a ratio-delay study. Although the process seems simple to plan and execute, in reality, operating conditions vary from one plant to another. For example, the culture of management might or might not be conducive to change. Or the workers might have varying attitudes toward change, or militant and suspicious unions might represent the employees.

Historically, practitioners have offered different approaches to planning and executing the process. However, good communications and planning are underlying commonalities. This proposed process has been developed over many years of trial and error. It underscores the importance of early communication with employees at all levels and being honest about the importance of this particular step in the improvement process.

Figure 2 depicts a nine-step process required to create awareness for the work-sampling program, communicate the need for change, implement the change, and confirm that the change has produced the desired results. A discussion of each step follows.

Identify the problem. A business problem may be specific or ambiguous. Either workers or management can identify a problem or suggest an improvement. This critical step simply highlights and brings to the forefront an opportunity for improvement. Ultimately, one of these groups will determine whether the problem warrants further consideration and study. Missing delivery deadlines, high labor costs, high costs of quality, or too much time spent on material handling are just a few examples of potential problems.

Define the problem. The term "defining the problem" often is confused with "identifying the problem." In this step, the team

OBSERVE AND REPORT

Figure 1. The analyst enters the number of observations and summarizes the data for each category. At the conclusion of the study, the analyst can easily and readily determine the proportion of time workers spend performing value-added versus non-value-added work.

COMPANY XZY									
Ratio-delay observation record									
		Non-value-added							
Date	**Value-added (VA)**	Waiting	Material handling	Receiving instructions	Cleaning machine	Cleaning work area	Machine setup	**Total non-value-added (NVA)**	Total observations Σ(VA+NVA)
D_1									
. . .									
D_n									
ΣObservations by activity	ΣVA							ΣNVA	Σ(VA+NVA)
% of Σ(VA+NVA)									

or observer collects specific empirical information about the current state of the problem, defines a future state and provides justification for solving the problem using accepted criteria such as return on investment (ROI), payback or internal rate of return (IRR). For example, an operation might want to reduce its delivery lead-times from 10 days to three days, or a company might want to produce CAD drawings for plant operations in one day instead of the current three days. Well-defined problems are the easiest to solve because they provide the empirical guidance and focus that teams often need in the improvement process.

Create awareness. Awareness is concerned with acknowledging and understanding that opportunities to improve business processes exist. To ensure that employees are aware of such opportunities and to initiate programs to exploit them, companies should meet with employees at all levels of the organization. During these meetings, the project sponsor or a company manager should explain the need to improve, the process, the various tools that will be used during the process, and the expected outcomes. A primary focus of the meeting should be to explain the ratio-delay process. It is imperative that management stress the importance of objectivity (e.g., random samples during random times throughout the day) and that the outcomes of the study will be shared with the employees.

Prepare for data collection. The observer needs to undertake a few measures before the data-gathering process starts. The observer must decide the sample size and accuracy, the frequency and length of data collection, the tools required to collect the data and the route used to collect the data.

For sample size and accuracy, the accuracy of the proportion will be determined by the degree of the allowable error (e) coupled with the level of confidence (z). The accuracy level is determined by the proportion of non-value-added work estimated by management and desired relative accuracy, which often is set at a = 5 percent for industrial settings with the degree of confidence set at z = 95 percent. The sample size can be calculated as: $n = (z/e) \times p(1-p)$. For example, if management suspects that workers are spending 30 percent of their time on non-value-added activities, then $p = 0.3$ and $(1-p) = 0.7$. The corresponding value for a confidence level of 95 percent is $z = +/-1.96$.

A recent study for a manufacturer of wood moldings yielded the following results. Management suspected that operators were spending approximately 40 percent of their time performing non-value-added activities such as material handling, receiving instructions from supervisors, and being away from their workstations. As such, p was set at 0.4 and (1-p) at 0.6. The company wanted the proportion of the non-value-added to be accurate within +/- 2 percent (i.e., e = 0.02) with a 95 percent degree of confidence (i.e., z = 1.96). As such, the number of observations required for this particular study was: $n = (1.96/0.02)^2 \times (0.4)(0.6) = 2{,}304.96$ or 2,305.

The cycle time of the operation often will dictate the length of the study. Furthermore, if more than one observer gathers data, then the length of the study will be reduced. Observers can choose random times to collect data from many sources such as predetermined random-number tables or random numbers generated by a computer. The observer will gather data until the required number of observations has been achieved.

A solid approach to achieve the required number of observations is to determine how many working days are available for the study and then determine the number of observations required each day. For example, assume from the above situation that 2,305 observations are needed to achieve the required level of accuracy, and you have 20 working days to carry out the study. The daily number of observations will be set at 116 (i.e., 2,305 observations divided by 20 working days).

Figure 1 depicts a simple yet effective data-gathering tool. Observers can adjust their tools to accommodate the uniqueness of each operation. The observer can use one form each day or one continuous form. Experience has shown that one form per day is best for both data entry and audit trail purposes. Data should be entered daily either into a simple spreadsheet or control chart. Both entries will provide immediate results for the data gathered to date. The observer will require no more than a pencil and clip chart to complete the data-gathering task.

Determining the route or routes for the study should follow a logical pattern that allows the observer to view and capture activities for the entire operation being studied in one trip. The observer can choose as many routes as he or she wishes as long as the pattern is an efficient one. I often choose two to three routes with different start and end points.

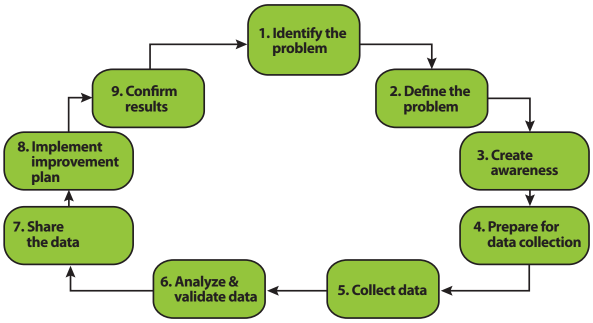
Collecting the data and removing bias. Random observations (i.e., times) ensure that each task is given an equal chance of being observed. If the observer is uncertain about the actual function the operator is performing, then it is best to skip the observation and later investigate the task. If an operator is not at the station, the observer should note the activity as "away from workstation" or "not working." In either case, this will be recorded as a non-value-added activity. The large number of observations will mitigate a few unrecorded observations. The observer can use a simple check mark to denote the operator activity.

It often is argued that operators behave differently whenever they know they are being observed or studied. This behavior might lead to inaccurate and biased results. To mitigate this concern, observers can take sample observations prior to conducting the actual study and compare them to observations taken after the workers are made aware of the study. Using a t-test revealed, over time, that the difference between the pre- and post-awareness sessions was not significant. As such, I stopped carrying out such studies and simply decided to make employees aware of the process before the study begins.

The observer should pre-select two to three different routes and use all routes during the study period. Doing so will ensure that operators do not have a chance to rearrange their work and to appear busy when they are not. I found this element of surprise useful, although it should be communicated with the operators during the awareness session.

THE RATIO-DELAY PROCESS

Figure 2. This nine-step process shows how to initiate and execute a ratio-delay study.



Analyze and validate data. An efficient method to analyze the data is to have the observer enter the data collected during the day at the end of each workday into a predesigned and formatted spreadsheet or control chart. Then, the information can be used to design and execute performance improvement projects for priority areas. For example, if operators spend the majority of time on material handling activities, then management might want to focus its attention and efforts on reducing material handling activities before embarking on other projects.

To ensure the data is valid, the observer should make sure that the study takes place when operations are considered at their normal level as opposed to peak or slow times. Second, it is important that the observer does not introduce bias into the study by guessing at an activity. To mitigate such a risk, the observer should not record an activity in question. Finally, reviewing the data with both the operators and the management team will reduce inaccuracies even more.

Sharing the data. Managers and employees participating in ratio-delay studies are keen to learn about the study findings. It is common knowledge that sharing information helps buy-in. Start by restating the need for the study and the method used to collect and analyze the data as well as conclusions resulting from the findings. I use PowerPoint and often meet during the lunch period in organized "lunch and learn" sessions. Urge management to observe the audience and distinguish between project inhibitors (i.e., blockers) and project assistors (i.e., pushers). Overcoming resistance is imperative.

Creating an improvement plan. Create three types of plans. The first type should be quick wins that target low-hanging fruit. These improvements do not require a great deal of time to investigate and often do not require significant amounts of money to implement. For example, one recent study found that approximately 100 operators spent 20 percent of their time on material handling activities, such as moving work-in-process and searching for raw materials in the plant or in the warehouse. This amounted to the equivalent of 20 operators.

The evidence highlighted the magnitude of the problem. Management allocated three individuals from within the plant to a function named "utility operators." Their sole responsibility was to ensure that operators have materials arriving at the workstations on time or moved away at the end of the cycle. Such a simple solution saved the company the equivalent of 17 operators. Since the utility operators came from within the plant, there were virtually no costs for training or cross-training.

The second type of plan could be referred to as "important projects." These projects often take six months to a year to plan and implement and involve a financial investment and employee training. For example, a second study concluded that the operations required streamlining. The objective was to arrange the flow of the plant so that manufacturing could meet a certain takt time. This project required the design of manufacturing cells, new product flow patterns, and employee cross-training to cope better with a changing product mix. This specific improvement resulted in productivity gains greater than 28 percent in the first year alone.

Let's call the third type "ponder." These are not must-have type projects, but if implemented they could significantly enhance the financial results of the business. These projects are considered complex, require significant resources such as time and treasure and often take more than 12 months to plan and execute.

In a third project, the ratio-delay results suggested that plant workers spent a great deal of non-value-added time asking for clarifications about work orders. The current information technology system was incapable of addressing ever-changing customer specifications. The solution was to replace the existing IT system with an ERP system. The result was a drop of nearly 60 percent in customer complaints, not to mention more time spent on value-added work.

NOT SO NEW STUFF

These days, the phrases "the wisdom of the crowds" and "crowd engineering" are touted as entirely new ideas. Much of that comes from the 2005 book by James Surowiecki titled *The Wisdom of Crowds: Why the Many Are Smarter than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations.*

But when applied to manufacturing and distribution centers, crowd engineering sounds quite familiar to industrial engineers who were trained for work sampling, at least as described in a white paper by The Progress Group.

The paper and an accompanying case study describe a three-month project at a company that assembles silk plant flower pots. Analyzing video of the process revealed that some operators were more efficient at certain suboperations than others.

Applying best practices across the board for the most popular plant sold by the company reduced the number of man minutes per unit assembled by 45 percent. Crowd engineering applied to other manufacturing and distribution centers yielded productivity gains ranging from 10 percent to 30 percent.

So for those IEs trying to sell work measurement to skeptical managers, perhaps the newfangled term of crowd engineering will work better.

Confirming the results of the improvement plan. Empirical evidence is the most effective way to confirm whether a project has achieved the desired results. Specific objectives, as opposed to broad goals, should guide the projects. For example, in a recent project, the company set a labor productivity improvement objective of 30 percent after one year of project initiation and implementation.

The second-year objective was to improve labor productivity a further 20 percent over the level achieved the previous year, and the third-year objective was to improve an even further 10 percent over the results achieved in year two.

Specifically, the productivity baseline at the start of the change management process was 2.35 hours per unit. This aggregate measure assumes that the product mix will not change radically in the next three years. In total, the project is expected to improve productivity over a three-year period to the tune of approximately 53 percent, from 2.35 hours per unit to 1.1 hours per unit.

It has been three years since the launch of the project in 2009. The productivity level achieved at the end of year one was 1.72 hours per unit. This clearly indicates that the company had in fact realized a significant improvement in productivity, approximately 27 percent, but it was slightly below the intended objective of 1.6 hours/unit. At the end of year two, the company realized productivity levels of 1.4 hours per unit. That again indicates a significant improvement of approximately 19 percent compared to the previous year.

However, the results for year three held at about 1.4 hours per unit because the housing market collapsed. The company

RECENT RESULTS

Figure 3. The proportion of time by percentage spent on value-added versus non-value-added activities in a series of recent ratio-delay studies.

Company	Value-added (%)	Non-value-added (%)						Total non-value-added (%)
		Machine setup	Not working	Material handling	Receiving instructions	Cleaning machine	Cleaning work area	
A	51	3	24	16	4	1	1	49
B	39	4	28	20	7	1	1	61
C	45	3	34	12	3	2	1	55
D	36	3	32	22	3	2	2	64
E	29	1	43	17	7	1	2	71
F	28	7	39	17	8	1	2	72
G	36	16	28	7	9	2	2	64
H	30	3	31	25	9	1	1	70
Average	**38**	**5**	**33**	**16**	**6**	**1**	**1**	**62**

chose not to lay off employees, expecting that housing starts would rebound, which has not happened. However, the project yielded so much extra production capacity that the company reduced its delivery lead-times to three days, which is considered outstanding.

Limitations

A limitation of the proposed approach is that it does not report the pace of the operator, nor does it report whether the operator is working efficiently. The purpose is not to develop accurate time standards but rather to provide a baseline for areas to focus productivity improvement projects.

Studies that are more detailed might indicate whether the operator is taking twice as long to perform a task than it should take or whether the pace is acceptable or not. Large samples, as is typically the case with ratio-delay studies, should mitigate these limitations.

Recent results

Figure 3 shows the results of eight different ratio-delay studies. All companies shown are in the manufacturing business and considered small-to-medium enterprises in British Columbia, Canada. The companies make a variety of products, including vinyl doors and windows (short cycle), steel fabricated products (long cycle), houseboats (long cycle), wood moldings (short cycle), and wooden doors and windows (short cycle), to name a few.

Additional studies can determine more specific reasons that operators are away from their workstations or spend too much time on material handling activities. The productivity achieved during the ratio-delay study should form the baseline for future improvement projects.

Benefits

Ratio-delay is a very simple and effective method to determine baseline productivity levels. Ratio-delay is also cost-effective because it does not require large amounts of time and treasure. Moreover, work sampling is one of the least invasive methods to collect operational data. The large amounts of data collected ensure validity and reliability and remove bias.

The observer needs a piece of paper, a pocket calculator, a list of random times and a pencil to conduct the study. Spreadsheets and control charts can be used to analyze the data. More advanced data-gathering tools such as hand-held or battery-operated devices are also available to the observer. Regardless of the method the observer uses to collect data, the outcome of the process will be the same.

Ratio-delay is extremely valuable for companies of all sizes and from a variety of industries. This tool is extremely useful to launch industrial engineering change management programs. The ratio-delay approach is economical, simple, and can be used by anyone with little training.

Industrial engineers as well as companies without industrial engineering skills are encouraged to use this tool more often. The outcomes of a ratio-delay study can be truly eye-opening. Ratio-delay has an appeal that goes far beyond setting standards for indirect or service labor.

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