HOW TO BALANCE A MANUFACTURING WORK CELL

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Balancing a work cell is really the question of how much capacity to provide at each station or operation. This, in turn, relates to overall capacity of the cell. Decisions on workstation and overall capacity intertwine with many other factors of the cell design.

Static and Dynamic Balance

Cell designers should consider two types of balance: static and dynamic. For example, a cell has six workstations. Over period of ..several days or weeks, the average work time at each station is identical. However, for shorter periods of hours or days the work times vary significantly due to differences in product mix or natural variation in processing.

Static balance refers to long-term differences in capacity over a period of several hours or longer. Static imbalance results in underutilization of certain workstations, machines or people.

Dynamic imbalance arises from either of two sources: product mix changes and variations in work time unrelated to product mix. Such imbalances are short term and occur over periods of minutes, hours or, at most, a few days.

Balancing People and Equipment

Historically, workstations have been viewed as single entities, even when comprised of several resources such as machines and people. When people have specific machine assignments, this simplification is acceptable. Work cells, however, often gain much of their productivity from separating the resources. One person, for example, may operate several machines. Here we should consider the balance of each resource separately.

Internal balance refers to balancing resources within the work cell. External balance refers to balancing the work cell with respect to external demands and supplies. External balance is frequently thought of as work cell capacity.

Balancing Equipment

In balancing equipment, we attempt to ensure that each piece of equipment in the work cell has the same amount of work. Frequently we also attempt to maximize the utilization of all equipment. Such balancing and high utilization is often counterproductive. The desire to achieve balance and high utilization comes from several sources: Accounting systems place high value on capital investment. They therefore discourage the acquisition of additional equipment if existing equipment is under-utilized. Second, the model of Henry Ford's assembly line stressed balance as a primary goal.

The Ford model was right for its time and product. It is, often, inappropriate for the varied product mix faced by today's manufacturers. Ford production used one of several balance methods, inherent balance.

High utilization may be the wrong goal. High utilization is usually accompanied by high inventory and poor delivery performance. Figure 2 illustrates the relationship between these two parameters for a wide variety of manufacturing situations. When fast, reliable delivery brings a premium price, high equipment utilization may actually work against the firm's long-term strategic goals.

Inherent

Inherent balance attempts to provide each workstation with precisely the same amount of work. With high-volume assembly lines this may be achievable, to some degree. Manual assembly is flexible because people are flexible. Analysts divide the work into minute tasks. They reassign these tasks to work stations such that each station has the same cycle time. Balancing mechanized or automated production lines with this method is more difficult since it is rarely possible to find equipment with identical cycle times. Figure 1 shows inherent equipment balance.

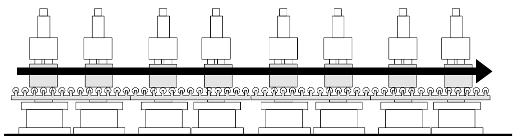

Figure 1- Inherent Equipment Balance

Inherent balance presents additional difficulties as well. It tends to be inflexible. For new products, the line must be re-configured and re-balanced. When multiple products run on an inherently balanced line and require differing cycle times at some operations, the line must be stopped and re-balanced at each changeover. This forces batch production.

Perhaps the most formidable problem of inherent balance comes from variation from one cycle to the next. The work times developed by traditional time study show average deterministic times of great accuracy. In reality, these times may vary significantly from one cycle to the next. The time at a given station is, in fact, a distribution. When the time on a station is longer than the average, it slows the entire line. When the time on a given station on a particular cycle is less than average, it cannot speed up the line. Thus, the real performance is less than the average cycle times indicate. The more stations, the more this variation affects performance.

Figure 2 shows the output of a simple production line at various levels of work time variation. On average, the stations are perfectly balanced at a 1.0 minutes cycle time. This line has 10 stations without queuing between stations. It shows that production output falls significantly with

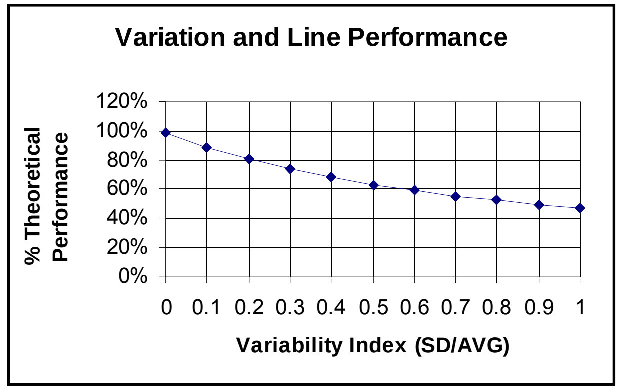

Figure 2--Variation & Line Performance

Queuing

Allowing queues between workstations is one approach that alleviates the variation problem in an inherently balanced system. Figure 3 illustrates. Here, the small queues between operations buffer small variations in cycle-to-cycle work time. Queuing does increase inventory as shown in figure 4.

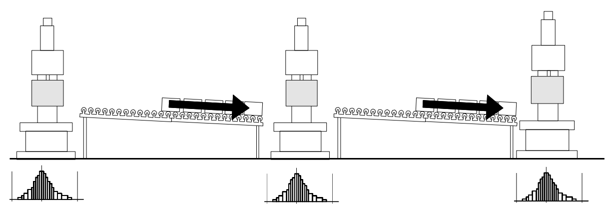

Figure 3- Queuing For Equipment Balance

Each curve in figure 4 represents a different value of the standard deviation at the workstations. As workstation utilization increases, the inventory increases. The increase is linear and moderate at low utilizations. At higher utilization the inventory level rises dramatically. With very large variations in work time, the system chokes itself at low utilization rates.

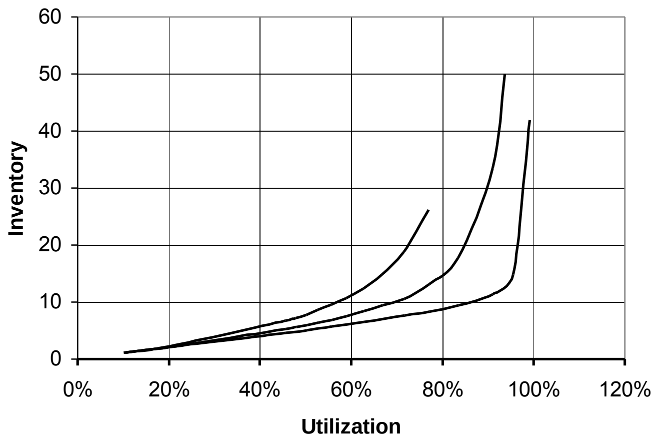

Figure 4- Inventory In A Queued System

Surplus Capacity

The most common and, also, the most effective method provides surplus capacity for most workstations. A cell with surplus capacity at many stations is only constrained by the slowest operation, the bottleneck. Moreover, it may operate with far less internal inventory than a cell that has balanced work times. In effect, excess capacity is the tradeoff for reduced inventory and faster throughput. In figure 5, all machines but one have surplus capacity.

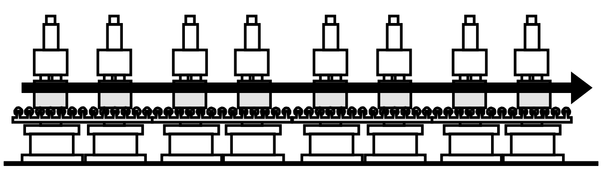

Figure 5- Surplus Machine Capacity

Balancing People

Balancing people within the cell is usually more important than balancing equipment. In most situations, the hourly cost for a person is far greater than the hourly cost for a machine or workstation. Moreover, when the workload among cell operators varies, it causes dissension in the cell team.

The methods for balancing people differ from equipment balance methods. This is because people are more flexible. They can move from one position to another. They often can perform more than a single prescribed job. They can communicate and autonomously shift to where their skills are needed.

Surplus People Capacity

While surplus capacity is a reasonable method for balancing machines, particularly inexpensive machines, it rarely is acceptable for balancing people. When customer delivery is critical and customer demand irregular, surplus capacity may be used to ensure fast delivery. In figure 6, one of the six operators requires more work than any of the others. This is the bottleneck. Other operators have surplus capacity.

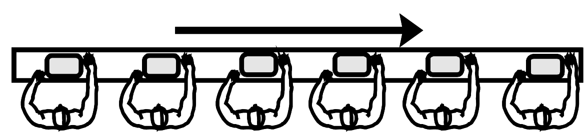

Figure 6--Surplus People Capacity

Queuing

When operators have permanent stations in a cell or line, queuing between them compensates for cycle-to-cycle variation. Floating-fixture assembly lines work on this principle. If the average work times differ, queuing alone is insufficient. Queuing alone balances the short-term or dynamic variations but it will not compensate for longer-term static variation. Figure 7 shows how these small queues buffer short-term variation. The size of the queues relates to the amount of variation. From Theory of Constraints, we know that by observing the queues, we can see which operators are most imbalanced.

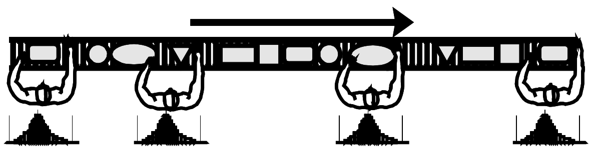

Figure 7--Queuing For People Balance

Floating

Floating balance, usually combined with queuing, is frequently a good method for balancing people. Here, operators monitor the queues to determine which stations are working ahead and which are falling behind. Operators move to the stations that are falling behind and assist until that station is caught up. This requires that stations allow for multiple operators when necessary. Figure 8 shows how operators shift position in a floating balance cell. The queues are their guide for this shifting.

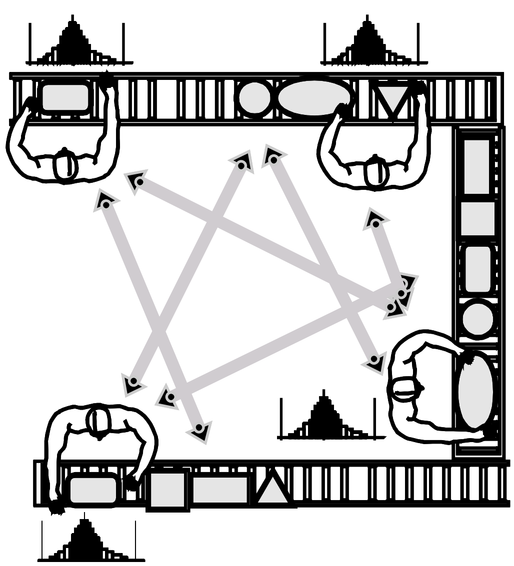

Figure 8--Floating Balance

Circulation

With circulation, an operator carries the workpiece through all operations in sequence. This method is very flexible and perfectly balances operations. It requires that operators be completely cross-trained. It also requires surplus equipment capacity on most or all stations. Figure 9 illustrates.

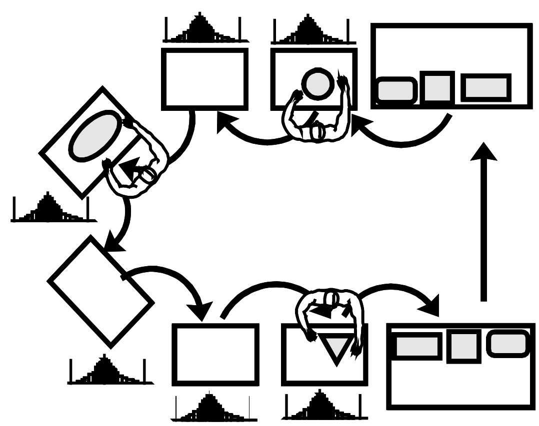

Figure 9--Circulation Balance

Summary

- Balancing work cells goes beyond traditional concepts that govern assembly line balance. Here are some of the main points from this paper:
- The issue of balance ties into larger issue of cell capacity: how much output do we need? How much capacity should each station have?
- Within a work cell, equipment and people balance are separate issues. This results from the differing characteristics of people and equipment.
- Several methods are available for balancing equipment.
- Other methods are available for balancing people.
- Hybrid approaches are also available.

Selecting an appropriate set of balancing mechanisms is one part of the cell design. Work cells are complex, subtle, and delicate socio-technical systems. The selection of balance methods must link with many other decisions for the system to function well.

§ The Presenter

Quarterman Lee has been an author, trainer and trusted advisor to business and industry for more than 23 years. Prior positions at Ford Motor Company, Rockwell International, McDonnell Douglas and Crown Zellerbach provided broad experience in Plant Engineering, Product Engineering and Management. Mr. Lee has authored more than 50 articles, books, papers and programs. He frequently speaks at conferences and has authored the book *Facilities Planning- An Illustrated Guide*. He holds a B.S. in Mechanical Engineering from Purdue University.