



You can't use line balancing to optimize a flow line

Line balancing **vs.** theory of constraints

By Luke Cheng

Recently in Phoenix, a helicopter and a handful of firefighters were dispatched to save a young man who fell ill during a hiking trip. This man, who was from a cold-weather state, assumed the hike was going to be like many he had taken. Unfortunately, he underestimated the heat factor: It was 110 degrees that day. The moral of the story is that even though some-

thing can be done well under a given set of conditions, it doesn't necessarily work in other conditions.

Line balancing

Even though line balancing works well for paced assembly lines, it is not appropriate for flow lines, which are unpaced. In paced assembly lines, conveyors determine

the speed of production; in flow lines, each workstation finishes subassemblies at its own pace. The reason line balancing is not suited to flow lines is the combination of dependent events and statistical fluctuations that exist. The performance measures of a workstation in a flow line — WIP, cycle time, and throughput — are influenced considerably by the performance of prior workstations. The performance measures are also affected by process variability.

The commonly cited benefits of line balancing are improved efficiencies, greater utilization of resources, and reduction of worker resentment for uneven workloads. However, theory of constraints creator Eliyahu Goldratt said, “Most of the time, your struggle for high efficiencies is taking you in the opposite direction of your goal.” He also noted that “A plant in which everyone is working all the time is very inefficient.”

Goldratt showed that increasing the efficiency and utilization of non-bottleneck stations causes an increase in inventory and operational expenses and a decrease in throughput. Wallace Hopp and Mark Spearman, authors of *Factory Physics*, show through mathematical analyses the negative effects of increasing utilization of non-bottleneck stations: Cycle times, quality, and services degrade depending on the level of variability. Counter to the traditional industrial engineering emphasis on line balancing, the authors recommend unbalancing the flow line to improve its performance.

Figure 1 contrasts traditional and modern views of capacity planning. Mathematical proof and empirical evidence support the validity of the modern view. According to the modern view, cycle time increases considerably as resource utilization gets closer to 100 percent.

The other benefit of line balancing — reducing worker resentment of uneven workloads — can be handled with proper communication and assurance by management.

We are bombarded by so many buzz words and manufacturing concepts that it is easy to lose sight of terminology’s relationship to the real world. Some companies have indicated that they would like to increase the utilization and efficiencies of machine and labor resources (not mentioning bottlenecks) while at the same time

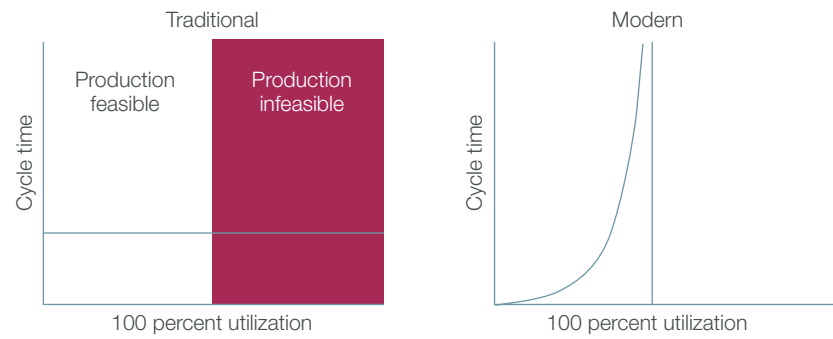


Figure 1. Traditional versus modern views of capacity planning

applying the theory of constraints. The confusion is propagated in part by 40-plus years of research on and industrial applications of line balancing. Many companies, consultants, and professors still talk about the value of line balancing. About 20 percent of industrial engineering job postings indicate that companies seek to improve utilization and efficiencies through line balancing.

Let’s look at two examples of the misuse of line balancing in manufacturing.

Case study #1

This case study illustrates the effort of a mixed-mode manufacturer of solids handling systems and accessories to increase

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capacity in its urethane parts molding department. This department has a flow line that consists of mixing, mold filling, and curing operations. Prior to the process improvement effort, the company operated at almost 100 percent of its demonstrated capacity level, using three shifts, seven days

a week. In addition to increasing capacity, the company sought to maximize throughput, minimize inventory, and minimize resources. The company claimed to achieve these goals by applying line balancing, scheduling, and mold mix optimization.

Minimizing resources means optimizing the efficiencies and utilization of labor and equipment. According to the theory of constraints, when utilization of resources is increased, excess inventory increases, which may cause throughput to decrease. Already, two of the project goals — minimize inventory and minimize resources — collided with each other.

What the company really meant by minimizing inventory was synchronization of production supply with demand. This is contrary to the theory of constraints, which discourages matching capacity of every resource with market demand. Jonah, a character in *The Goal*, put it this way: “The closer you come to a balanced plant, the closer you are to bankruptcy.”

The company reported results such as a decrease in total unit cost, an increase in return of assets, a 20 percent increase in labor efficiency due to elimination of non-value-added activities, a 50 percent increase in throughput due to proper balancing of operator activities, a 60 percent reduction of parts inventory, and a 10 percent to 15 percent reduction of cycle time.

These kinds of results are impressive, but they become questionable when viewed under the light of TOC. To be fair, the company did well to eliminate non-value-added activities, reduce the number of parts handled per cycle, and eliminate the need to make time-consuming changes to the mold mix during the run. However, many companies strive for local rather than global optimization. It is possible for the manufacturing department to achieve its goals

while the company is losing money. What we need is key performance measurements such as throughput, cycle time, inventory, and operational expense from the point of view of the company, not the manufacturing department.

Case study #2

The next case study is about the application of a line balancing heuristic for automated surface mount assembly line setups. The heuristic was designed to assist the process planner in allocating machine components to balance an assembly line. This flow line consists of a screen printer, an epoxy dispenser, a chip shooter, two pick-and-place machines, two hand stations, and a reflow oven.

This kind of thinking is quite typical among managers and engineers. It is exemplified in Alex Rogo, the character in *The Goal* who believed that if a line is left unbalanced, precious line capacity is lost. Early in the story, Alex is obsessed with maximizing utilization of the company's robots to achieve a reduction in the cost per part. He didn't want to "waste" any of the expensive investment in the robots. Later, Alex learns that to improve productivity, the company needs to identify and exploit the bottleneck, which may not necessarily be the robots.

Good applications of TOC

The current literature does offer examples of companies that applied theory of constraints

improvement since it is concerned with the welfare of the company, not just the optimization of the manufacturing department. The key performance measurements such as throughput, inventory, and operational expense help us check whether we really are making productivity improvement.

Industrial engineers and managers have the responsibility to inform their colleagues about the proper tools for productivity improvement and help steer the company from investing in the wrong thing.

For further reading

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The current literature does offer examples of companies that applied theory of constraints successfully. Virginia Semiconductor, for example, applied the five-step theory of constraints process to realize dramatic results.

The reported results on the chip shooter and two pick-and-place machines resulted in saving 2.95 hours of assembly line time over the expected lifetime of five weeks. One of the main objectives of the project was to maximize line capacity. The authors of the case study suggest that the nearly three hours of assembly line time that was saved could be used to process other products. This reflects the traditional thinking shown in Figure 1 — to get as much efficiency and utilization as possible.

It is not clear how the nearly three hours of assembly line time savings will impact the key performance measurements (throughput, work-in-process, cycle time, and operational expense). It also seems the goal of the project is to gain local optimization, which may not translate into benefits for the company as a whole.

In this case study, factory management wanted a tactical solution for better line balancing. Though management sought the best interest of the company, it is not asking for the right thing.

successfully. Virginia Semiconductor, for example, applied the five-step theory of constraints process to realize dramatic results of a 90 percent drop in work-in-process, a 27 percent reduction in power consumption, an 82 percent reduction in cycle time, a 26 percent increase in on-time delivery (to 96 percent), a process yield improvement of 4.5 percent, savings of raw material and scrap costs, and a 23 percent increase in organizational productive capacity.

Another example is Flow International, which successfully combined the application of the theory of constraints with finite-capacity scheduling. Management there realized that aiming for 100 percent labor efficiency does not equal productivity and that the philosophy of a balanced plant was costing the company money.

Conclusions

Line balancing has a place in paced assembly line manufacturing, but not in flow line situations. The theory of constraints is a wholesome approach for productivity