Production Line Balancing: Is it a Balanced Act?

Abhishek Shinde and Dileep More

Case Analysis

Sumanta Basu
Assistant Professor
Indian Institute of Management Calcutta.
e-mail: sumanta@iimcal.ac.in

This case discusses a traditional line balancing problem, highlighting practical issues, such as, resource allocation, importance of quality in the context of a synchronized assembly line, consideration of machine failure probabilities and allocation of buffer stock in an assembly line with machine failure. Although the problem context is set to discuss an assembly line situation, the issues discussed in this case spread beyond the traditional line balancing problem. The issue of machine failure in an assembly line situation is tackled through simulation to showcase some interesting results that justify the inclusion of buffer stock in an assembly line.

In an assembly line, a set of distinct work elements for the assembly of a final product is processed in a defined order through the workstations. The order in which the work elements are processed is defined by the precedence diagram (Thomopoulos, 1967). Line balancing is usually used in flow-oriented production systems for cost-efficient mass production of standardized products. In practical situations, various definitions of efficiency of an assembly line are used, based on the context under consideration, including (Baybars, 1986):

- minimizing the number of opened stations (for a given cycle time);
- minimizing the cycle time (for a given number of opened stations);
- feasible balance between the number of opened stations and cycle time; and
- maximizing the efficiency of the assembly line in terms of increasing the utilization of available time.

Given the cycle time to process one unit of the product, the first objective focuses on minimizing the number of open workstations without exceeding the cycle time.
Reverse to the first one, the second objective is to achieve the minimum cycle time with a given number of workstations. The third one tries to do a trade-off between the first two objectives. The last objective is specifically to minimize the unutilized time of each machine or to minimize the total unutilized time of all machines.

Broadly, line balancing problems can be categorized into two distinct problem types: deterministic and probabilistic. In the deterministic version, all input parameters, for example, feed rate, time taken by each resource to complete the task, etc., are known and will not change over time. The probabilistic version deals with uncertainties in parameters such as feed rate, processing time, etc. The attempt to address such kind of problems can be traced back to the scholarly literature from the 1960s.

A generic version of the line balancing problem talks about a multi-model case where more than one variant of the same product type can be manufactured in batches or mixed model case where the variants are intermixed during production. One or more of the following issues are typically considered in a generic version of line balancing problem (Boysen, Fliedner, & Scholl, 2007):

- zoning constraints restricting the grouping of certain tasks in a particular cell;
- tasks that have to be performed in particular cells; and
- restriction on balance delay: the amount of time idle on the line due to unequal task assignments.

This case elaborates on a single product semi-deterministic assembly line with an objective to increase productivity to the desired level. It does not specify any additional constraint in the assembly line. We call it semi-deterministic because of the machine’s failure probabilities considered in the problem.

**PRACTICAL RELEVANCE OF THE PROBLEM CONSIDERED**

The problem context in this case is a diesel engine manufacturing company, suitable for highlighting the issues for an assembly line situation. The production system consists of two departments: machining department and engine assembly department, where machining department is segregated into three production areas: Engine Auxiliary Machining Department (EAMD), Engine Component Machining Department (ECMD) and Engine Frame Manufacturing Department (EFMD), of which EFMD is the most critical production area. From the difference between the target and the actual production in Exhibit I of the case, selection of EFMD is evident. Exhibit I also makes it clear that engine frames produced in EFMD determine the throughput rate of DEL. Therefore, it is very important to increase the production rate of engine frames to increase DEL’s total throughput.

**Shift from Process-based Layout to Product-based Layout**

To resolve the throughput issue of EFMD, the case mentions about changing the layout of EFMD from process based to product based. Although it is a good way to introduce the readers to a rational decision-making approach, the reason behind changing the layout design is not very clearly specified in the case. Intuitively, it is understood that a line designed to produce a single product type with a steady demand should perform better in a product-based layout vis-à-vis a process-based layout. In process layout, general-purpose machines are used and so it is extremely flexible to bring changes in both product and process design. Generally, process layout increases material handling, higher work in process, higher inspection cost and problems in routing and scheduling, which ultimately reduces output. However, the engine frame is a standard component and does not require frequent changes in the product design. More information on this process change is desirable to bring interesting insights from the readers.

A product-based layout is generally preferred where a product has to be manufactured or assembled in large quantities. In this layout, the machinery and auxiliary services are located according to the processing sequence of the product without any buffer storage within the line itself. Along with advantages like low material-handling cost, less cycle time and streamlined process, it has disadvantages like inflexible set-up, higher system delay due to machine failure, etc. In a process layout (also referred to as a job shop layout), similar machines and services are located together. Process layouts are also quite common in
non-manufacturing environments. They lead to a better resource utilization along with creating an ability to handle diversified jobs but at the cost of reduced capacity. Hence, the initial suggestion of shifting from process layout to product layout looks justified, although it is unclear from the case why it failed to increase the throughput to a desired level. It may bring interesting insights to the case.

Comments about Increase in Capacity of EFMD

The capacity of an assembly line can be increased in two ways: by reducing the cycle time or by increasing the total available working hours. Given the information provided in the case, the reduction of cycle time through line balancing is not under the control of the production manager, as each task along with its workstation is clearly designated. The only possibility of increasing the throughput is by increasing the working hours.

Following Exhibits 4 and 5, the work time allocation in four cells is as follows: 2,396 seconds in Cell 1, 2,003 seconds in Cell 2, 2,339 seconds in Cell 3 and 1,589 seconds in Cell 4. Readers may be interested in finding out a better cell configuration to reduce the variance of work time across cells. The two assistant operators could be utilized to warm up the machines to release 30 minutes of production time. This will definitely lead to an increase in productivity of EFMD. One difficulty, which readers may face in reaching to this suggestion, is that the roles and responsibilities of the operator and the assistant operators are not clearly defined a priori. Other obvious suggestions to increase the working hours include introduction of new shifts or granting overtime, etc. Adding resources will help if work elements can be split subsequently to reduce the cycle time.

Effect of Machine Breakdown in Line Balancing

The probability of machines breaking down in the assembly line creates an additional complexity in this case. In my view, this is the most interesting part of this case from an operational point of view. In this context, Exhibit 6 can be made more useful by providing a reference time period for which the failure data is collected. Currently, the availability (%) makes sense and helps in identifying two machines, P09 and P18, with lower availability due to frequent breakdowns. Often factory managers prefer to balance the production line to equalize the utilization of the available machines and human capital, eliminating waiting time or idle time for the machines and workers. Conventionally, managers prefer to rearrange various operations to keep the mean processing time constant throughout the line. While doing so, they often ignore interdependency between various machines. For instance, if any of the machines breaks down, it results in stoppage of the entire production line, thereby resulting in reduction of the total production. There are various ways by which this problem can be tackled: reduction of failure probabilities by taking appropriate actions, unbalancing the line by seeing the propensity of failure and machining time and introduction of buffer between two working stations. Again the rationale of keeping buffer in between the work stations is governed by the variance of machining times and average machine failure time with probability values. Readers may be curious to view this case from these alternate angles in order to derive some conclusions.

As correctly pointed out in the case, quality plays a vital role in defining the throughput rate of EFMD. Low rejections of 0.53% due to quality failure after inspection and assembly yield higher productivity as seen in this particular case. This emphasis on strong quality check has a drawback too. As per quality initiative mandate, the production process stops whenever there is a failure. Following the principle of product-based layout with no inventory in between workstations, failure of a machine will result in a complete shutdown of the production process. Authors question the idea of zero buffer policy in this situation with machine failures.

Finally, the use of simulation is a good way to introduce the readers to a widely used methodology for handling uncertain situations like these. There are various analytical methods developed to tackle this uncertainty in an assembly line environment, as reported in recent papers (such as Bentaha, Battaïa, & Dolgui, 2014). Following their findings, there is still an opportunity to address the situation considered in the case from an analytical angle.
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