PROJECT monitor

The challenge of balancing supply and demand

Dr. Alan Barnard, **Tuesday, January 24, 2012, 14:35 Hrs [IST]**

Cumulative Flow Diagrams provide a method for 'Bottleneck Identification' as well as a tool to understand why stock or time buffers go into the red, writes **Dr. Alan Barnard**, Chief Executive Officer, Goldratt Research Labs.

To ensure an organization, supply chain or even a country can reliably meet the demand, it needs to know where the capacity constraint(s) are within the system that can limit it from reliably meeting the demand and/or catching up on a backlog in demand. The increased complexity of organizations, supply chains and countries today is making it more and more difficult to identify the real capacity constraints that currently govern the throughput of their entire system. When the demand exceeds capacity of a system, it might appear as if every part of the chain is a constraint or that it moves all the time. Considering the need to best allocate scarce resources to improve systems by focusing on the "weakest link" of the system, is there a practical way to allow decision makers to identify the true "weakest link" in the system to focus improvement on?

Private and public sector organizations and supply chains use stock, time and capacity buffers to both protect their product/service throughput, due date performance and/or availability from inherent variation in demand and supply. The status of these buffers can therefore be used to monitor the status of the overall "system". If a buffer is green, it means the overall system is well protected against that part. If a buffer is red, it means the system throughput and reliability are in danger of being compromised.

However, when a specific capacity, stock or time buffer goes in the red or black (out-ofstock or overdue), we frequently do not know the cause of this "red or black zone penetration". For example, if a stock buffer goes into the red or black, it could be that either the demand has increased (above what was expected) or that there has been some breakdown or slow down in the supply. Knowing the cause of this status can be critical in deciding the best way to respond for decisions makers within organizations and governments.

Balancing Flow not Capacity

To solve both the problem of identification of real bottlenecks in the flow (capacity constrained resources) and the identification of the "causes of buffer status" within complex flow environments, managers can use a "Cumulative Flow diagram" to track the Cumulative Flow of Orders (demand) and Cumulative Flow of Production or Shipments (supply) for the whole process or even for each of the sub-processes or links.

In his groundbreaking book titled The Race (1986), Dr. Eli Goldratt stated that one of the key "global optima" principles for improving flow and synchronization within and throughout a supply chain is to "Balance Flow-not Capacity". This principle highlights the need to "unbalance capacities" to ensure that each process has sufficient protective capacity to keep the flow synchronized with the current System Constraint. When capacities are balanced, you can get interactive constraints that cause highly erratic and unpredictable fluctuations (chaos) and losses in throughput. But knowing how much protective capacity nonconstraints need to ensure the system constraint is never starved or blocked is not an easy question to answer since most organizations have processes that experience high levels of variation and uncertainty. This means the data is simply not accurate enough to identify the System Constraint and to identify how much protective capacity each link should have in order to ensure the constraint is never starved or blocked (to ensure balanced flow)

The simplest way to identify whether flows are balanced is simply to graph the cumulative flows through each of the processes. This not only provides a practical way to identify if the flows are balanced (parallel flows) but also to identify current constraint (the process with the lowest Throughput/ Time slope and where WIP is building up in front of it).

Figure 1 shows such a cumulative flow diagram within a software environment, clearly showing how the flow of each process is "balanced" to the demand.

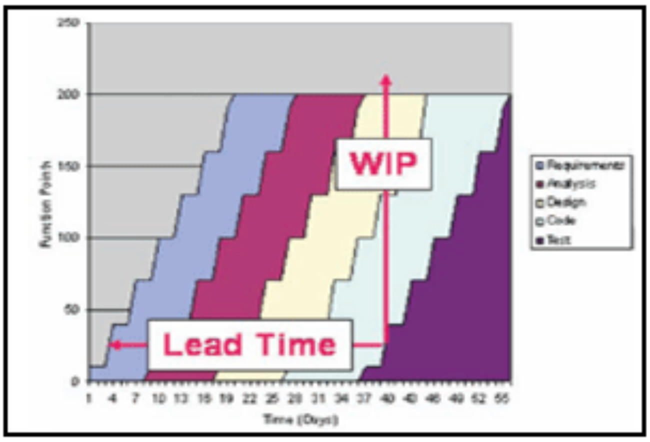

Figure 1: Cumulative flows for a software development environment (Diagram from article by David Anderson, May 2005, Using Cumulative Flow Diagrams).

The way to prepare CFD is to simply plot over time the arrivals of orders, and when those orders pass through each of the processes until it is shipped out of the system to the customer. This means the value or units related to an order arriving on day 1 will appear on day 1 in the graph. This same order will show departing from the system some time later. This time equals the total lead-time the order spent in the system. If it is not possible or impractical to get this arrival and departure data by order, simply plotting the cumulative arrivals of orders in the system vs. the cumulative departures/ shipments will also show whether these flows are (on average) balanced or not. The vertical access can either represent the value (in $) of orders arriving and departing or the units.

There are a number of benefits of a Cumulative Flow Diagram (CFD):

1. Little's Law states the Average Inventory within a system is equal to the Average Lead-time or Flow Time multiplied by the Average Throughput or Flow Rate. Simply put, the inventory is directly proportional to the lead-time for processing that inventory. Figure 1 also shows how to read the WIP inventory and Lead-times directly from the CFD. The total lead-time a "job" spends in the system is the horizontal difference between the arrival of that job in the system and its departure some time later. The total WIP in the system is the vertical difference between the job arrival graph and the job departure graph.
2. Figure 1 also demonstrates how batch sizes and batch transfers affect the cumulative flow plot. The large transfer batch can be clearly seen from the jaggedness of the plot. With larger transfer batch sizes, there is more WIP and longer lead-times. With smaller batch sizes [as in Figure 2], WIP is reduced and lead-time falls accordingly. Note the smoothness of the plot in Figure 2. The lead-times can be clearly read from the diagram.
3. The CFD also shows why sometime it takes so long to recover from a breakdown/shutdown in the supply of a product and or when the demand exceeds capacity for some period of time. If there is a breakdown or shutdown, the Throughput through that process will be a flat line [for the time of the breakdown or shutdown].

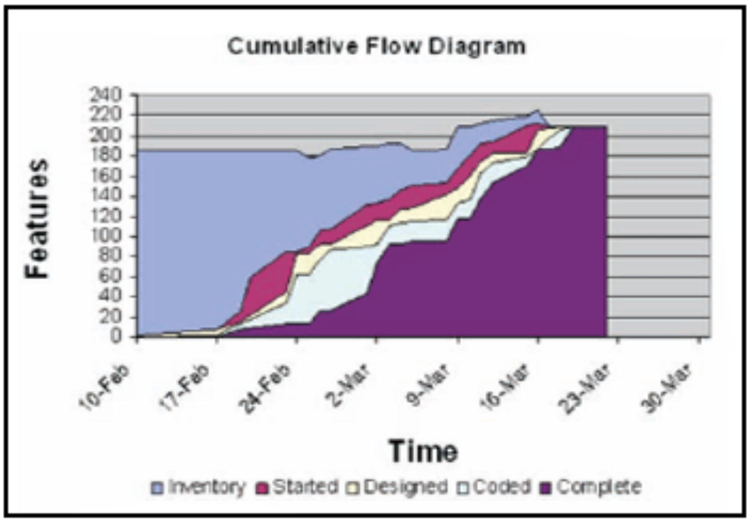

Figure 2: CFD showing lead-time fall as a result of reduced Batches and Reduced WIP (Diagram from article by David Anderson, May 2005, Using Cumulative Flow Diagrams.)

However, if the process does not have catch-up capacity, the number of back-orders would have increased and, at the same time, the lead-time [the difference between the cumulative arrivals of new orders and the cumulative shipments] would increase permanently.

1. When a stock or time buffer goes into the red or black, we can look at the CFD to identify whether, for this product group, the rate of arrival of orders have increased or whether the rate of shipments (departures) have decreased to identify the cause of the red or black buffer status.
2. There is a major risk to the stability of a process or even supply chain to ensure a vicious cycle is not triggered when there is a real capacity constraint. For example, when stock buffers spend too much time in the red, the dynamic buffer management system will trigger an increase in stock buffer sizes to prevent the risk of stock-outs. However, if the "cause" of the frequent red zone penetration is a capacity constraint either internally or at a supplier, this will trigger a vicious cycle where additional orders is placed on the system (to fill the larger buffers), consuming constraint capacity (which is already under pressure) causing buffers not to come out of the red. This in turn will trigger another buffer increase, which will generate more orders etc. It is therefore critical to have a mechanism such as a CFD to help buyers, operations planners and other stakeholders responsible for maintaining a balanced flow with sufficient time and stock buffers, to be able to differentiate when buffers are increased (or decreased) whether this is due to a change in demand or supply capacity/ reliability.

Summary

Cumulative Flow Diagrams provide a method for "Bottleneck Identification" as well as a tool to understand why stock or time buffers go into the red (is it due to increase in demand or reduction in supply?). CFDs also offer us a simple method of tracking work-inprogress and visually analyzing the trend in lead-time or cycle times between the links in the supply chain—either just the processes within your manufacturing process or even across a whole supply chain They provide a leading metric which allows managers to react early to emerging vendor, capacity or market constraints provide transparency into the supply chain performance for each of the links—each link can see whether they are synchronized or not and how their performance impact the rest of the system. It also provides a simple mechanism for determining what causes a time or stock buffer to be too much in the red or too much in the green to prevent vicious cycles of increasing buffers when these are caused by capacity constraints.

A cumulative flow graph, which graphs the cumulative orders received against the cumulative shipments provides the simplest visual way to identify whether the overall flows into and out of any system is balanced or not. The objective is to balance these two flows and any change in demand or supply clearly shows up to explain the current buffer status. It can be used for the total company, a total product group or a specific stock keeping unit and the vertical axis can be either value (dollars) or units arrived and departed.

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