Using Systems Thinking and Dynamic Simulations to Reengineer Manufacturing Processes at Silicon Graphics

Matt Mayberry, Kent Hoxsey, Kerry McCracken, Carl Rendell
Silicon Graphics Inc.
Mountain View, CA 94043-1389

Abstract
Business Process Reengineering (BPR) is a methodology for fundamentally changing key business processes to improve performance. The type of systemic change implied by the notion in "radical rethinking of business processes" lends itself well to a systems dynamics (SD) approach. In this paper, we describe how various SD tools have helped our reengineering team implement fundamental changes to our material planning and control processes at Silicon Graphics (SGI). These methods have helped our organization gain a deeper understanding of our supply chain dynamics, develop alternative structures and ultimately change the way material flow is managed.

Introduction

Reengineering is about radical change. Hammer [1] refers to the need for "discontinuous thinking-- identifying and abandoning the outdated rules and fundamental assumptions that underlie current business operations." But how do we identify the old thinking that needs to be abandoned and how do we challenge it? And how do we create low-risk opportunities for members of an organization to develop fundamentally new thinking and experiment with new behaviors? These were questions our reengineering team realized we needed to address if we were to be effective catalysts of change within our organization.

Our pilot BPR project took place within the manufacturing division of Silicon Graphics Inc., a maker of high-performance graphics workstations and servers. Late in 1994, our team [2] was formed in manufacturing to address the problem of inconsistent material flow though our factory. Chronic shortages of printed circuit assemblies (PCAs) on the production floor prevented us from creating credible build plans and meeting customer delivery commitments. Reducing the PCA cycle time--the elapsed time from the start of the process to the delivery of boards--was seen as a way to increase flexibility by "postponing" the commitment of material. Our reengineering team (dubbed the CORE PCA team) was thus presented with the following challenge: to reduce PCA cycle times from "3 weeks to 3 days." We were largely on our own as a team to figure out how to tackle this problem and influence the rest of the organization to change.

As our project evolved, we eventually incorporated a variety of SD tools into our effort. Ultimately, these tools helped us to cut inventory levels on the factory floor by a third, and virtually eliminate material shortages.

Developing the Systems "Story"

Our first challenge as a team was to figure out why PCA cycle times were so long. Through a scientific approach to data collection, we quickly determined that material shortages throughout the supply chain (which caused process delays) were independent of PCA size, type or technology. Systems thinking enabled us within a few weeks to piece together a dynamic "story" about why these chronic shortages were an inevitable consequence of our material planning and control system. This story is depicted in Fig. 1 and described below.

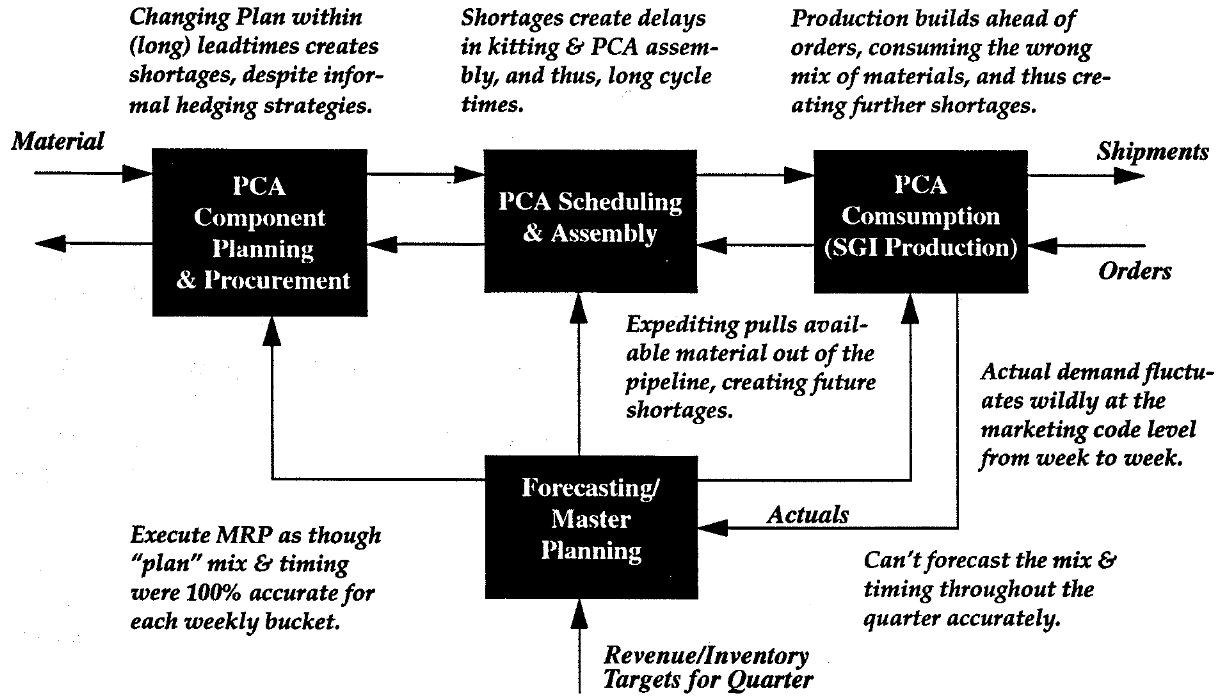

Fig. 1. The systems "story" about long PCA cycle times

The basic structure is that of a "quick fix that backfires." Our story begins with our customer demand, which fluctuates wildly at the product level. In part, this is due to the wide range of workstation configurations (i.e. different memory, processor, graphics, etc.) SGI offers to customers. Because of these statistical variations in demand, it is virtually impossible to predict accurately the mix and timing of customer orders throughout the quarter. Yet, we tended to use our Material Resource Planning (MRP) scheduling system as though the forecasts were in fact accurate. Purchase orders, work orders and production schedules were all established with precise quantities and timings. Whenever pre-programmed schedules did not coincide with actual demand, the material plans and schedules got changed, and components and subassemblies were expedited to meet the urgent demands of the production lines. Expedites became especially prevalent each quarter-end.

While this expediting activity temporarily eliminated the shortages--especially at quarter-end--it created a host of other problems. For example, expediting from suppliers to satisfy near-term demand created future shortages because on-order material in the pipeline was depleted. Thus, intense expediting to "make the quarter" resulted in scarce material availability at the beginning of the following quarter. In addition, the time spent rescheduling and expediting material diverted attention away from longer-term problem solving.

Even local attempts to reduce the effects of uncertain demand and supply by "hedging" backfired. Planners and schedulers built up inventories of subassemblies or systems before they were needed--so-called "just in case" inventory. This committed common material to particular workstation configurations earlier than necessary, thus creating additional shortages.

The beauty of this story, compared to traditional BPR analyses using flowcharts and cycle time accounting, was that it could be summarized on one page, it was easily understood, and it presented a dynamic picture of why shortages were so tough to eliminate. Furthermore, we weren't blaming any one functional area for the systemic problems. The fact that the "system" was flawed helped our team overcome organizational resistance to our analysis.

Using Simulation to Experiment with Conceptual Process Designs

To confirm our systems story, we created a simulation game to recreate the typical patterns of material shortages and quarter-end expediting observed. This simulation game was inspired by the "Beer Game" as well as a simulation used by the consulting firm of Pittiglio, Rabin, Todd, and McGrath to teach just-in-time (JIT) material control principles. In our simulation, we recreated a simplified supply chain and represented material processing through the movement and assembly of Legos on several gameboards. Participants played roles patterned after traditional functional roles in SGI's manufacturing organization and made real-life decisions about material scheduling, ordering and processing. The only constraints were the process leadtimes, the stream of customer orders, and the marketing forecasts. With this game, we were able to validate our "systems story" remarkably well, reproducing observed patterns of material shortages and process delays.

We quickly realized that the same game could be used to experiment with our conceptual design ideas. A key breakthrough for our team occurred one day when we lined up a single row of cups (representing kanbans) and played with basic demand-pull (JIT) material replenishment techniques. The self-regulating property of demand-pull was most striking: material moved along the supply chain only when there was demand for it. If demand decreased, the material movement automatically slowed. If demand increased, material movement sped up. No "rescheduling" was needed and material shortages were virtually eliminated. It was just this insight which convinced us to propose a demand-pull implementation for our division and it was this same learning experience that we hoped to share with the rest of the organization to build enthusiasm for the effort.

Since then, we have conducted over twenty-five full day sessions with our MRP/pull simulation for various manufacturing teams and vendor partners. Typically, we spend the morning on the MRP simulation, break for lunch, and then change the game over to demonstrate a demand-pull system. The simulation provides a direct juxtaposition of the present system (MRP) with a fundamentally different system (pull), providing players with a clear idea of the differences and advantages of pull-based execution. Rather than lecturing to the organization about the advantages of demand-pull, participants experience for themselves the differences between the two systems. This approach helped generate a great deal of support for our subsequent implementation of a pilot process on our highest volume production line.

Using Dynamic Simulation to Facilitate Implementation

It is one thing to demonstrate a conceptual design in a simulation game and quite another to formalize the design to the point where implementation is feasible. To successfully implement a new process, roles must be defined, I/S tools developed, employees trained and diagnostics put in place to measure performance. For our reengineering team, these requirements meant that the "science" of dynamic kanban sizing in an environment with nonlinear demand had to be developed. Using dynamic simulations helped us to develop our pull theory by allowing us to experiment. What began as an informal "guessing" about how to size ended up as hard business rules and a systematic approach which could be coded into our information system.

Even highly complex supply chains can be build up from simple modules or "cells" which are easily modelled using dynamic simulation tools such as ithink. Using simple models it is relatively straightforward to reproduce realistic conditions, including demand fluctuations, the "hockey stick" (non-linear orders), supplier leadtime variability, forecast accuracy, product transitions and so on. Playing with these factors allowed us to develop an intuitive understanding of "pull" dynamics and thus develop a comprehensive approach which addressed real-life issues.

By varying the parameters to reproduce specific situations, the model also allowed us to deal with a number of practical issues which surfaced during the pilot implementation. For example, there was concern that "postponing" the production build until later in the quarter would create a risk of getting caught short of capacity at quarter end. Using ithink, we were able to develop a capacity planning tool which allowed the line to identify the critical point in the quarter where they needed to utilize all of their capacity by building to stock. This tool was rapidly adopted by the line and replaced their existing MRP scheduling tool.

One of our challenges during implementation was to compress our team's learning into a relatively simple set of principles which we could transfer to the organization. To accomplish this, we developed a training course in pull. For the theoretical portion of the class, we used ithink dynamic models to demonstrate concepts and allow students to experiment with their new roles as managers of the pull process. We used a step-by-step approach, adding complexity to the models gradually so that successive exercises built upon knowledge gained from previous exercises. By the end of the course, students were able to successfully size kanbans in a variety of realistic situations. They also gained experience working as a team to manage the supply chain, react to problems, diagnose them and fix them.

We also developed a fundamentally new set of metrics based on our experience with simulation. These metrics allowed us to track pull part performance, diagnose problems and evaluate the success of our pilot implementation effort.

Conclusion

We have outlined briefly here how the use of systems thinking and dynamic simulations throughout the re-engineering process can help streamline analysis, improve conceptual designs, refine concepts, gain organizational acceptance, overcome obstacles during implementation, train the organization, and create new metrics. What started out for our team as an interest in gaining a deeper understanding of the root causes of material shortages in manufacturing ultimately became an indispensable part of our effort to lead organizational change.

While our team has solved a variety of complex materials problems, we also realize that we have not addressed many of the cultural factors and organizational dynamics which have allowed these problems to persist for so long. These issues cannot be addressed by a reengineering team in isolation. They require "discontinuous thinking" beyond the dynamics of material flow. Our next challenge, then, is to find ways to get the organization itself engaged in this broader learning process. Only then will self-sustaining improvements be achieved.

References

[1] Michael Hammer and James Champy, *Reengineering the Corporation: a Manifesto for Business Revolution*, New York: HarperBusiness, 1993.
[2] We'd like to acknowledge the invaluable contributions of our CORE PCA teammates: Angel Figueroa, Jason Landis, Kristine Brezovec, Bob Spiegel, and Steve Hussey with the consulting firm of Pittiglio, Rabin, Todd & McGrath.