Delivering Solutions to Customers: High-Velocity Manufacturing

http://kuper..ASCET.com

André Kuper, Heinz Schmid, Bublu Thakur-Weigold, and Doug Kahn
Hewlett-Packard Company

HP's "solution factory" is an innovative production environment with a build-to-order strategy. The result is a minimum amount of inventory, and operational excellence that is driven by responsiveness to the customer rather than by factory utilization.

Background

Heinz Schmid has been supply chain manager at HP in Europe for 2 years. Before taking on this role, he received the assignment to design, build, and implement a solutions factory in Gueltstein, Germany in 1995. This operations facility has been in production since 1998, and has a sibling in Roseville, California built a year later [Blake H. Jr., 2000]. The production test of a third version in Singapore is currently in progress. This is the story of the creation of a highly innovative manufacturing operation that focuses on velocity, and strives to eliminate delays in delivering products to the customer. The development of the Gueltstein operation is a unique achievement: a small team, with only one outside consultant, designed high-velocity material- and information-flows and their associated systems, within significant time and budget constraints. The speed they aimed for is achieved by a combination of parallel processes, flexible labor practices, and state-of-the-art systems.

Gueltstein's velocity thereby exploits the best practices of a seemingly unrelated industry: food and groceries. Comparing high-tech to fresh products like fruit and vegetables, where spoilage drives the velocity of processing and sales, Schmid's team resolved to eliminate the "spoilage," i.e., obsolescence and depreciation, of computer components. The custom-ordered products manufactured in Gueltstein are typically unique in their configuration. The likelihood of a new order for a similar configuration might only be once a year, increasing the pressure on planning to be accurate and on the supply chain to be flexible. In a race against time, critical components must be put to immediate use because of the price erosion typical of high-tech market dynamics. As the insightful design team concluded, "no one likes to buy brown bananas."

Also unique to the Gueltstein project was the collaboration with workplace services to face the challenges posed by civil engineering and building the physical plant. For example, how were they to resolve the inevitable conflict between full manufacturing flexibility and the business imperative to maximize return on both assets (ROA) and investment (ROI)?

Building a factory from scratch, which will have the flexibility to build the yet-unknown products, while tying up a minimum of assets, is no small task. Undaunted, Heinz' broad experience in manufacturing led him to ask the all the tough questions, and to arrive at a holistic view of the scope of the project. His promotion to supply chain manager in May 1999 was a natural extension of this experience—allowing HP to capitalize on collaborative networks. As Heinz put it, "Our global supply chain has characteristics similar to a shopfloor. It is a network with many nodes (elements) and links between nodes."

Schmid identified the few fundamental processes, which were instrumental to the success of his complex manufacturing environment: managing information and material flows, subcontracting, assurance of supply, and price negotiation. To appreciate the complexities he faced, one look at the backbone of the product, HP's Superdome computer, will suffice. These machines are so big that the mere physical necessity of moving them around is a hindrance to manufacturing velocity.

The project team had to think about limiting the area in which product assembly, configuration, and product building is carried out. Similarly, the manufacturing activities had to be centered on completing the product, rather than moving the component parts and products from work-center to center. From the planning of these simple physical facts, the Gueltstein plant team rose to the challenge of holistic manufacturing processes.

A Closer Look at the Process Flows

What distinguishes the Gueltstein facility is the fact that the team assumes responsibil-

André Kuper is employed by the Hewlett-Packard Company. He works with internal and external experts to define business models incorporating the power of the Internet. He creates supply chain communities balancing the need for personal contact, access to information, and action. André collaborates with a multitude of partners to define business webs driven by customer needs for small business, consumer, and major account segments. He focuses on velocity, volatility, and flexibility. He holds master's degrees in applied physics and in instructional design from The University of Twente (UT), The Netherlands. He has published in Cutter IT Journal, achieving supply chain excellence through technology (ascet), Production and Operations Management Society (POMS), the IT Journal, and on the Internet (www.hp.com/go/supplychain) Prior to his work with HP, Mr. Kuper worked at the Applied Superconductivity Lab at UT and at Andersen Consulting ECC in Enschede, The Netherlands, doing research and applying innovations in superconducting technology and multimedia self-learning tools, respectively.

ity for all the processes involved around manufacturing, starting from the assembly of the configuration, through to switching on the final product at the customer's site. Among the products it creates are the complete, ready-to-power-up Global Systems it delivers to the end-customers of mobile telecommunications.

In order to deliver complex products with high quality, they perfected a few key processes:

- Order fulfillment—from order to shipment and powering-up the finished product.
- Lifecycle management—focusing on customer value.
- Shopfloor Planning—driven by shipment process.
- Shipping—driven by commitments to customer expectations.
- Product Design—balancing the generic with customer-specific.
- Sourcing—forecasting, planning, tracking and tracing.

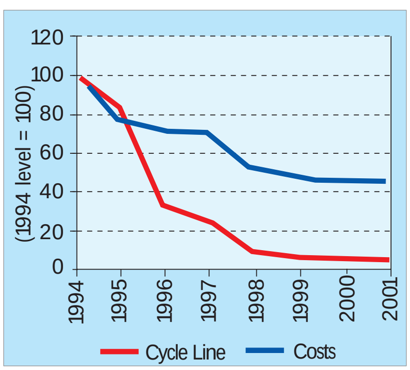

Figure 1 Performance Relative to 1994

The project team turned its attention to product design, particularly the amount of customization allowed, which would ultimately determine the velocity of their operations. They split their manufacturing process into a generic (build-to-forecast) segment and a customer-specific (build-to-order) segment, and a decision had to be made on which point in the manufacturing process the generic switched over to the custom. The positioning of this push-pull boundary entails a trade-off between technology, physical constraints, product costs (landed product costs), together with time-to-market targets. The team decided to define the most effective lowest common denominator item within the assembly of any one product: the sub-product or component upon which all potential product configurations could be built. This lowest common denominator "box" could then be produced to plan, based on total expected forecast quantities. To arrive at a design that would reliably optimize future production, HP considered the role of various physical product features. The manufacturing team within the factory had to anticipate constraints waiting at the customer's site. Network infrastructure configuration, the capacity for room temperature control, airflow limitations, and even simple physical access to the customer's location can all have significant ramifications. These factors outside the factory's walls influence when, where, and how the product is built on the assembly line so it can be effortlessly plugged in and powered up at the customer site.

The Gueltstein team ultimately decided to allow configuration choice at the product level. Specifically, configuration at the product or lowest common denominator box level consists of a chassis, to which mechanical parts, input-output devices, memory storage, processors, and software are added. The customer order could potentially have been introduced at the time of any one of these assembly elements but was shifted upstream, to the most generic sub-assembly to permit mass customization.

Sourcing of the product's lowest common denominator box is done principally from outside Europe, resorting to local sourcing in exceptional cases. The LCD's pre-prepared material kit is bought against plan. Under forecast boundary conditions, the stock on-hand typically represents three weeks of supply. Because Gueltstein's local stock is generic, thus unsold, inventory, the materials management processes strive to always keep the actual quantity at a minimum. The products factory is nevertheless able meet the delivery expectations of its customers with so little buffer because it is part of a continuous global replenishment process. Critical components are stockpiled in a worldwide central location, applying principles of risk pooling. HP aggregates demand uncertainty across multiple operations, to ultimately reduce the minimum inventory required for a responsive supply chain (safety stock). Fast-moving worldwide replenishment processes (two to three days) allow HP's regions to take advantage of the centralized inventory pool.

The further away the source of parts, subassemblies, and products, the higher the risk and uncertainty around timely availability of supply. Across the street from the factory, any contingencies can be quickly tackled. HP's contingency planning has deliberately shifted its focus from execution to transit variability (also to exploit the tax savings made possible when materials flow through certain overseas locations). Prompted by the increased risk of disrupted air transport, planners in Gueltstein recently decided to accumulate an additional week of buffer inventory. Attention to global transport risk increased after the September 11th terrorist attacks in New York, when air shipments to and from the United States were halted for one and a half weeks.

Memory is one such commodity - subject to high volatility of price and supply - which is centrally procured and stockpiled in Puerto Rico. This HP-owned warehouse acts as a virtual buyer for the products factories abroad. The Puerto Rican procurement teams have direct systems access to the material resource planning systems in Gueltstein and Roseville, which eliminates the usual redundancies in the information flow between suppliers and point-of-use. Through the transatlantic systems integration there is an overall reduction of transactional costs.

Sourcing of the Gueltstein facility is integrated into its ERP systems (HP's worldwide SAP/R3 installation), and committed to meeting customer expectations. Suppliers are notified automatically (and occasionally through fax and email), to meet order-fulfillment's locally defined target dates. A monthly forecast update is transmitted to the entire supply chain to ensure that everyone works from the same image of the demand. Although this factory works within a regional fulfillment strategy, sourcing of strategic parts is globally managed.

While operational sourcing occurs locally, the Gueltstein operation buys the majority of its parts from the global marketplace. This magnitude), poses a unique challenge to labor management. Spurred on by allegations of wage/productivity liability in their selected location, the HP solution factory proceeded to invent a viable concept for labor flexibility. A novelty in the German market, with its strong tradition of conservative and powerful trade unions, the Gueltstein approach manages phases of low workload under declining orders, together with the multiple shifts necessary to meet exploding demand, with equal effectiveness. Manufacturing facilities in Germany have a comparatively high wage level on the world market, and must maintain a high productivity level in order to achieve competitive cost-per-product. Making trade-offs remains instrumental to tackling these challenges, since a high-end plant must be able to attract and retain a highly qualified—thus highly-paid—workforce. Rather than committing workers to a fixed, 40-hour, weekly contract, they offered flexible labor options for 160 hours distributed over a month, or approximately 1,600 hours performed per year. These innovative contracts, devised in close collaboration with the workers' council, allowed employees new and attractive choices, with no detrimental effect on sick leave or dedicated time off. Convinced of the mutual benefits of the model, the workers' council approved the plan as required by German law. Gueltstein typically distributes its workload into two shifts over five days a week. These 10 shifts can, however, be stepped up to 18 shifts within a short period. The flexible labor concept extends into remuneration. A practical distinction creates incentives for skill flexibility: the highest skill workers can work everywhere in the plant, while the lowest skill workers are dedicated to a limited number of tasks and work centers. The skill level and flexibility of the workers, in turn, determines their salary.

A further innovation was made in how labor and capacity allocation were integrated into the factory's processes and IT systems. Both labor and plant capacity are actually entered as items in the electronic bill of materials (BOM). For the execution of the Materials Requirements Planning run, they have a unique characteristic, because, unlike real components, they cannot be

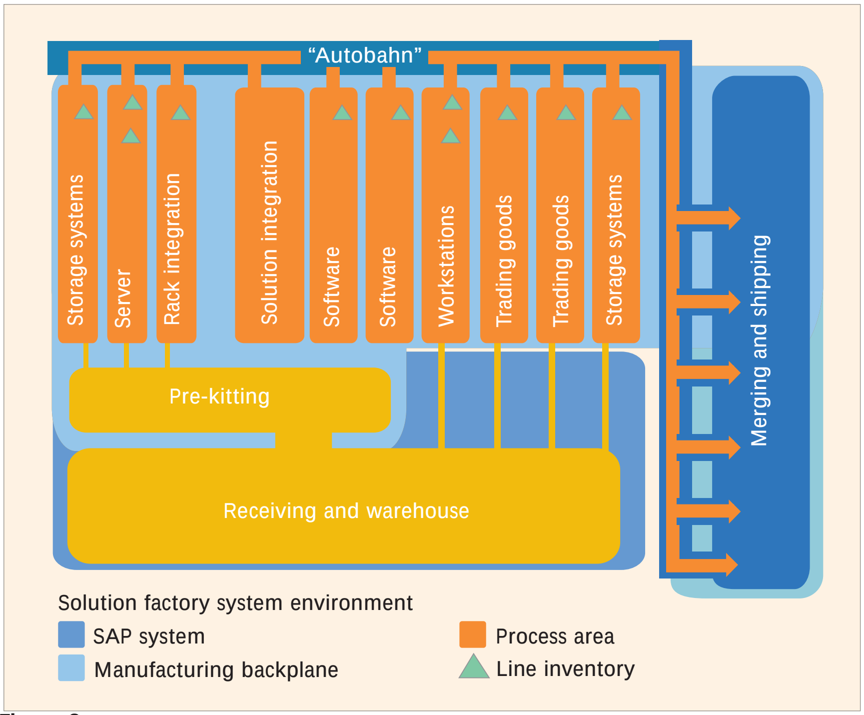

Figure 2 The performance improvement achieved as a result of changing to a modular process and strategic choices the push-pull boundaries. This operations model is enabled by the HP proprietary manufacturing backplane integrated with a SAP R/3 system.

allows for the pooling of demand volatility, while creating procurement leverage around strategic parts. Finally, a worldwide procurement process allows global product consistency for HP's manufacturing.

At a practical level, this means HP's preferred suppliers receive an aggregate demand report, split by region. Individual transactions are then executed and managed on a regional level. To ensure visibility, HP effectively owns all material flows between suppliers, manufacturing locations, and customers. The capability to track and trace goods in transit eliminates the uncertainty around (inbound and outbound) material flows. The visibility, which HP gains by owning this forwarding process, in turn, allows for flexible and informed decision-making within high-velocity order fulfillment. Common knowledge at HP says: "it is important to be in-the-know."

Flexibility

To attain flexibility in order fulfillment, HP needed to be flexible with both labor and plant capacity. At the high-velocity factory, this flexibility is accomplished by tying the manufacturing planning process to the capacity allocation process. It starts with the physical layout of the plant, which must, as a principle, be able to cope with the maximum potential capacity requirements. However, by building a plant to accommodate possible demand peaks, the asset impact on HP's balance sheet becomes a concern. There is an inherent risk in a costly build-up of plant capacity when combined with the demand uncertainties natural in a build-to-order strategy. When building high-end computer products, the order peaks of other products or products cannot fill the troughs of little work. To avoid being pressured into a more continuous usage of the manufacturing facilities just to offset fixed costs, the Gueltstein team put great care into creating the lowest possible asset load to begin with. The simplification and multi-usage of their physical plant averts some of the justifications inevitably demanded by financial controllers when demand (and consequently utilization), drops.

Beyond the return on factory capacity, the demand volatility inherent to the industry (which can swing by two to three orders of reused or redeployed. Once the allocated time has expired, unused capacity is deleted manually from the systems. Management of individual work schedules, taking both lead times for reporting to work and personal freedom into account, are also integrated into systems at Gueltstein: short message services (SMS) via workers' mobile phones alert them, within the hour, of unplanned changes to scheduled shifts. This degree of precision within the matching of planned work to labor availability eliminates the waiting times so common to assembly lines, and accelerates the overall manufacturing velocity in Gueltstein.

Velocity

The high velocity factory devised manufacturing processes that work in parallel. The all-too common need to stage and store on the shop floor is eliminated, resulting in a significant reduction of work-in-progress. The overall inventory reduction in the plant keeps the total costs down.

Looking back on this phase of factory design, Heinz stated that, "Legacy systems focus on a serial approach to scheduling. They are batch-oriented. When we shift to velocity this doesn't apply anymore." His radical goal to cut out waiting time meant that none of the standard software suites available on the market at the time could be used. The team decided to develop their own proprietary system to support the vision of parallel, delivery-driven scheduling. The times at which the trucks leave the factory determine the manufacturing timeline and their departure connects directly to the European logistics network. The Gueltstein approach is centered on what they call work objects, 15 to 20 of which typically comprise a complete customer order. Committed to completion within the order's promised date, each of these objects (computers, disk drives, software loads, and accessory kits) is managed independently of one another, scheduled individually according to their own cycle times. Starting with the work object requiring the longest lead-time, all objects are targeted to fit through the narrow window of time preset for final shipment. Again, this parallel backwards-scheduling drives out the delays, which conventionally result from misaligned processes and information. The precision of tightly-scheduled, parallel assembly clearly eliminates any need for local storage. Some carefully-selected redundancy and buffer (for example, in cycle times) is, however, built in to permit self-adjustment, and avoid micro-management. An automated conveyer system dubbed "the Autobahn" orchestrates the apparently random movement of workobjects through the aisles.

The Gueltstein scheduling concept is comparable to an airline gate, which only permits those ticketed passengers who arrive on time to pass. It treats the final destination (completed customer order) very much like a gate. On his computer screen at each assembly station, each operator sees the associated subassembly flows, which are color-coded—green for those comfortably within the anticipated lead time, yellow when about to be delivered, and red when assembly is behind schedule. The different colored-signals thereby facilitate exception processes. In exceptional cases, red flows receive preferential treatment, and can be inserted into the schedule to cope with unexpected volatility in the process or in customer demand.

Lessons Learned

The solution factory realized that since late and early deliveries alike contribute to negative customer experience, timing is everything. Defining velocity to be the goal meant transforming the working mode from batch and serial processes, to parallel processes. Velocity implied linking all processes and systems seamlessly, which, in turn, reduced costs.

Wary of total automation, Schmid insisted upon establishing an explicit and inescapable value-added by each and every transactional workflow, be it between people, or between people and systems. In other words, assembly processes were designed so that it is impossible for a worker to complete a work object independent of its supporting system. Consequently, maverick, trial-and-error, and uncoordinated work steps are rendered impossible. For example, it is impossible to carry out an automatic test of an incorrect (defined to be a less than 100 percent match to the customer specifications) product configuration. By doing it right the first time, quality, avoidance of costly rework, and velocity were assured.

> **more on the Web**
>
> *Read more about this and the case study at authorname.ASCET.com*

At the same time, the team systematically eliminated any dependencies between material and information flows that were not absolutely necessary to completing a product. An example of this is the "Autobahn" or conveyor system, which is a stand-alone facility. Because it is not (electronically) automated to link with the production control system, a mechanical breakdown or delay in this "taxi" system would have no significant impact on the surrounding systems environment.

The most important prerequisite for the unfailing innovation displayed by the Gueltstein project was the ability to look out beyond traditional functional and organizational horizons. The attention of a manufacturing team to the specifics of customer expectations, expanding beyond just making the best product, exemplifies this attitude.

The factory design team drew upon a variety of functions, organizations, and enterprises to comprise the decision-making team. They included all stakeholders in the process, i.e., all those people that can either make the program a success, or prevent it from ever becoming reality. In any supply chain, the material flows are administered by organizations, and the various points at which information is generated and transferred, need to be aligned.

Schmid's team discovered a critical opportunity in learning from other industries with similar challenges. The comparison of high-tech products to fresh produce was both enlightening and bold, clearly a refreshing—and highly profitable—departure from the "not-invented-here" syndrome.

Results

- The design and building of the plant in Gueltstein had the a measurable business impact in the 1997 to 2001 period.
- Cycle time, from order entry to customer receipt, reduced from 60 days in 1993 to six days in 1998. This is an 80 percent performance improvement.

- Inventory levels decreased by 30 percent.
- Operations cost cut by 30 percent
- Distribution cost shrunk by 70 percent. That is, order fulfillment costs were reduced to 30 percent of original value.
- On-time delivery performance increased by 100 percent.
- These results were achieved by focusing on customers (1994 to 1995), distribution (1995 to 1996), site completion, the implementation of SAP R/3, and supply chain management (2000 to present), respectively.

Acknowledgements

We would like to thank Oliver Schulz and Klaus Tippelt for their assistance and support. We also appreciate Tim Brown's time for financial information. ■

References

[1] *Blake, H., Jr., 2000, Measuring Service Quality in Proceedings of the 12th annual CSU-POM Conference, California State University, Sacramento, February 25-26, 2000*

[2] *Schräder, C., 2001, Produktivität und Lohnstückkosten im internationalen Vergleich, iw-trends 4/2001*

[3] *Kraaijeveld, K., 2001, Philips en ASML korten leveranciers, in de Volkskrant, 12 Oktober 2001*

[4] *Sharman, G. 1984, The rediscovery of logistics, Harvard Business Review, September-October, pp 71-79*

[5] *Billington, C. 1999, The language of supply chain,* Supply Chain Management Review, *Summer 1999, pp 86-99*

[6] *Kuper, A., 2000, Managing supply chains while moving at Internet speed,* Cutter IT Journal, *Vol 13, No. 3, March 2000, pp 17-22, see also www.hp.com/solutions1/supplychain*