The Modernization of Merit Brass

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The Merit Brass Company embarked on a modernization program at midyear 1990. Its goal was to improve customer service as economically as possible, since customer service is the most important variable in the industry. The company had outgrown its people-intensive systems and needed to implement management science methodologies to elevate it to the next level of performance. The new integrated management system relied on four major methodologies: statistical forecasting, cellular manufacturing, manufacturing (and purchasing) resource planning (MRP), and finished goods inventory management. At a modest cost and in record time, the company completed the implementation of all four components. The effects proved to be both synergistic and dramatic. The company has made major improvements in customer service while reducing costs.

Merit Brass is a 55-year-old family-owned company that supplies a variety of product families to the pipe, valve, and fittings (PVF) industry. At 55 years of age, it is the dean of the companies operating in its industry and an acknowledged leader. The company manufactures approximately 2,000 of the 8,000 products it distributes and is a super master distributor of the other 6,000. A super master distributor offers a very broad product line and sells only to wholesalers. Merit has a network of over 4,000 distributors, a small number of which account for
a large volume of company sales. For calendar years 1990 and 1991, the company's sales were essentially flat at over $30 million each year, as the recession hurt the industry.

In May 1990, the company decided to review many of its planning and control operations with a view toward modernization. It had reached a critical stage: people-intensive systems could no longer keep up with the volume of work. By people-intensive systems, we mean managers and analysts personally reviewing the inventory status of finished goods one item at a time to make production and purchasing decisions (also one at a time). The result of this approach was a fire-fighting mentality with all its drawbacks. The company held large inventories yet provided only fair customer service.

The PVF industry is characterized by intense competition on customer service and fairly severe price competition as well. Customers view products as commodities and assume they are of good quality if purchased from a reputable seller. The top managers of Merit Brass were surveyed by the author during the process that led to the company's quality strategy and were asked to rank the importance of the various dimensions of quality to their industry and to the company. All but one of the top 12 managers rated customer service as the most important short-term measure, and all 12 rated it as the most important long-term measure of quality.

With this customer-service objective in mind, the operations review identified four areas that needed attention: statistical forecasting, manufacturing (and purchasing) resource planning (MRP), cellular manufacturing, and finished goods inventory management. In September 1990, the company began serious efforts to implement these methodologies. By August 1991, the implementations were complete for the entire company (Figure 1). Two important ingredients facilitated this speed of implementation: the total cooperation of the key Merit Brass personnel in assembling the information necessary to support the applications and an off-the-shelf software package, STORM (1989). STORM (1) met the company's needs, (2) was easy to use, and (3) was inexpensive to implement. It runs on IBM-PC and compatible machines. The author is a principal in Storm Software Inc.

**Statistical Forecasting**

With over 8,000 skus (stock keeping units) to forecast, it was clear that quick but reasonable extrapolative methods would be the appropriate way to go. STORM's forecasting module [1989, Chapter 17] employs exponential smoothing methods with automatic model selection and smoothing constant optimization. The model selection process consists of trying to fit all four basic models to each time series and selecting the one that gives the lowest root mean squared error (RMSE) value on historical data. For each model, a search is performed to find the smoothing constant values that give the lowest RMSE for that time series. The search process
uses evolutionary operation to quickly home in on good values for the smoothing constants. The model and smoothing constants selected can then be saved to the forecasting data base so that the search does not have to be repeated each time the forecasts are prepared. Even with the program performing these tasks, the forecasting analyst still has plenty of work to do.

Some of the historical data had undesirable anomalies in it that had to be changed. The Merit Brass historical data contained statistical outliers and erratic data. A statistical outlier is a value for demand that is inconsistent with the remainder of the data. The causes of such outliers are numerous and are usually impossible to track down. The outlier may reflect a large one-time order received from a customer or an accounting error in which one period’s sales are credited to another. Customer returns from some previous period’s sales may be netted against the current period’s sales. In extreme cases, such events can result in negative sales for the current period (which are replaced with zeroes for forecasting purposes). Statistical outliers need to be replaced in the data base with some more reasonable values. Often we simply average the preceding and following value to come up with a sensible value. It is very important to clean up the data for two reasons. First, the computer software may choose the wrong model or the wrong
smoothing constants if outliers are left in. Second, the RMSE, which is ultimately used to establish safety inventory levels, will be substantially overstated if such bogus data are left in.

Erratic data are a string of observations that are inconsistent with other demand data. These data often occur at the beginning of a product's life. The first few periods may show only a dribble of demand, followed by a strong surge (to fill the distribution pipeline), and then stable or increasing demand as field sales commence. The dribble and surge parts of the history should simply be deleted from the data base to avoid some of the same problems that result from outliers.

The prospect of performing careful data cleanup for each of over 8,000 part numbers did not bring forth hoards of volunteers. To benefit quickly from the forecasting system, we decided to clean up only the Class A items, the small percent of items that account for a large percent of corporate sales—only a few hundred items.

Some other interesting problems had to be solved. The demand data for the products resided on the company's host minicomputer, but the forecasting software was on a PC. The company's systems analyst designed a utility that solved the problem in less than two weeks. For each product group in a forecasting data base, the forecast analyst uploads the part numbers to the minicomputer utility. It reads the part number, matches it to the demand data, and downloads the demand data to the PC. These data are then imported into the forecasting program. This takes only a few minutes per product group and allows the forecast analyst complete control in selecting part numbers for each group.

Product groups are very important at Merit Brass. The company uses a policy of sole or dual sourcing to gain the advantages of partnering with vendors. Typically, the company buys all items in a product group from only one or two vendors. Thus, it is convenient to modularize the forecasting data base to match the way the company does business, rather than to have one massive data base of all skus. This also facilitates processing, since processing one product group doesn't tie up a PC for long. The analyst can insert other critical tasks between running different product groups. This allowed us to implement the forecasting system product group by product group, rather than wait until all part numbers were implemented in a total implementation.

The analyst reviews the model and the smoothing constant selection results from the program. Since the products are generally industrial as opposed to consumer products, we did not expect to see a lot of seasonality in the data. This expectation was confirmed, but occasionally the software would pick up a spurious seasonal. The analyst simply overrode such selections with more rational selections. In general, only models without seasonality (level only, and level and trend components) are reasonable for this company. Another red
flag was the selection of extremely high
smoothing constant values. Such values
can lead to unstable forecasts and high er-
ror rates. The analyst simply reset any
value above 0.5 back down to 0.5 for such
time series.

We needed the program to output fore-
casts in a format that could be imported
into the master schedule file in the manu-
facturing resource planning system. This
master schedule file then drives the bill of
material explosion process. Storm Software
provided such a feature within two weeks
of a request at no charge to Merit Brass.
These issues were not major problems in
the implementation, but they illustrate the
fact that the software rarely does every-
thing for the manager/analyst. People us-
ing it should understand its benefits and its
limitations and interact with it in such a
way that they, and not the software
designers, are in control.

Manufacturing and Purchasing Resource
Planning

People normally think of MRP systems
primarily in conjunction with dependent
demand inventory management, and the
system did play that role at Merit Brass.
However, an equally critical role for the
system was capacity requirements planning
(CRP); CRP is a more complex and de-
manding process for Merit Brass than ma-
terial planning. The company manufac-
tures primarily brass and stainless nipples,
which have only brass and stainless steel
pipe as material inputs. The primary oper-
ations consist of cutting the pipe to length,
threading it to make nipples, degreasing
the nipples, and packaging them to go into
distribution inventories. Because the nip-
ples have a wide variety of diameters and
lengths (thus, the 2,000 plus part num-
bers), plant managers never knew whether
a particular production schedule was feasi-
ble before MRP. They found this very
frustrating, as did other managers in the
company with whom they interact,
particularly sales managers.

Since the plant was organized into manu-
f acturing cells, we constructed a separate
MRP data base for each cell. This provided

The threading operation is the
bottleneck operation.

the same advantages of modularity de-
scribed for forecasting. The eight manufac-
turing cells vary in the number of part
numbers and the volume of parts they
produce. One small cell has less than 100
part numbers assigned to it, while a large
one has over 600. Each large cell has its
own day of the week for its weekly update
run, but small cells are combined to allow
more than one of them to be run on one
day. The result is a five-day schedule that
covers all eight cells. The PC on which
MRP is run performs many other functions
as well and is not dedicated to MRP alone.
The only information not available on the
PC that is needed to run the update is the
current inventory level for each part or
material item. The company’s systems ana-
lyst developed a simple utility exactly anal-
ogous to the one described above for fore-
casting to download these data so that
they can be imported into MRP’s inventory
status file. This utility allows the plant
management personnel to add or delete
part numbers from an MRP data base as
needed without any additional program-
Another capability of the STORM MRP program is maintaining safety inventory levels. Providing the desired levels of safety stock for each item, the MRP program corrects planned orders according to the prevailing understock or overstock situation. This prevents inventory from building up if a part number is not selling and quickly rebuilds safety stocks if there is a run on an item.

By using the firm planned order capability, the plant management can override the MRP system’s suggested planned orders. This is useful for smoothing capacity loads during the planning horizon.

The lot sizing procedures also proved useful, but in some interesting and unusual ways. Since the manufacturing cells are organized around part families, each time a part family is run we want to run every part in the family that has a net need. In this way, we spread the setup cost for the family over all the part numbers. Economic lot sizing procedures are generally designed for individual part numbers, however, not for part families. We needed to support a rolling schedule wherein all part numbers in a family called for production at about the same time.

To accomplish this task, we performed an independent economic lot sizing exercise using a spreadsheet. We sought to identify an economic production cycle for each part family by trading off the inventory carrying costs of both cycle stocks and safety stocks against the setup costs. If the family had a single class A high volume demand item, the family would have an economic production cycle of about one month regardless of the demand for other part numbers. If the family included no
such high volume part, a cycle of about two months provided a reasonable trade-off. Since there is zero changeover time to go from one part number to another within a product family, we can run the low volume parts in the family on the same cycle as the high volume parts. It was easy to construct a master plan calling for high volume families to be produced

The company has reduced inventory in five product groups.

once a month and low volume families every other month. We used STORM’s fixed period lot-sizing rule to implement the results of our off-line economic analysis.

After a few months of operation, we noticed a disturbing problem with parts for which there was very little demand. MRP would call for production of a one-month supply of two units. However, the packaging quantity for the part number might be five, 25, or more units per pack. We corrected this problem for these specific items by changing the lot-sizing rule to a fixed quantity rule and entering the minimal packaging quantity as the fixed quantity value. Once again, we found that meeting the user’s needs required both ingenuity and software.

Preparing purchase orders for approximately 6,000 part numbers is an important task for Merit Brass acting as a master distributor. Prior to implementing MRP, the company made such purchases quarterly. Several problems were associated with this practice. First, extremely large shipments had to be received and put away. Many of these purchased parts had to be repackaged before they could be resold, and this created very lumpy demand on the packaging area. Second, the company was forced to make very large investments in inventory whenever it kept several months supply plus safety stock on hand. The vendors also had to build large inventories before shipping the orders since, in some cases, sales to Merit Brass represented large parts of their capacity. Finally, if the company ran out of an item, another shipment might not be due for months, during which the item would be backordered. Because each quarterly purchase order might contain several hundred items, each reviewed manually by the purchasing manager, the company was unable to support more frequent orders without modern management systems.

Now the company prepares forecasts for purchased items just as it does for manufactured ones. These forecasts drive an MRP process that allows for corrections to safety-stock inventories just as for manufactured products. Since the MRP data bases are by product group, the company now places monthly purchases with each vendor, resulting in more frequent and even shipments. It shares the bill-of-material explosion reports for several months into the future with its vendor partners to facilitate their capacity planning. This has resulted in shorter vendor lead times and more reliable vendor deliveries.

Cellular Manufacturing

The standard process the company uses to manufacture nipples (Figure 2) is to first cut the pipe into blanks, then thread both ends, degrease the nipples, and pack them into boxes to go to the finished goods.
gressed from one range of lengths to another.

In spite of the intentions of plant management, without an adequate planning system, the company often had to tear down a setup in the middle of running a part family to run "hot" items that were not members of that family. Since many machines can run several different part families, managers had to decide what to run next and on which machine. The shop floor situation that resulted was fairly messy and difficult to control.

The ability to produce demand forecasts for a year (or more) into the future and the bill of resources information allowed the company to design and install a much more coherent system. By taking the forecasts and multiplying by the capacity required per unit of processing time, we could estimate how many machines we needed to run each part family. This included both cutters and threaders. We then assigned a group of families to a set of equipment in such a way that the demand on the equipment matched its available capacity. We designated this set of equipment a manufacturing cell with the limited objective of making those part families. These are conceptual cells as opposed to physical cells; that is, two machines that belong to the same cell may not be located together in the plant. There are many benefits to such a cellular approach for Merit Brass.

**Finished Goods Inventory Management**

Merit Brass had to decide how much safety stock to keep for each part number. The company was using supply rules that were essentially rules of thumb (when inventory reaches a level estimated to last $n$
months, build it up to an amount expected to last \( n + m \) months, where \( n \) and \( m \) are integers). For parts with a high forecast error, such a month's supply rule may produce too little safety stock. The converse is true for a part with low forecast error. Our experience was that high volume, class A part numbers had low forecast errors relative to their average monthly demand. Low volume class C part numbers had high errors relative to their average demand. We were overstocking class A items and understocking class C items. Much of the company's fire fighting was the result of running out of nickel-and-dime class C items.

We input the forecast error values (RMSE) from our forecasting analysis into the STORM inventory management module and converted them to an estimate of the standard deviation of the forecast error. We next computed required safety stocks for each part number based on its forecast error rate and lead time using standard statistical inventory theory (1989, Chapter 13). We then transferred these safety-stock values to the appropriate MRP database for operational use.

These different applications are interrelated in a way that makes them synergistic for Merit Brass. The forecasts drive the MRP system, and the forecast errors drive the inventory management analysis to determine safety stocks. The safety stocks are used in the MRP system so that production schedules can be adjusted to maintain them. The manufacturing cells and purchasing by product group allow for a modularity that permeates the entire system and allows us to work with it in manageable pieces. The sum of these parts produces many benefits.

**The Impact of the Implementations**

By far the most significant impact of the applications is the improvement in customer service as measured by product availability (Table 1). In the table, the customer service rate is defined as the number of skus with available inventory divided by the total number of skus, then converted to a percentage. The total includes those that have stocked out, and a customer has been denied product. Such stockouts result in back orders, which are filled as soon as inventory becomes available; however, Merit Brass pays the shipping for such back orders. The top managers of Merit Brass all consider customer service to be the number one issue in their industry.

The improvements in customer service have not been gained by simply buying and holding more inventory. In fact, the company has reduced inventory in five product groups (Table 2). All values in this table have been rounded to the nearest $1,000. Three forces have limited the reductions in inventory in these five groups and kept the reductions from extending to other product groups. First, the economic

<table>
<thead>
<tr>
<th>Products</th>
<th>Service Level 11/90</th>
<th>Service Level 10/91</th>
<th>% Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>All skus</td>
<td>82%</td>
<td>96%</td>
<td>17%</td>
</tr>
<tr>
<td>Class A</td>
<td>74%</td>
<td>98%</td>
<td>32%</td>
</tr>
</tbody>
</table>

Table 1: This table summarizes the impact of the applications on customer service for all part numbers (skus) and for only class A part numbers.
recession during 1991 has slowed sales from expected levels. Second, a number of Merit Brass’s key vendors are overseas and have lead times of six months or more for delivery of orders. Since the applications were implemented in a modular fashion, they have not yet had much effect on orders received since the program began.

Third, Merit Brass has ties with some of its vendors that mitigated against immediate drastic reductions. It is phasing in reductions to maintain some of its partnering relationships. However, the systems in place allow the company to manage inventory more efficiently and provide better customer service by holding the right items in inventory and turning them more rapidly.

The cost effectiveness of the program was impressive. The project costs include both capital and expense items. The total incremental one-time costs to the company were $78,090. This included two personal computers, two copies of the STORM software package, and net personnel costs for the temporary people needed for the project. An annual increase of $19,500 in personnel costs will continue. The company uses a 15-percent inventory carrying charge rate to assess inventory carrying charges. At that rate, inventory reductions alone saved $201,000 for the first year, a figure that should grow as the three forces hindering savings begin to fade.

The company has obtained a number of additional benefits, some of which we have been able to quantify. It has reduced the dollar value of back orders outstanding. From April of 1991, when the first MRP cell was installed, to mid-February 1992, the total dollar value of back orders decreased by over 75 percent. This has certainly saved shipping costs that the company pays for back orders; however, we cannot quantify this value because of limitations of our accounting system. Similarly, the company makes some gains by billing customers earlier for items not back ordered and thus collecting the money faster. We have not attempted to quantify this benefit.

As the company accumulated the information for the purchased products, management realized that long lead times and unreliable vendor performance were affecting the company operations adversely. In response to long lead times, Merit Brass increased its safety stocks as the square root of the lead time, and because of unreliable deliveries, it used safety lead times. This produced excessive inventories and congestion. On the other hand, the company had a responsibility to work with its

<table>
<thead>
<tr>
<th>Product Group</th>
<th>11/90 Investment</th>
<th>1/92 Investment</th>
<th>Reduction</th>
<th>% Reduction</th>
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<tbody>
<tr>
<td>1</td>
<td>$1,300,000</td>
<td>$538,000</td>
<td>$762,000</td>
<td>59</td>
</tr>
<tr>
<td>2</td>
<td>864,000</td>
<td>836,000</td>
<td>28,000</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>129,000</td>
<td>93,000</td>
<td>36,000</td>
<td>28</td>
</tr>
<tr>
<td>4</td>
<td>823,000</td>
<td>595,000</td>
<td>228,000</td>
<td>28</td>
</tr>
<tr>
<td>5</td>
<td>1,158,000</td>
<td>872,000</td>
<td>286,000</td>
<td>25</td>
</tr>
<tr>
<td>All 5 Groups</td>
<td>$4,274,000</td>
<td>$2,934,000</td>
<td>$1,340,000</td>
<td>31</td>
</tr>
</tbody>
</table>

Table 2: This table illustrates the impact of the applications on inventory investment for five product groups and their sum.
vendors to help them improve their performance. In some cases, Merit Brass was buying as much as one-half the output of an overseas vendor. Clearly, keeping the vendor in the dark about Merit’s needs until the last moment lengthened the lead time the vendor needed.

The director of purchasing for Merit Brass now routinely shares the projected requirements for purchased items with the vendors. The vendors have also been made aware of the problems that long lead times and unreliable performance create for Merit Brass. Because of the company’s sourcing policies, it typically relies on no more than 10 to 15 active vendors. Since the initiation of the program, improvements have been made (Table 3). The data in the table reflect the one year prior to the implementation becoming effective versus the one year following. We still have a way to go, but we are making progress. Once lead times are reduced, we can make changes to all the affected items in the database and redetermine the correct safety stocks within minutes.

The plant managers have observed some further benefits as a result of the cellular manufacturing approach in responsiveness, quality, efficiency, economy, and organization:

- The plant makes most part families once a month, improving availability;
- It is easy to switch to any nipple in the family or subfamily;
- Operators and machines get very good at making fewer things;
- Setup personnel can specialize, and they’ve gotten faster;
- One setup serves many nipples in a family;
- Frequent runs mean lower safety stocks and inventory costs;
- Lower inventories turned more frequently lead to more efficient warehouse operations;
- The manufacturing cell is responsible for customer service for its part families, which improves accountability;
- The responsibility for the quality of parts is clearer;
- Pride in workmanship and customer service has increased; and
- Personnel are assigned to jobs for which they are most suited;

The managers of Merit Brass cannot know what their sales and financial performance would have been during the recession that began in 1991 had they not implemented these management science concepts. They believe the recession would have hit the company much harder than it

<table>
<thead>
<tr>
<th>Vendor #</th>
<th>Original Lead Time</th>
<th>Current Lead Time</th>
<th>Original On Time %</th>
<th>Current On Time %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6 months</td>
<td>3.5 months</td>
<td>75</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>6 months</td>
<td>4 months</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>6 months</td>
<td>3.5 months</td>
<td>25</td>
<td>65</td>
</tr>
<tr>
<td>4</td>
<td>4 months</td>
<td>2 months</td>
<td>80</td>
<td>92</td>
</tr>
<tr>
<td>5</td>
<td>6 months</td>
<td>3 months</td>
<td>70</td>
<td>85</td>
</tr>
</tbody>
</table>

Table 3: This table summarizes the improvements in both vendor lead times and on-time delivery performance for five of Merit Brass’s key vendors.
did had the implementations not been well underway. The company expects to be
poised and ready to take advantage of new opportunities once the economy picks up.
The new management science systems that have contributed to the modernization of
Merit Brass provide a foundation for its confidence.

Acknowledgments

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The entire top management team at Merit
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References

STORM 1989, Professional Version 2.0, Quantitative Modeling for Decision Support, 1989,

Edward R. Waters, R.P.A., Vice-Presi-
dent, General Manager, Merit Brass, PO
Box 43127, Cleveland, Ohio 44143, writes
"I hereby certify that the information re-
ported in Professor A. Dale Flowers' paper
entitled "The Modernization of Merit
Brass" is true and accurate. The results re-
ported in the paper are in accordance with
'Generally Accepted Accounting
Principles.'"