White collar factories create significant problems for manufacturing factories.

- When a salesman does not get the specs right for a technical product and the factory has to make adjustments—that’s the white collar factory impeding progress in the manufacturing factory.
- When orders are changed hours before they are to be built—that’s the white collar factory impeding progress in the manufacturing factory.
- When a new car is designed and the doors don’t fit on the car—that’s the white collar factory impeding progress in the manufacturing factory.

Beyond the factory floor, there is an even larger opportunity to improve performance. The true world-class competitors have discovered this opportunity and have extended the principles that worked on the factory floor to the upstream processes that feed production, “white collar” factories. They have reorganized their white collar factories, moving away from functional organization toward process organization to reduce both waiting and setup time. (See Figure 1.)

Two of the most important of these processes are:

Order flow: The steps that take place to gather customer orders, to process them into a form that can be built by the factories, and to transfer the information to the factories and the parts suppliers.
**Product development:** The steps that take place to design a new product and translate it into information that the factory can use.

There are important similarities between these operations and manufacturing factories. Both have traditionally been organized around functional specialties — all lathes in one area, all milling machines in another, with products passing from one processing center to another.

Similarly, orders in the order flow process pass through specialized departments — sales, scheduling, specification — on their way to the factory floor. Traditional new product development processes have also been organized around specialties. Both factories have waiting time between steps and setup time at each step.

Setups on the factory floor are physical, adjusting tooling and machinery to get ready to manufacture the product. Setups in white collar factories are intellectual; design engineers shifting from work on one project to another must refamiliarize themselves with the new project.

Setups in white collar processes can’t be seen or touched, so they are hard to measure, but they are nonetheless real. The principles used to reduce machine setup time will also reduce intellectual setup time in white collar factories, a possibility not well understood by most managers. The two factories share similar problems and solutions.

**One Company’s Experience**

The story begins in the early 1980s. A heavy equipment manufacturer began its improvement efforts in its manufacturing facility, but moved on to its order flow and new product development processes. The company’s operations are complex, offering customers many optional product features. Most orders are unique and require custom engineering.

Filling an order requires work by many departments. All the parts of the order come together on the factory floor, where production people coordinate thousands of details to make it happen.

**The manufacturing factory**

There was always a raging fire to put out. Manufacturing executives worked 60-hour weeks, and the employees on the factory floor had come to count on their overtime checks. Customers changed orders that were already being built. Engineering was late with the drawings. The sales force promised shorter leadtimes to secure a large order from an important customer. Parts were not available to assemble another order.

Almost everyone went home at the end of the day feeling good about pulling something out of the fire. The factory was where it happened; the “A” players thrived there, fueled by black coffee and hot tempers.

Attempting to reduce overtime costs and improve productivity, the company implemented a JIT program. They also formed quality circles with high employee involvement, invested in CIM, and applied single minute exchange of dies (SMED) and JIT concepts. The factory implemented a flexible manufacturing system, automated inventory control, and sophisticated robotics.

The company invested significant capital and many hours of overtime. When it was all done, everyone felt good about what they had achieved. They had reorganized the factory floor around the process to make the product, instead of around manufacturing steps. All machines needed to manufacture a product line were collocated. These programs allowed the company to significantly reduce setup time, to move to a batch size of one, and to eliminate WIP inventory at every step. Because inventory could no longer be used to keep sloppy activities upstream from impeding downstream activities, every step in the manufacturing process became critical.

**What happened?**

The company reduced average manufacturing time 33 percent, from 12 to 8 hours, and increased productivity ten percent. But only 50 percent of customers’ orders shipped on time. Rework had dropped a mere five percent. Cost reductions were less than hoped for. Overtime was still too high, and the next new product was introduced late.

At first the company was sure these measures would improve with time, as everyone learned the new system. But several years later, with only modest additional improvements, the frustration level was high. Where was the big payoff?

Senior management blamed manufacturing for not delivering on its promises. When the manu-
Senior management was surprised; they thought manufacturing was slowing down the company.

Manufacturing executives assembled, trying to understand what went wrong, they had some interesting observations. They couldn’t do much about the problems remaining in the factory. They couldn’t stop changes to customers’ orders or prevent improperly spec’d orders from reaching the factory floor. They couldn’t get engineering to provide drawings on time, nor could they make designers stop changing the designs of new products once they came to manufacturing. Outside events beyond their control frequently limited their ability to effectively utilize the factory.

**Hitting the wall**

Manufacturing had improved performance in areas they controlled, but they inherited the problems of the product development and order flow processes. If the factory operations were to improve further, white collar operations had to change. The company formed two teams, one for the order flow process and one for the new product development process, to look into the white collar factory problems.

**The Order Flow Factory**

The order flow team began by cataloguing problems that interrupted manufacturing operations and that appeared to be related to the order flow process. They discovered these problems:
- orders where customers changed the specs
- orders that were not complete
- orders that couldn’t be built as spec’d
- orders that were rescheduled.

To identify root causes, the team traced a sample of orders through the order flow system. At each step, the team noted both hands-on time — the time consumed in executing the step — and elapsed time, the total time the order spent in a particular step.

**Orders Passed Through 32 Steps Before Manufacturing**

![Diagram showing the order flow process](image)

**Figure 2.**
The order flow

The team mapped a lengthy order flow process that showed the average order spending 90 days in the order flow system. Worse, the maximum time for complex orders was 225 days. On average, less than one percent of elapsed time was actually spent processing the order. Senior management was surprised; they thought manufacturing was slowing down the company.

The order flow process was very complex. Most orders passed through seven different specialized departments before manufacturing. Each department performed several steps, then passed the order to the next department. The average order encountered 32 handling steps (See Figure 2); most orders passed through the process four times. Each department operated autonomously, with little consideration or even knowledge of other departments’ activities. During its journey, the order changed physical location 22 times, shuttling between five states.

The length and complexity of the order flow system led directly to the problems the team had observed on the factory floor. And long leadtimes allowed customers plenty of time to change their minds.

One customer who had placed an order for ten identical products discovered 95 days later that the company had introduced a new feature. The customer told his salesman that he wanted this feature on the products he had ordered. The salesman agreed to change the order, not knowing that the order was three days away from production. The firefighters went to work, and the customer got his change at a cost of $300,000 to the company. Changing this customer’s order delayed other orders, giving those customers more time to change their minds.

Even the company’s distributors learned to circumvent the process. Knowing that potential customers would not wait three months or more, they tried to speed things up by entering dummy orders for basic equipment. Usually missing pieces of information, the dummy orders simply reserved a place in the production line. After the distributor had actually sold the equipment, he entered change notices to meet the customer’s particular needs.

Product line complexity abounded. The company offered 15 product lines; each could be customized with thousands of features. However, not all of the options were compatible with all of the products. Distributors, working from huge paper catalogs of products and parts, sometimes submitted orders that couldn’t be built. They specified parts that wouldn’t fit on the product they were ordering. The order processors, who were expected to process hundreds of orders each day, didn’t always catch the incompatibilities. When these orders reached the factory floor, they had to be returned to order flow and rescheduled, sometimes after work had already started on them. Orders were processed through functional specialties—sales, engineering, costing, product specing, etc., just as they had once been manufactured through a series of separate functional specialties. The paperwork did not move through the process in a smooth flow; it was batched, moving from step to step in large groups. At each step the order usually waited in someone’s in-box (the queue), sometimes for days.

Too many queues

Each step included significant intellectual setup time as each worker in the chain familiarized himself with it. The worker had to know what type of equipment was being ordered, what had already been done on it, what remained to be done. With some orders having over 500 hand-offs, intellectual setup time occurred 500 times.

The team had seen enough. They understood how the order flow system worked and the causes of the problems they were observing on the factory floor. It was time to brainstorm some solutions. As they reviewed the data, the manufacturing people became convinced that the problems were the same ones that had existed in the factory.

The solution

The team wondered if they could reorganize the order flow system as they had reorganized the factory. Could a series of cross-functional work cells smooth the order flow process? Would a cross-functional approach take time and cost out of the order flow system, as it had on the manufacturing floor? They recommended these changes:

- Dedicate cross-functional processing cells to
Reorganized Around Processes, Not Departments

- Pricing
- Specification
- Engineering
- Manufacturing

Customer/Distributor

Pricing Specification

Engineering Manufacturing

Pricing Specification

Engineering Manufacturing

Pricing

Systems

Coordination

Support

Support

System Organization
- Order handled by one to three people beyond sales organization
- Only specialization is engineering versus non-engineering
- Order problems worked until successfully resolved
- Compensation based on performance of each cell measured by accuracy, timeliness, customer satisfaction, and profitability.

Figure 3.

specific product lines, one for each manufacturing line in the three plants
- Collocate the cells
- Link the system electronically.

Order flow by-products
To reduce queue and setup time, the company reorganized its order flow factory around products, rather than functional specialties. Each product line cell included three functions: pricing, specification, and engineering. (See Figure 3.) Collocating the seven to nine team members in the cell reduced hand-off time and increased communication.

Because the cells were dedicated to one product line, each cell member became very familiar with those products. Setup time dropped while service to the distributors improved. When a distributor called the cell’s direct phone number, a team member responded with the features that would be compatible with the product being ordered, and the price and delivery time.

Cross-training for flexibility
To increase flexibility, members of the cells were cross-trained as much as possible. When the person responsible for specifying orders was overburdened, another team member could help out, thus reducing queue time. People who understood pricing could easily be cross-trained to specify products, and those who specified learned to price.

Engineering was more difficult. The engineering department consisted of specialists for each part of the product. But most engineering requests attached to orders were simple, and any engineer assigned to the cell could handle them. Difficult requests could be referred to the specialized engineering resources assigned to product design.

Communications
To improve communication among departments, the company replaced its manual logs with an electronic system that linked the order flow factory. This system tracked customers’ orders as they went through the order flow and the manufacturing factories. At any time a distributor or customer could determine the exact status of the order.

The system also included an electronic catalog that related the product lines and the possible options on each product. The catalog helped distributors dramatically reduce the number of orders that could not be built as specified.

Order flow factory results
The results of this effort were impressive.
- In the five years since the company reorganized the order flow factory, average time to process orders dropped from 90 to 25 days, significantly increasing customer satisfaction and reducing the number of changes the factory had to deal with.
- Cost, as measured by the number of people required, dropped by more than 40 percent.
- First-time yield, orders going through the order flow factory correctly the first time, rose from virtually 0 to 85 percent. This greatly facilitated the manufacturing operation, as it received much more accurate information.

The New Product Development Factory
The new product development process impeded the blue collar factory in many ways.
- Designs were high cost and nearly impossible to manufacture.
- Designs changed frequently.
- Resolving design problems took too long.

The new product development team traced the history of the last new product introduced and found that this white collar factory was just as complex and lengthy as the order flow one.

Like the order flow process, this process was complex, organized around a series of functional engineering specialties. Each specialist designed a piece of the product. Some engineers only designed
fasteners; others focused exclusively on sheet metal.

Each specialty concentrated on producing parts that were state-of-the-art, but no one was designated as the keeper of the overall architecture. No one was charged with making sure that all the parts worked together optimally. While all the engineers had access to the plans for all the pieces, no formal mechanisms assured that the various specialists communicated with each other.

Because the design engineers and the manufacturing folks didn't talk, new products were sometimes physically impossible to assemble or required bulky, inefficient tooling that minimized the effects of automation. These products were very expensive and time consuming to manufacture.

- The average new product design process consumed 36 months, of which less than 16 percent was hands-on time. Twenty departments, coordinating over 100 interdependent output points, and 67 handoffs, got involved. The process took place in four locations in two countries. There were 13 approval reviews requiring, on average, 15 signatures. Two hundred fifty design changes consumed 40 percent of total cost.

_A crooked mile_

A new product design did not flow smoothly through the process; it spent a substantial amount of time waiting. Queue time accumulated as the design engineers, organized in functional specialties, worked on more than one project. Although each project had a project administrator who tracked work on the project, the project administrators often competed for resources. The project with the most acute crisis won, and the others waited.

Queue time accumulated during the complex approval process. (See Figure 4.) As the product was designed, 13 documents circulated for approval (some documents went through several approval cycles), requiring up to 15 signatures. Anyone along the chain could ask for a modification for any number of reasons—cost, functionality, even appearance. The approval process could take as long as three months; meanwhile the design of other parts was moving ahead.

The design often backtracked through the process to accommodate change; each of the 250 design changes added setup time. To make the change, the engineer had to look at the design work that had already been done on related parts in order to make his redesign compatible with them.

Intellectual setup time increased as the project approached manufacturing, when more and more time was required to check compatibility. For example, an executive on a trip to a foreign competitor saw a different way to fasten a part and insisted on changing the design during the last stage of the development process. To change the design, the engineers had to review over 20 detailed drawings to ensure that the new part would "fit up" correctly with them. Unfortunately, they missed one!

When projects began to fall behind schedule, people tried to work around the system, starting one part of the design before a prior, related part was finished. This practice often led to major incompatibilities which did not become visible until manufacturing began.

Sometimes, to speed up the process, products were released to manufacturing before all the design problems were resolved. Attempts to save the schedule were responsible for many of the design changes that complicated the manufacturing process. The length of the process also contributed to a feeling that there was always time to make just one more change. After all the time and effort devoted to developing the product, it had to be as up-to-date as possible.

The design changes were a serious problem on
The engineers began to design the system rather than the parts.

The factory floor. Each change generated an engineering change notice (ECN) which was sent to the factory floor. The foreman then had to locate the affected parts, which were scattered throughout the factory, and make the changes. ECNs were like a virus spreading throughout the plant; a change in one part meant that adjacent parts also had to change. It seemed to manufacturing that if left alone, the engineers would change the design until the customer accepted delivery.

When design problems surfaced, they took forever to resolve because of the intellectual setup time. In the manufacturing stage, the product had thousands of drawings; to make the necessary changes, the engineers had to become familiar with many aspects of the product that they knew nothing about.

A better way

When the team finished studying the new product development factory, they made these recommendations.

- Form a cross-functional design team to develop each new product; the team would be collocated during the project.
- Substitute design review meetings for the current approval process.
- Clearly separate the design and manufacturing processes and add resources to the front end of the new product development factory.

Cross-functional design teams

The cross-functional design teams consisted of product architects who were experts on various parts of the design and who collectively could develop and maintain the product architecture. Right from the beginning these teams included representatives from manufacturing to assure that manufacturability was part of the design process at every step. The product development teams were given strong leaders to whom the dedicated resources reported for the duration of the project. The team leaders were responsible for producing a design within schedule and cost constraints. Everyone on the team was evaluated by his or her contribution toward that goal.

The teams were collocated during the project so that the engineers could communicate more frequently and understand better how one design interfaced with the others. When a problem came up, everyone involved was right there to discuss it immediately; work did not stop while the problem went through the proper channels to be resolved. The engineers began to design the system rather than the parts.

Previously, in comparing its products to competitors' products, the company had found that its individual parts were all superior, but that the product as a whole didn't function as well as the competitors' products. By managing its product development factory more effectively, the company was now in a position to improve the system as well as the pieces.

Approval cycles changed from a series of handoffs to a design review meeting. Both technical experts and management attended these meetings, where participants identified problems and assigned responsibility for resolving them to particular individuals. Deadlines for resolution were set, and the chairman of the design review committee was the only person who signed off on the resolution.

The final recommendation was to clearly separate the design and manufacturing factories. Once the design went to manufacturing, few changes were allowed. A separate product improvement cycle was established to update designs quickly as needed after the product was introduced.

New product development factory results

Design cycle time dropped 40 percent. ECNs, while still numerous, were reduced dramatically, and manufacturing and design routinely worked together to develop new products. Improvements in the new product development factory fixed problems before they occurred, greatly improving manufacturing performance.

Conclusion

To significantly improve performance, management had to look at the company as a whole. Improving capabilities only on the factory floor, while useful, was not enough. Management had to extend its focus to the white collar factories to see truly striking results. These results encouraged the company to work to improve capabilities throughout its system—the sales force, the distributors, even the suppliers.
The company recognized that problems outside of the manufacturing facility were impeding manufacturing and moved to improve its white collar factories using the same principles that had worked so well on the factory floor. Consequently, the company was able to:

- Reduce intellectual setup time in both the order flow and new product development factories
- Create a batch size of one in the order flow factory
- Eliminate inventory (full in-boxes) at each step in the white collar factories to achieve a continuous work flow.

**Results**

- Improvements in the white collar factories were critical to success on the manufacturing floor. As the performance of the white collar factories improved, so did the performance of the manufacturing factory, which was able to realize the full benefits of its investments in advanced manufacturing.

  Over a five-year period, overtime in the factory was cut in half, while production volume increased 40 percent with no increase in headcount. Late deliveries dropped 95 percent, quality improved as rework dropped 75 percent, and customer complaints fell 90 percent.

  The reduced cost, improved quality, and enhanced responsiveness went right to the bottom line. Earnings from operations nearly doubled; when inventory levels fell 50 percent, operating returns on assets rose dramatically.

  But the biggest impact of all has been on the morale of employees in the factories, both blue and white collar. Misunderstandings born of lack of information became mostly a thing of the past; it is now clear how activities in one area affect those in another. With fewer fires to put out, the firefighters are working on prevention. And, of course, bonuses increased as performance improved.

**Manufacturing leads the way**

Few companies recognize the similarity between their white collar factories and their blue collar factory. (See Figure 5.) While most senior managers now understand that investment in manufacturing can yield significant returns, they do not recognize that advanced manufacturing principles also apply to their white collar factories. Convincing senior management to apply these principles beyond the factory floor will require a significant effort, one comparable to that made by the early advocates of advanced manufacturing.

Often manufacturing will need to lead this effort—they are the people who understand the principles, know how to apply them, and have the incentive to undertake the task (they inherit the white collar factories' problems). It's time to prove that those who wear brown shoes can also wear white collars.

### Figure 5.

<table>
<thead>
<tr>
<th>Blue Collar Factory</th>
<th>White Collar Factory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce physical set up time</td>
<td>Reduce Intellectual set-up time</td>
</tr>
<tr>
<td>SMED</td>
<td>Teams</td>
</tr>
<tr>
<td>Tooling</td>
<td></td>
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<tr>
<td>Institute continuous flow versus batch</td>
<td>Institute continuous flow</td>
</tr>
<tr>
<td>Batch one size</td>
<td>Real time versus batch</td>
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<tr>
<td>JIT</td>
<td></td>
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<tr>
<td>Minimize work-in-process, inventory</td>
<td></td>
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<tr>
<td>Establish work cells</td>
<td>Establish collocated, dedicated teams</td>
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<tr>
<td>Emphasize quality</td>
<td>Emphasize quality</td>
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<tr>
<td>Zero defects</td>
<td>Error-free</td>
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<td>QFD</td>
<td>On time</td>
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<td></td>
<td>First-time yield</td>
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