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HIGHLIGHTS

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The Six Sigma Program at the Rochester Plant

Steve Lewis
IBM

Rochester, Minnesota is the home of IBM's Application Business Systems which has world-wide responsibility for product and process development and manufacture of small and intermediate business systems. The Rochester plant produces the AS/400 and was a recipient of the Malcolm Baldridge Quality Award for 1990. The 250,000 square foot plant employs 904 people and primarily assembles and tests AS/400s and loads them with software; it also manufactures circuit cards and some plastic parts.

The AS/400 is the successor to IBM's System 36 and 38. There are three basic models which range in price from $15 thousand to $1 million. Each AS/400 is built to order with variations in direct access storage device (DASD), hardware and software. The plant produces around 20,000 units a year. About 60% of sales are non-U.S. (50% Europe and 10% Japan). IBM has been selling this product to other than their typical business customers, e.g., banks, educational institutions, hospitals. The company views its traditional market as being transformed into a giant niche market in which 500 to 1000 machines will be configured for specific customers. It also sees itself as being transformed from a supplier of hardware to a supplier of solutions. In light of this, it works closely with 7000 software vendors who have helped IBM develop 8000 application specific solutions for use with the AS/400.

One of the major goals of IBM's Six Sigma quality program is to develop efficient processes. Reduction of cycle time is one means for achieving this goal. Some of the initiatives undertaken to reduce cycle time include: (1) consolidation of processes that were performed in four different buildings into one building; in fact, everything needed to produce the product is in line of sight, (2) smooth production, e.g., although orders are received two to three weeks in advance of delivery, the factory is discouraged from varying from an established schedule in order to build ahead; extra support is provided if needed for peak production, (3) design for assembly has led to the design of one AS/400 model that can be assembled without use of any tools, (4) attention has been given to ergonomics, so as to minimize fatigue or tendon or muscle problems, (5) teams meet with all internal and external suppliers. In the latter case, the visits have extended as far back as three levels in the supplier chain. As a result of these and other efforts, the number of days of supply has been reduced significantly for major components as has the average lead time for purchased parts. The cycle time for assembling AS/400s also has been reduced significantly.

Another means for achieving efficient processes is to maximize flexibility. One initiative involved integrating quality tools into the production process by (1) developing quality tools that facilitate the man/machine interface, i.e., keeping workers close to the product and involved in the loop so as to maintain their consistent attention, (2) integrating inspection into every production step instead of having an inspection station only at the end of a set of steps, (3) developing artificial intelligence to assist workers in determining what repair action is appropriate for particular types of system failures. Other initiatives involved assembly of all components of a total systems package, e.g.,

printer, storage, software, etc. at the plant, and development of a common floor control system for all products produced at the Rochester plant.

A third means for achieving efficient processes is to integrate product and process development so as to increase manufacturing return on assets (ROA). Integration will speed new product development and help cope with shorter product life cycles which are now three years on average and fifteen to twenty months for products that involve no new technology. Initiatives at the plant include: early establishment of cross-functional teams, assignment of manufacturing engineers to development labs so that they are included in the product design process, involvement of customers and suppliers in the development process. These initiatives have led to higher inventory turns, reduced warehouse space, and the design of complementary product/process technology.

Another major goal of IBM's Six Sigma program is quality improvement. The plant's goal for 1991 is to reduce its defect rate by a factor of 10 over 1989, by a factor of 100 by 1993 and to achieve six sigma (3.4 defects per million) by 1994. One initiative is early manufacturing involvement (EMI) in the product development cycle. Manufacturing is involved as early as the initial business proposal stage and contributes during the product design and test stage. An elaborate set of key internal and external benchmarks are established and tracked, including on-time delivery, defects at subsystem and total system levels, time from receipt of order to installation, etc. Cross-functional teams diagnose sources of defects and seek to continuously improve performance on these measures.

A third major goal of the Six Sigma program is to develop skilled and motivated people. Team performance and leadership are encouraged at all levels in the plant as is development of multiple skills. Training is provided in classrooms that are located close to the shop floor. Managers rather than classroom teachers are encouraged to provide as much training as possible and to do so as close to when a question or a need arises.

Designing Products to Lower Manufacturing Costs and Improve Quality

Dick Bradyhouse
Black & Decker

Dick has corporate responsibility for value analysis and design for assembly. Competitive pressures have led Black & Decker to focus increasing attention on VA and DFA. For example, the company wants global standardization of parts in order to gain economies of scale for products which are manufactured world-wide as well as to lower manufacturing costs generally and to maintain high quality.

Dick gave several examples of successful application of VA and DFM. One was an analysis of the number of different types of ball bearings that the company used in its power tools. They were using 149 different types of ball bearings; their analysis indicated that only 17 were needed.

Consequently, they developed a design library which permits designers to choose only from the 17 types. A designer needs special approval from a supervisor to use any other type of ball bearing.

An analysis of parts failure in a finishing sander revealed that on-off switches were among the first parts to fail because of exposure to dust and dirt. The initial recommendation was to seal the switch. B&D's supplier said that sealing the switch would add 8 cents to the cost of the part. B&D countered by offering to value analyze the switch for the supplier which resulted in lowering the added cost to 5 cents. Flexible posts were another vulnerable product part. The posts were assessed using artificial intelligence software which B&D developed jointly with GE. The posts were assessed against 105 rules for injection molding practices which, in turn, led to the discovery that 12 design rules had been violated. Correcting the rules reduced the costs of the posts significantly. Finally, the material for the sander pad was upgraded to nylon.

Dick provided an assessment of the finishing sander base using Boothroyd and Dewhurst's design for assembly methodology. Each part of the product was assessed for its function. A single function is represented by a verb and a noun, e.g., transmit motion, release clamp. Dick called parts that have only a single function "lazy parts," a label which usually applies to fasteners. Three criteria indicate whether or not a part is necessary, i.e., does it move, is it made from two or more types of materials, is it required for assembly or disassembly? If the answer to each question is no, then the part is a candidate for elimination or combination with other parts. The initial assessment of the finishing sander base indicated that 23 parts performed 7 functions. The redesigned sander base has 5 parts that perform 6 functions. The redesigned sander base thus has 18 fewer parts; assembly time was reduced from 80.7 seconds to 20.8 seconds and assembly costs were reduced from 32.3 cents to 8.3 cents. Only 12% of these savings were needed to pay for the upgraded materials now being used in the product. On a scale from 0 to 100% which Boothroyd and Dewhurst developed for assessing product assemblability, this product improved from 19% to 72%. More generally, Black and Decker's older products averaged 45% on Boothroyd and Dewhurst's scale, while its redesigned products averaged 70%.

Other methods used by B&D included pretesting parts before they were introduced into the final assembly process. Label placement and packaging were also analyzed for potential cost reduction. Also used were Taguchi methods, rationalization of design (based on design axioms developed by Nam Suh of MIT), and an SME desk manual containing good design axioms. Each new product design has to be approved by Dick's group before the design can proceed to finite element analysis. Dick also is currently putting together a book of design tips for internal company use.

Dick was asked about the trade-off between fewer parts versus more complex parts. He said that 98% of the time the balance was in favor of saving more money by using fewer parts than increasing costs with more complex parts. Company buyers may resist paying more money for complex and expensive parts, however, since their bonuses and raises are based on how much money they save on purchased parts. Changing their priorities will require changing their rewards as well as moving toward assessment of costs using activity-based accounting methods.

The concept development phase of Black and Decker's product development cycle has seven "tollgates." Two tollgates deal with design for assembly and others deal with parts standardization, safety and quality. Dick still reverse engineers most of B&D's competitor's products, but he emphasized

that assessments involve a lot of subtleties and judgment. He also noted that product functions sometimes can be replaced by new technology rather than be modified by better assemblability criteria. Lastly, B&D is trying to introduce some order into how and when engineering changes are introduced. They are following Hitachi's practice of making no changes once a product has been released from design, but saving the changes for inclusion in the next model or product type.

Designing Products for Manufacturability and Recyclability

Gil Gilliland
ALCOA

Gil discussed some of the trends in Alcoa's competitive environment. Of particular concern is the introduction of new materials that might compete with or substitute for aluminum, such as biomaterials, e.g., plant fibers, ceramics, polymers. Also of interest are increasing requirements for quality, increasing energy costs and the prominence of environmental issues. Alcoa hopes to differentiate itself from its competitors by high product quality and product function. One of the ways for Alcoa to achieve this is to focus on design for manufacturing and recyclability. Achieving these objectives in a process industry requires advanced materials systems and an understanding of product and process design and control. In Gil's words, "you can't control what you don't understand." Alcoa relies heavily on simulation and modeling to better understand its processes as well as on sensors and actuators to collect data for process control which, in turn, is maintained by control hierarchies and strategies.

Gil views recyclability to result from integration of product and process design, material sciences and technology. Recyclability is becoming increasingly important because of energy and environmental concerns. The issue of recyclability is of general interest to Alcoa because it expects to produce or compete with companies that produce advanced metallics, biobased materials, laminates and composites. The issue is of particular interest to Alcoa because aluminum processing is very energy intensive.

Alcoa is a major producer of rigid container sheet used for beverage cans. Alcoa does not make cans, but sells aluminum sheet to can makers. Sheet is sold in 50 thousand pound coils from which approximately 100 thousand aluminum cans can be made. One thousand cans weighed 44 pounds in the 1970s, they now weigh about 25 pounds including opening tabs. It is important to roll aluminum ingots so that a consistent gage (.004 inch) can be maintained throughout the coil. Ingots are rolled into sheets at the rate of a mile per minute. One side of the coiled sheets is coated to protect the future contents of the cans from corrosion. Alcoa maintains a can making lab so that it can test sheet for manufacturability.

Concern for recyclability surged after the 1974 oil embargo, given aluminum's high energy intensive manufacturing process. Alcoa employs about 500 people in teams of two or three at its own recyclability centers around the country. The company pays a nickel per can or 40 to 50 cents a pound for cans. It also buys cans from independent recyclability centers. New ingots cannot be made from 100% recycled aluminum, so they must be supplemented with virgin alloy. Still, the price

differential between a virgin can and one made from recycled aluminum is 50%. Recovery of pure aluminum is difficult, given that recycled cans have to be thoroughly washed before being reheated and that foreign materials are often stuffed inside of used cans.

One of the major issues in aluminum recyclability is melt loss. At one time, 65% of reheated aluminum went up the smoke stack during recycling, now only 7% does so and projections are that it will soon be only 1%. In 1973, only 13% of aluminum cans were recycled, now 65% are recycled. In 1989, 12 billion kilowatts of energy were saved as a result of recycling, which is the equivalent of 20 million barrels of oil.

Alcoa expects to continue to compete in the future with manufacturers of plastic beverage containers. It also plans to become a producer of plastic material for such containers. One disadvantage of plastic containers is that they limit the shelf life of products contained within them to about two weeks. The competitive situation in Europe is different for Alcoa because glass is the dominant material used for beverage containers. Alcoa also plans to encourage use of aluminum as a food container, a use now dominated by steel. There are some advantages and unique problems with using aluminum for food containers. There is less concern about pressurization, but more concern about the impact of corrosion on food taste.

Survey of Factors Related to New Product Development Success

Gerry Susman and Jim Dean
Penn State
Cathy Rusinko
Villanova University

Gerry Susman provided an overview of the Penn State study on design for manufacturability (DFM) which involved twelve companies. These companies were Boeing Helicopter, British Tire and Rubber, Caterpillar, Cleveland Pneumatic, Corning-Asahi, Digital Equipment, Dupont Electronics, Dupont Electronic Imaging, GE Astrospace, Honeywell, McDonnell-Douglas, and Westinghouse. Representatives from these companies met in Chicago in December 1988 to develop research questions for the study and to decide what type of projects within their respective companies to include in the study. The three research questions developed were: What are the most common barriers to DFM? What different methods do companies use to measure DFM performance? What combination of approaches, context and communication patterns leads to the highest performance outcome? It was decided that each company would select two projects for inclusion in the study. One project would be a "stretch" project with difficult goals and high technical risk; the other project would focus on a routine product enhancement.

Jim Dean and Gerry Susman visited each company twice during 1989-90. The purpose of the first meeting was to meet with senior function managers and program managers, to select projects for inclusion in the study and to collect general information about company policies and practices

related to DFM. The purpose of the second visit was to interview personnel with direct "hands-on" experience with each project.

Jim Dean provided an overview of the data collected from the interviews. First, only 41% of project personnel expected any special recognition if their project was successful and of those who did expect any recognition, 50% expected money and 20% expected promotion. Second, design personnel were assigned about twice the percentage of time to a project as were manufacturing personnel, which might put the latter at a disadvantage in staying sufficiently abreast of project developments to influence project outcomes. Third, only 25% percent of the project personnel reported that any time was devoted to team-building issues at project start-up. Fourth, poor data quality was the main inhibitor to use of manufacturability data by both design and manufacturing personnel. Lastly, manufacturing engineers reported considerably less satisfaction with the DFM process than did design engineers and program managers.

Cathy Rusinko provided an overview of the next stage of the Penn State study, which was to develop and mail a self-administered questionnaire to several hundred design and manufacturing managers. Three major factors were hypothesized to predict DFM success. Integrative mechanisms are organization-wide policies and practices such as status parity in pay and education, number of levels to a common report, frequency of rotation of design and manufacturing personnel between their respective functions. Group level factors include goal consensus, project team continuity and group problem-solving capability. Codification and computerization of data include manufacturability data and guidelines which vary in scope, applicability and speed of access. Measures of project success include reduced lead-time and cost and increased quality and product performance. Most of the questionnaires have been completed and returned and the data they contain are currently being analyzed. Results of the analysis will be available shortly.

Gerry Susman showed results from preliminary tests of the hypotheses based on the interview data collected earlier. These results show that co-location and project-based rewards are significantly related to project success, while, surprisingly, cross-functional coordination, e.g., number of levels to a common report, is negatively related to project success. Integrative problem-solving and percent of time on projects are related to project success also.

Plans for future studies include continued development of the questionnaire as a diagnostic instrument for use as a catalyst for team development at project start-up. The predictive capability of the questionnaire will continue to be refined also. Finally, the questionnaire will be administered to increasingly larger samples of project personnel and lead to establishment of reliable norms against which any new project can be compared and assessed for the likelihood of project success.

The GM Product Program Management Process

Steve Maggio
General Motors-AC Rochester Division

AC Rochester Division generates $3.5 billion in annual sales, employs 24,000 people and has 33 manufacturing plants world-wide. It is one of GM's twelve component manufacturing divisions and specializes in engine management subsystems, such as fuel injection, emission controls, catalytic converters, spark plugs, oil and air filters, gas tanks, fuel pumps, valve lifters, rocker arms, etc. Steve supervises the group that represents AC Rochester on the GM corporate team that developed the Product Program Management System or "Four Phase." Four Phase took three years to develop and has been operational for six months.

GM was aware that its greatest opportunities for reducing product and process development time and costs were in the earliest phases of the product development cycle. Yet GM was expending the greatest amount of its engineering resources late in the cycle. One of the main objectives of Four Phase was to shift the expenditure of engineering resources earlier in the cycle and thereby reduce overall product development time and cost. Four Phase can accomplish this by (1) focusing on customer satisfaction through involving marketing personnel early in a quality function deployment exercise, (2) picking suppliers and the manufacturing site early in the cycle, (3) articulating key decision points and addressing them as early as possible, (4) developing exit criteria that must be met before moving on to the next phase, (5) carrying out concurrent or simultaneous activities in multi-disciplinary teams.

Each of the four phases has one or more major decision points. Between each decision point are minor milestones; between the latter are activities summaries which, in turn, can be broken further into statements of work and even further into logic networks. No major decision point can be passed until all related exit criteria have been met. GM's hope is that such detailed articulation and completion of phases will reduce product development costs and eventually shorten development time. GM's current development time for new cars is 48 months, while for one of its major foreign competitors, it is 24 months.

The first phase, Phase 0, is called Technology and Concept Development. Steve thinks that Technology Development ought to be a phase in its own right (Phase 00) within which new technology is developed and placed on the shelf for future application. Most of the new technology that is developed starts with a customer who asks AC Rochester to develop a product for a specific model and vehicle application. The first major decision point within Phase 0 is called Concept Initiation. Several tools and techniques have been developed to help reach this decision point. Collectively, these tools help make a business case for a new product development effort. The tools include product image maps, QFD, competitive benchmarking, market segmentation and various market projections for the product based on assumed price, performance, etc. The product concept that emerges from use of these tools should make strategic sense and be identified with a targeted customer. The exit criteria for Concept Initiation include definition of customer requirements, a proposed business plan, and appointment of a program manager.

The next major decision point within Phase 0 is called Concept Direction. Two major milestones must be passed before a product development effort reaches this point. The activities involved in passing the first milestone (Concept Requirements) include identification of candidate subsystems and feasible product and process technologies. The activities involved in passing the second milestone (Concept Alternative Selection) include developing a list of potential manufacturing facilities, a preliminary parts list, and a transportation and sourcing strategy. Refining the selected alternative includes designation of manufacturing facilities, picking suppliers and making them part of the development team. The exit criteria include an established business plan and approval of concept development resources and timing.

The third and final decision point within Phase 0 is called Concept Approval. The activities leading to Concept Approval include building demonstration vehicles, use of math modeling, etc. Every vehicle component goes through the same procedure. The exit criteria for Concept Approval includes a freeze on styling and content, use of proven product and process technology, and approval for funding of long lead-time items. Once Phase 0 has been completed, no executive at any level of the company can change the product concept.

Phase 1 is called Product/Process Development Prototype Validation. This phase involves completing the detailed design, building prototype tools, and procuring prototype parts. The prototype then is built and validated. Exit criteria includes freezing of all detailed design and approval of funds for manufacturing and assembly design.

Phase 2 is called Process Validation and Product Confirmation. The main activities of this phase involve the preparation of production facilities. All vendor equipment is qualified and manufacturing and assembly tools installed. Phase 2 ends with approval to begin a high volume production run.

Phase 3 is called Production and Continuous Improvement. As the name implies, improvement of the product development process never ends. Steve said that GM is still working on the details of carrying out this phase.