Six Sigma on a Tight Budget

Bradley A. Pritts
Technical Director, Results Systems Corporation, Troy, Michigan, U.S.A.
Email: **bpritts@pritts.com**

ABSTRACT

One critique of Six Sigma efforts has been that many company-wide initiatives demand investment in thousands of dollars in training and "infrastructure" investments, long before payoffs occur. In some cases these criticisms are warranted; yet effective Six Sigma projects can succeed without such investments. This case study describes a manufacturing/assembly process which was relocated and upgraded under strict time and budget controls due to a short planned product life cycle (8 months). The project achieved an eightfold improvement in quality performance, while reducing costs as well.

Keywords: Six Sigma, Assembly Processes, Quality Planning

1.0 Project Background & Goals

The scope of the project was the re-location of an existing product assembly operation from an automotive OEM's internal parts manufacturing facility to a Tier I supplier. The product was an automobile drum brake assembly. Because of the safety implications of brakes, the supplier's commitment to quality, and customer expectations, flawless performance was expected.

The product was historically assembled by the automotive OEM's parts-making division. In order to meet long term goals for the manufacturing facility, it was necessary to relocate the assembly process. However, the product/process life cycle was reduced to only eight months, due to changes in the customer's product plans. Other customer changes compressed lead time, with production ready (as measured by Production Part Approval Process or PPAP) within four months of project launch. Yet the financial resources available to the project had been reduced by 66% (originally, the program was planned for 24 months life) and the launch time reduced by 50%. The limited development time made the creation of new mechanized assembly or test equipment effectively impossible. It was necessary to refocus the project to attain Six Sigma quality levels, with reliance on manual assembly… in four months' time.

The Tier I supplier assuming the production process was a manufacturer of brake components with experience in final drum brake assembly. Existing assembly processes provided a benchmark for production methods; additionally, the most recent product launch was used as a benchmark for the process development and launch program.

2.0 Project Approach

By focusing on "soft" quality techniques, product/ process quality was improved significantly over previous results. All of the typical quality planning techniques mandated by North American automotive producers were used [Chrysler, Ford, General Motors 2002]. Special attention was given in certain areas described below.

Six Sigma Phase	Methods Used
Define	Definition: Meeting customer requirements 100% at defined cost and schedule. Stretch Goal of flawless launch.
Measure	PPM/ DPMO of the specific operation prior to relocation PPM/ DPMO of historical operations at the receiving plant Customer Complaints during launch/ infancy as measure of flawless launch Labor content and balance Capacity/throughput
Analyze	Process Flow Diagramming with special emphasis on the Hidden Factory Process Failure Mode Effects Analysis with additional consideration of side effects/ pass through characteristics Training and Staffing systems
Improve	Develop Assembly Process Develop Assembly Equipment & Fixtures Pilot Tests of Assembly Process
Control	Inspection process Internal audit process Product audits Performance Measurement

Figure 1: Categorization of automotive quality methods used to Six Sigma phases

Customer and internal perspectives were considered in establishing objectives. Customer direction specified the targeted line capacity, and dictated zero defect performance. The firm's previous brake assembly operations history was used as a baseline, with breakthrough improvements targeted (tenfold improvement in Defects per Million Operations or DPMO).

3.0 Quality Planning & Engineering Tasks

3.1 Process Definition:
In addition to the macro level process flow diagram required by the automotive APQP/PPAP process, a microscopic level process definition was prepared, accounting for individual hand movements and machine operations during the assembly process.

At the suggestion of the customer's Supplier Quality Assurance personnel, the launch team expanded the standard automotive production process flow diagram to include a "micro" level of detail. The process flow analysis traditionally used in the standard North American quality planning process considers only the normal process flow. Many individual exceptional conditions are not adequately considered during the planning process. For example, material flow was to consider every part run through the process, including setup parts, first piece approval parts, parts removed from the line for QA inspection, parts repaired or reworked, parts built but accumulated in "partials" (remaining finished goods inventory not adequate to complete a standard customer shipping container.)

Inclusion of these alternate flows or diversions from the production line identified six additional product movements in the process flow diagram. (These included, for example, first piece approval samples which left the area, and "partials".) This prompted efforts to improve the process by eliminating these exceptional operations where possible. Where the process was essential more visible controls were added to control the re-introduction of this material to the process flow. For example, a policy decision was made that no defective assemblies would be repaired; instead, these would be fully disassembled and the components re-introduced as raw material. While costing a slight labor penalty this action decreased variability.

3.2 Process Failure Mode & Effects Analysis (PFMEA)

The traditional automotive industry PFMEA is focused on identifying the specific functions of each individual manufacturing operation and possible failure modes that could impact the functions/features in operation in that station. Prior experience had shown that many nonconformities had resulted from damage, misalignment, or loss of components as "side effects" while an unrelated operation was performed. For example, one chronic complaint in the past had been the loss of a rubber thread protector plug installed in the wheel cylinder. The plug was installed in the wheel cylinder by the component supplier. Previous PFMEA studies had never considered the plug loss, as no operations were intentionally performed on this component. By considering possible side effects, issues such as this were incorporated into the process planning stage. Study of the line showed that the largest incidence of this problem occurred at steps of the process when the assembly was inverted. Consideration of this factor led to a re-processing of the line which eliminated two of the four times when the assembly was inverted. This had the further benefit of reducing non-value added part handling.

This enhanced PFMEA process focusing on "pass through" characteristics was applied to every operation. Additionally, PFMEA's were extended to include packaging and labeling operations.

3.3 Operator Training/ Certification

A rigorous product training program (including process certification) ensured that each operator demonstrated capability at production rate. Cross-training and job rotation were included.

While previous assembly department operations had envisioned wide operator cross-training, implementation was limited. In practice, few operators participated, and department supervision did not fully implement cross-training.

For the new line, an initial goal of training each operator for each job was established. A series of training and skill requirements were used.

1. Existing hiring criteria required operators to pass a paper and pencil test demonstrating literacy and basic arithmetic skills. This test was retained.

2. Operator candidates were trained for four hours on individual "bench" assembly. In this stage the operator was required to learn how to fully build the product, learning all assembly steps in sequence, on a stationary fixture. Satisfactory completion of this phase required completion of five consecutive assemblies, attaining 85% of targeted line speed. One defective assembly was allowed, provided that the operator detected it themselves.

3. Next, the operator was put on an individual assembly station on the line with a trainer assisting. Selected jobs with less labor content were used for initial training.

4. After working for several shifts, the operator was rotated to several other jobs.

5. Upon mastery of five workstations and completion of 30 days tenure, the operator was promoted from trainee to general operator.

Originally the goal was to fully train all operators for all jobs. This was found to be impractical for cost and ergonomic reasons (a few operators were incapable of performing several operations at rate). The goal was reduced to require training on 5 of the 14 total job positions to attain full operator certification. Operators received increased compensation when mastery was demonstrated with a promotion to general operator status.

A simple but useful insight gained from review of previous defect history was that above average numbers of defects had occurred on Mondays. (This confirmed automotive industry anecdotes about Monday quality!) Analysis showed that many of the defects had resulted from inadequate training of newly assigned personnel; for personnel department convenience new employees were always scheduled to start Mondays. Management established a policy that new employees would start work only on

Tuesday through Thursday, and further that their first "day" on the job would be limited to 4 hours, starting after lunch. This reduced time pressure on the line leaders and relief workers, improving resources available for training.

3.4 Visual Controls

A new format for visual assembly instructions was developed. The standard format included:

1. Identification of incoming parts used by the operation
2. Step by step instructions for the operation
3. Quality checks to be performed by the operator

The improved visual instructions were judged superior to the earlier generation of assembly instructions. While meeting the detailed criteria of the QS-9000 automotive quality standard, the previous instructions relied on text descriptions of the operations. As a result, the instructions weren't used other than as an internal audit tool.

One lesson learned was that a surprising amount of additional work was required to make the photos effective. Despite editing, enlargement of key features, and annotations with arrows and legends, many of the photos were not clearly visible to the operator when hung at a distance of a few feet. With advice from a professional photographer, we re-shot many of the photographs. Many of the original photos were retaken after "enhancing" sample parts visually. For example, we applied white and black paint to sample assemblies to make the outlines of parts stand out with greater contrast. This was necessary to make the black brake shoes visible against the background of a black backing plate. Other photos were retouched using photographic editing software to exaggerate small part features.

Color coding: Many of the parts were color coded, simplifying the changeover process. Similarly, operator instructions and part labels were color coded.

Part Access: Doors were installed on the bins for parts which were interchanged between right and left hand assemblies. Swinging the door open to access right hand parts closed the left hand parts bin, and vice versa. This further reduced the possibility of mixed parts.

3.5 Error-proofing

A number of error-proofing techniques were deployed, with a particular focus on avoiding part mixing for right hand/left hand parts. A common assembly line was used to build both "hands" of parts, which were mirror images. Error proofing measures included:

1. Assembly torque guns were programmed to monitor number of bolt or nut rotations, torque and torque angle. This ensured meeting the torque requirements for the fasteners, while detecting strips, cross-threading and other assembly defects.

2. Although the primary part fixtures were common to right or left hand assemblies, adjustable details were included on fixtures to prevent the inadvertent mixing of right and left hand parts.

3. Initial defect reports (see below) identified one particular operation – installation of the brake strut – to be a high defect operation. A problem-solving team of operators and skilled trades people developed an assembly fixture to assist in this operation.

4. Process Studies: Short-term and long-term capability studies were performed using variables data (in selected areas) and attribute data for assembly operations. Only two of the operations afforded the possibility of variable data measurement; studies showed these to be statistically capable at the outset.

Assembly defects were tracked and reported hourly by the inspector/packer. Running totals of defects were used by the leader, trainer and relief operator to identify areas needing attention. (Consideration was given to using p-charts for this operation. It was not clear that the P chart provided additional benefits over a simple Pareto chart, and the routine P chart was discontinued.)

4.0 Results

4.1 Metrics

Defects per million operations (DPMO) were reduced from 37 to 4.4 when compared to the previous benchmarks. While the "stretch goal" of totally flawless launch was not attained, the 88% improvement over the previous generation exceeded the targeted 75% improvement.

Three customer concern incidents were documented within 60 days of startup. (Defects within 60 days of startup were the measure for flawless launch.) One of these issues was attributable to a lack of engineering follow-up by the previous manufacturing plant staff; this resulted in use of a component which was obsolete (although saleable.) It is possible although uncertain that more diligent engineering investigations during the job transition would have detected this issue. The remaining incidents involved actual assembly defects.

Piece rate and labor targets for the job were met. Labor content was improved slightly from the previous plant's performance.

Program schedule milestones were met.

4.2 Lessons Learned

Project results demonstrated that high assembly quality could be attained, without the automation investment used in similar operations. Project team and assembly production personnel gave particular credit to the intense focus on process definition, operator training, and operator certification as the key drivers of success.

Focusing the effort to identify and define the "hidden factory" operations, and systematize these operations was a particularly beneficial aspect of process definition. Traditional quality planning as practiced in the industry disregarded many of these "exceptional" process flows; as a result they were often the source of problems.

While the technical tools and analysis made useful contributions, many team members believe that the simple measures – Pareto charts, part color coding, and illustrated instructions – made the biggest impacts. Project elapsed time did not permit the classic 6 Sigma approach of intense training in statistics, analysis and problem-solving techniques in depth, or the traditional manufacturing engineering route of process automation. Nonetheless, by engaging the people, dramatic improvement in quality was attained.

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Author’s Background

Bradley A. Pritts *has been a consulting engineer specializing in quality and project management in the automotive industry for twenty-seven years. His experience includes:*

> *Project Manager for new product/process launches at several automotive parts suppliers and vehicle OEM’s in North America and the People’s Republic of China. Personally led Advanced Quality Planning teams from project conception through successful launch programs for five major product programs representing over fifty (50) product part numbers.*
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> *Leadership of ISO 9000, QS-9000, ISO/TS 16949, and customer specific quality system implementations with over twenty-five client plant sites.*
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> *Consultation in problem-solving efforts involving customer complaints, in many cases crossing multiple players in automotive supply chains.*
>
> *Six years tenure as an RAB certified QMS Lead Auditor*
>
> *Pritts’ academic qualifications include the M.B.A., University of Michigan; and B.S., Ohio State University. He is an ASQ Certified Six Sigma Black Belt.*