Chinese OEM Reduces Returns With Improved Product Testing

by ASQ staff writer

At a Glance . . .

- When Continental Automotive Systems, Tianjin, China, began producing an electronic component known as the silver box, the return rate was more than 1,200 parts per million (ppm), versus a goal of less than 100 ppm.
- A Six Sigma improvement team used quality tools including trend charts, Pareto charts, and cause-and-effect diagrams to analyze the failure modes for the reported defects, finding that many were not being covered by product testing processes.
- A combination of technical innovation tools, including test coverage analysis, fault insertion, and a test methods selection matrix, along with Six Sigma process improvement and statistical tools, led the team to the solution of adding new testing items and a new testing station to the process.
- Adding the new tests reduced silver box returns to fewer than 50 ppm, producing cost savings of $130,000 per year while also strengthening relations with a major customer.

For original equipment manufacturers (OEMs) supplying the automotive industry, a product can be returned well before the car it's in reaches the end customer. A key metric suppliers often use in tracking the performance of their products is therefore the number of defective parts per million (ppm) occurring while the car still has 0 kilometers (km) on the odometer.

When Continental Automotive Systems, Tianjin, China, began producing an electronic component known as the silver box for a General Motors subsidiary, the 0 km return goal was less than 100 ppm; the actual return rate, however, was 1,200 ppm.

Company personnel launched a Six Sigma improvement project to make process improvements that would achieve the 100 ppm goal within a year.

About Continental Tianjin

Continental Corporation has 16 plants in China. Its automotive system plant is located in Tianjin, a city on the eastern coast of China not far from the East China Sea. More than 1,200 employees work at the facility and take pride in the plant's "quality first" philosophy and TS16949, ISO 14001, OHSAS 18001, ESD20:20, and Ford Q1 certifications.

The plant produces electronic systems for automobiles such as vehicle body control modules, engine control systems, transmission control modules, and multimedia infotainment systems. In addition to supplying Chinese vehicle manufacturers, Continental Tianjin produces components for car makers all over the world, with Chrysler, Ford, General Motors, and Volkswagen among its customers.

First launched in May 2010, the silver box is supplied to GM Holden, located in Melbourne, Australia. It includes a CD player, USB jack, GPS, and hands-free Bluetooth feature. Each unit has more than 2,200 components, which introduces a lot of room for error. "The silver box is a challenging product, but we think it's a good opportunity for growing our output," said Li Xiang, quality engineer.

The silver box includes a CD player, USB/iPod jack, global positioning system, a hands-free Bluetooth feature, and more.

Beginning With the End in Mind

As part of strategic planning and operations reviews, Continental Tianjin selects improvement projects using voice of the customer and voice of the business information. Potential projects are categorized either as lean, quick-win efforts, or as longer-term, Six Sigma undertakings.

During the initial months of production of the silver box, customers complained about defects and reported that its quality was not stable. In fact, the silver box customer return rate was 1,260 ppm. An improvement effort named the GM Holden 0 km Return Reduction Project was proposed to lower the return rate and restore customer confidence.

Continental Tianjin projects are ranked according to how well they meet various criteria, including cost and process impacts, customer advantages, employee motivation, and whether the project benefits the greater community. For each criterion, a project receives scores for importance and impact. The scores must meet a specified total to qualify as a continuous improvement project, and projects that score higher receive higher priority.

The GM Holden 0 km Return Reduction Project was approved as a Six Sigma define-measure-analyze-improve-control (DMAIC) project based on its predicted high impact on organizational strategies around cost and customer satisfaction, and its moderate impact on strategies around processes and employees. Figure 1 details the expected improvements. Cost savings would occur from reducing scrap and additional shipping, and customer satisfaction was expected to increase as defects decreased. Additionally, the improvements would increase process capability and give employees the opportunity to gain experience using problem-solving skills and statistical tools.

Define Phase

A team was assembled in October 2010, and by November 1 a team charter had been created, with the primary goals defined as reducing 0 km returns to 100 ppm by the end of June 2011.

Team leader and Green Belt Zhang Ji-Jun describes the project team as “the Great Wall to protect Continental’s customers.” Core team members, selected based on project requirements and the knowledge and skills of individual candidates, included:

- Cao Zhen-Qi, champion
- Chat Miao, test engineer
- Jian Dong Shi, Black Belt
- Li Xiang, quality engineer
- Yan Yun, test engineer
- Gx Wang, test engineer

A suppliers, inputs, process, outputs, customers (SIPOC) diagram helped the team identify the potential impact of the project on stakeholders. Internal stakeholders included Continental Tianjin quality assurance; process, test, and product engineers; supplier quality management; and Six Sigma belts. External stakeholders included project management, suppliers, customers, and end users. Those that would be affected most were quality assurance, test engineers, product engineers, and customers.

Measure Phase

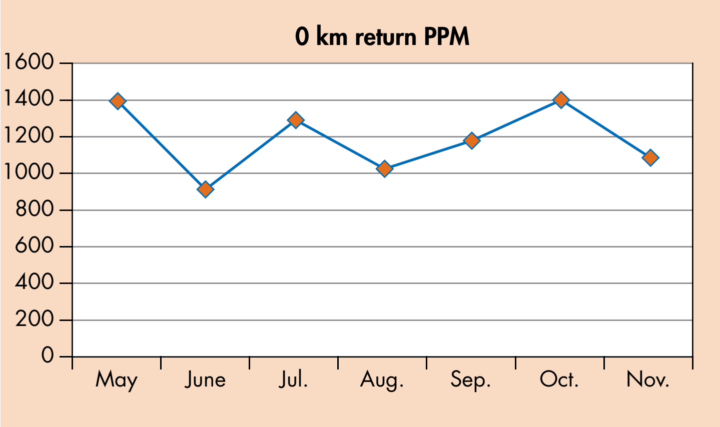
To better understand silver box defects, the team used a trend chart to analyze process performance over time and identify strengths and weaknesses. According to Ji-Jun, Continental Tianjin’s return tracking system made it easy to obtain quality data for the trend chart. As Figure 2 shows, the return rate was stable at 1,260 ppm from May to November 2010.

After verifying the measurement system by conducting a gage repeatability and reproducibility (GR&R) study, the team proceeded to investigate the types of defects that were occurring. They summarized and categorized different return failure modes, and Pareto analysis showed that the top three issues reported by customers were navigation failure, faulty screen display, and electronic data interchange (EDI) screen problems (see Figure 3).

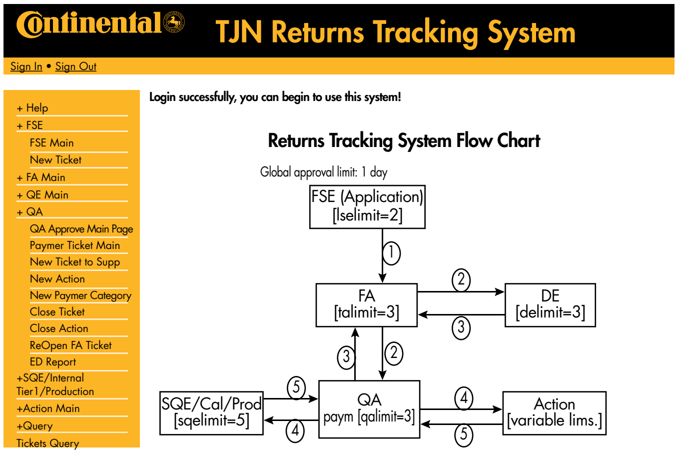
Figure 1*—Degree of impact on organizational strategies*

Organization Strategies	Goals	Measure	Current	Degree of Impact
Cost	Cost savings	Reduce 20%/year	10%	High
Customer	0 km return	100 ppm	1,026 ppm	High
Process	Key process capability	Cpk/Cp>2	1.67%	Mid
Employee	• Problem-solving skills • Statistical tools skills	10 Six Sigma projects/year	2	Mid

Figure 2—Trend chart showing process performance before improvements



0 km return monthly



The trend chart = > 0 km return ppm was staying at a high level, almost 1,260 ppm.

Collect the customer return data from RTS, get the trend chart of 0 km ppm.

Analyze Phase

All returned products that caused 0 km failures were verified as faulty by Continental Tianjin; each had a functional problem that surfaced in application but was not detected prior to shipment. "For example," said Zhen-Qi, champion, "investigation revealed that the navigation failure was caused by a printed circuit board assembly (PCBA) process issue, but it wasn't detectable in the testing process." Similarly, the screen display and EDI issues were tracked to the PCBA process but had no testing coverage.

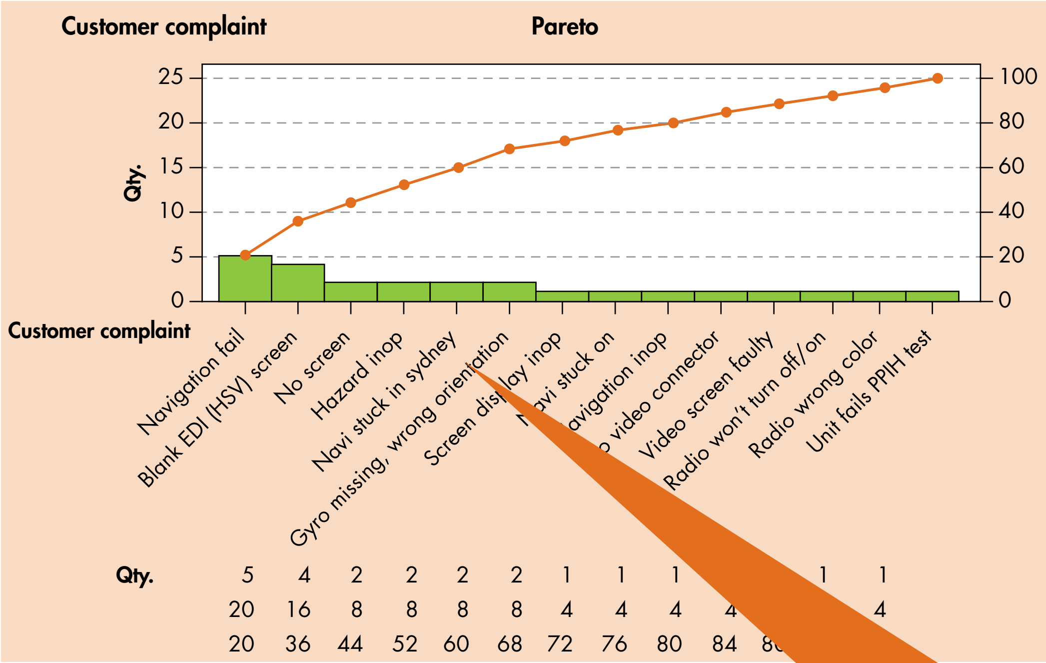
The team performed a test coverage analysis to study the detectability of all 16,213 failure modes and discovered that 191 modes with high risk priority numbers were not covered in testing before shipment.

A fishbone diagram (see Figure 4) helped point to two main causes for the lack of testing coverage for the failure modes: inadequate test specifications and testing designs that did not address all specification requirements.

Stakeholders from test engineering, quality assurance, and the design center helped conduct the technical reviews and experimentation required to validate the two primary root causes:

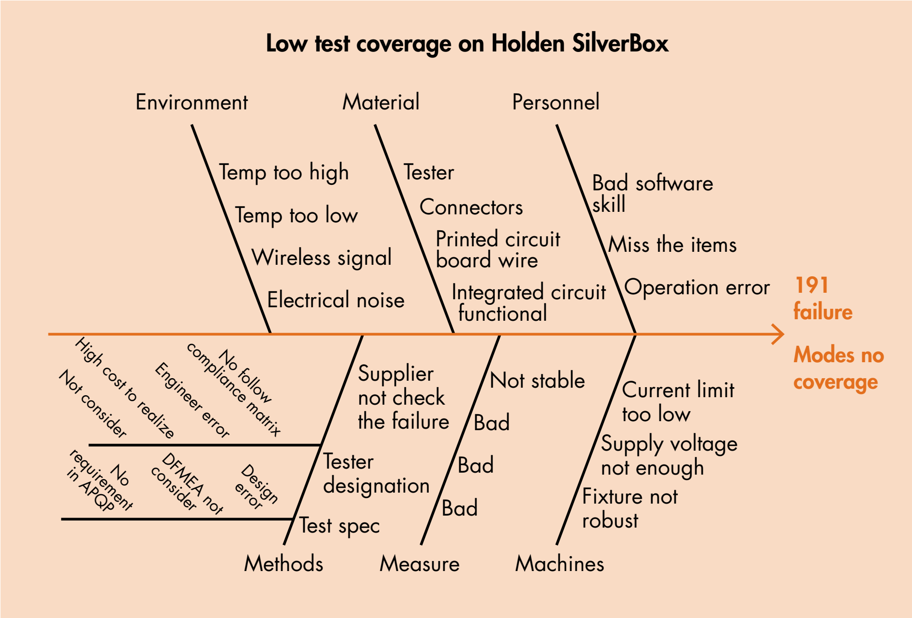
- **Some items were missed in the tester design**—A compliance matrix review showed that 19 items were not included in the tester design. Adding these items would help

Figure 3—Pareto chart identifying top categories of defects



Data from RTS, the trend chart showed the top issue = > test escaping 0 km ppm.

Figure 4—Fishbone diagram isolating causes for lack of testing coverage for 191 failure modes



improve testing coverage for a total of 134 failure modes and reduce the 0 km return rate by an estimated 812 ppm.

- **Some items were not considered in specifications**—Review of design failure modes and effects analysis showed that many of the failure modes actually had been covered, but they were not defined in product test specifications. Adding these items to the specifications would result in coverage of 57 failure modes and reduce the 0 km return rate by about 400 ppm.

Improve Phase

Identifying solutions

A combination of technical innovation tools including test coverage analysis, fault insertion, and a test methods selection matrix, along with Six Sigma process improvement and statistical tools, helped the team develop and validate solutions.

First, process mapping showed that the 191 failure modes without coverage should actually be covered by three test stations in the production line—the in-circuit test (ICT) station, the general hardware (GHW) test station, and the general function test (GFT) station. Next, the team categorized the failure modes in detail, finding the top three to be an integrated circuit functional problem, a capacitor open circuit, and an electrical short between adjacent integrated circuit pins.

Before creating a plan for improving test coverage, the team agreed upon four criteria for evaluating potential solutions:

1. Ease of implementation
2. Timeliness of implementation
3. Cost
4. Ease of reversibility/recovery of original status

For each of the three top failure modes, solutions were assessed according to these criteria using a selection matrix. Figure 5 shows how the matrix for the integrated circuit functional failure supports the solution of adding test items to the GHW testing station.

The team's final solutions involved adding a total of 17 new tests for the three existing test stations: seven tests would be added for ICT, five would be added for GHW, and five for GFT. Additionally, one new testing station,

Figure 5—One of the solution selection matrices the team created

Testing methods selection matrix
Failure mode: Integrated circuit (IC) functional failure

Potential improvement opportunity	Easy to implement	Time to implement	Cost (US$)	Easily reversible	Solutions selected
ICT	Need to add test pad, design change on PCB, not easy	Design change, six months	10,000	No	
GHW	Yes	Software change, update test code, two weeks	2,000	Yes	V
GFT	Yes	Need to buy new test cards, lead time four months	32,000	Yes	

general quality assurance (GQA), would be added to the process.

The design center confirmed the data analysis supporting the new tests, and test software was upgraded accordingly. All new test items were further validated by fault insertion, capability studies, GR&R studies, and a two-sample T-test showed that adding the new test items would not have a significant impact on the original test items.

Implementing solutions

To implement the new testing solutions, design, test, and product staff would focus on technical improvements, and the factory focus manager and quality department would be responsible for change control. The team was careful to invest enough effort into optimizing the build plan, dedicating 90 minutes for engineering experiments each day. A Gantt chart also helped the team plan the step-by-step implementation of the solution from December 2010 through June 2011.

The most serious resistance to the improvements was expected to come from the production department. "Personnel were concerned because we needed to shut down normal manufacturing and perform an experiment to evaluate how well the changes associated with our solution would work," said Black Belt Dong Shi. "We also needed to stop the testers in the normal production line, which would impact on-time delivery." Careful communication with production staff at all stages helped secure and maintain their cooperation.

Other concerns stemmed from the limited knowledge that some stakeholders had of the product testing process, the geographical distance of the design center from the testing stations, the time required to debug the testing equipment and verify the test code, and the lack of a full-time Black Belt to lead the implementation. Key actions for overcoming resistance and ensuring cooperation included providing product training for nontechnical staff; holding conference calls and online meetings, as well as coordinating sufficient staff travel during the implementation period; holding weekly project meetings to keep all stakeholders informed; and debugging the test code during trial runs in the daily 90-minute trials.

Figure 6 shows that upon implementing the new test items and test station, Continental achieved test coverage of 179 items and a defect reduction of 1,260 ppm.

***Figure 6**—Results from implementing new test items*

Change description	Results
Add ICT test items	Test coverage: 93 items PPM: 740 reduction
Add GHW test items	Test coverage: 36 items PPM: 340 reduction
Add GFT test items	Test coverage: 34 items PPM: 130 reduction
Add new test station: GQA	Test coverage: 16 items PPM: 50 reduction

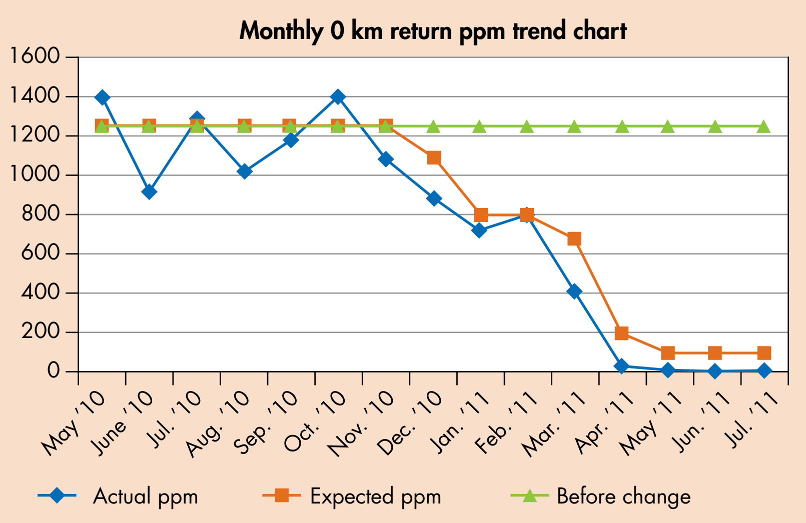
To sustain these results, the team followed existing control procedures at Continental, such as having the change approved in the electronic process change authorization (ePCA) system, a tool to control any change in the test station or assembly process. Other control measures included a process validation build and using the production part approval process to secure GM Holden's approval.

Additionally, Continental uses statistical process control in its test systems to detect and eliminate special causes of process variation. For the new test items added by this project, control limits were calculated, and alarms are triggered for failure counts of three or greater. The existing return tracking system, process failure modes and effects analysis documentation, and process control plan were also updated to cover the added failure modes for the new test items and station.

Continuous Improvement From Beginning to End

The GM Holden 0 km Return Reduction Project, which ended in June 2011, ultimately exceed its goals, reducing silver box 0 km returns to fewer than 50 ppm, and achieving cost savings of US$130,000 per year (see Figure 7).

***Figure 7**—Tangible benefits of the improvement project*



Team members said one intangible benefit was positive feedback from GM Holden that might set the stage for additional business. As another benefit, Continental reduced industrial waste that would have been generated from scrapped products.

The project also serves as a lesson learned that will help Continental Tianjin implement process improvements in other areas and for other products. Results have been shared in weekly project reviews, staff meetings, monthly operation reviews, and updates in quarterly Continental Tianjin business system reports. The effort was also publicized in a continuous improvement project showcase.

External recognition came when the team qualified as a finalist in the ASQ International Team Excellence Award (ITEA) Process. The team was invited to present its project at the 2012 World Conference on Quality and Improvement, held in Anaheim, California.

Champion Zhen-Qi concluded, "Total customer satisfaction is our goal, and this project helped us achieve it. We began with the end in mind, and practiced continuous improvement from beginning to end."

For more information

- Learn more about Continential's Automotive Group at http://www.conti-online.com/generator/www/de/en/continental/automotive/general/home/index_en.html.
- Learn more about the ASQ International Team Excellence Award Process at http://wcqi.asq.org/team-competition/.
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