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Reducing Assembly Defects in Automotive Wiring Harness Production Using Six Sigma DMAIC: A Case Study at PT. XYZ

Gabrielle Rebecca Christisa[a], Fandy Bestario Harlan[a*]

[a]International Trade Logistics Study Program, Batam State Polytechnic, Batam, Indonesia. fandybestario@polibatam.ac.id

ABSTRACT

Intense competition in the automotive component industry requires manufacturers to manage product quality systematically to sustain customer satisfaction and control operational costs. PT. XYZ, an automotive wiring harness manufacturer in Indonesia, saw its annual defect rate rise from 0.61% in 2022 to 0.95% in 2023. This study assesses the baseline quality condition of wiring harness production, identifies the root causes of the two most frequent and critical defect types, and formulates managerial improvement and control actions using the Six Sigma Define, Measure, Analyze, Improve, and Control (DMAIC) cycle. A single case study with a mixed quantitative–qualitative approach was applied, using interviews, direct observation, daily production reports, and company documentation, supported by a Pareto chart, a proportion control chart (p-chart), fishbone diagrams based on the man, machine, method, and material (4M) factors, and the 5W+1H technique. Connector housing breakage and terminal tip arrangement defects were the two most frequent defect types (28.9% of recorded defects) and were prioritized because of their repair burden and short-circuit risk. In the observed production plant, the baseline proportion defective between August and October 2023 was 7.6%, equivalent to a sigma level of about 2.9. No daily point fell outside the control limits, but the monthly proportion rose significantly ($\chi^2 = 27.64$; $p < 0.001$), with long runs below the center line in August and above it in October, indicating a systemic upward shift rather than isolated incidents. The suspected root causes were insufficient operator understanding and self-checking, unprotected assembly stands and damaged aprons, rushed handling methods, and fragile or upstream-damaged materials. Improvement actions, namely operator retraining, protective pads on the assembly board, revised work standards, and a maximum material stock level of 80%, were followed by a reported 2.90% decrease in the defect percentage, which still requires statistical verification. The findings indicate that DMAIC can support quality decision-making in labor-intensive assembly operations when stability, capability, and managerial levers are examined together.

Keywords:

continuous improvement; DMAIC; p-chart; quality management; Six Sigma; wiring harness

Introduction

Competition in the manufacturing industry, particularly among suppliers of automotive components, encourages companies to continuously improve the quality of their products in order to remain competitive. From an industrial management perspective, quality is no longer only a technical inspection activity but a strategic responsibility that determines customer satisfaction, production cost, and delivery performance. Quality has been defined as the degree to which a product or service conforms to applied standards and requirements, and also as fitness for use, which covers product features that meet customer needs and freedom from defects or deficiencies [1], [31]. Companies

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* Corresponding author: Fandy Bestario Harlan, fandybestario@polibatam.ac.id

therefore need a strong quality improvement program that is sustained by continuous improvement. Case evidence from manufacturing firms shows that sustaining such improvement depends on leadership commitment and funding, a clear implementation method, documented improvement data, employee training and incentives, and monitoring and control systems [2]. Empirical evidence from manufacturing enterprises also shows that the extent to which quality management practices are applied is associated with business performance [3].

PT. XYZ is a manufacturing company that produces wiring harnesses for the automotive industry. Company records show that its quality performance declined between 2022 and 2023. In 2022, the company recorded 7,084 defective units out of a total production of 1,156,986 units, a defect rate of 0.61%. In 2023, the number of defective units increased to 15,444 out of 1,625,306 units, a defect rate of 0.95%. This increase of 0.34 percentage points indicates a decline in the level of quality and raises the cost of poor quality through rework, material waste, and production delays. For a supplier that operates within a tightly coordinated automotive supply chain, such a decline also threatens customer trust and the company's competitive position.

To overcome this problem, management requires a structured approach to identify the causes that affect the quality of wiring harness production and to translate the findings into managerial decisions. Six Sigma is a continuous improvement methodology that aims to minimize the level of product defects. As an approach to quality control, Six Sigma can help quality management achieve breakthroughs in controlling and improving production quality [4]. Its Define, Measure, Analyze, Improve, and Control (DMAIC) cycle links statistical evidence with decisions about people, equipment, work methods, and materials, which are the core resources managed in an industrial operation. Systematic reviews show that DMAIC is the most widely applied Six Sigma approach in manufacturing [5], that it adapts well to both manufacturing and service industries in Indonesia [6], and that structured problem-solving methods remain central to defect reduction efforts in the manufacturing industry [7].

Six Sigma DMAIC has been applied successfully in a wide range of manufacturing settings [4], [8]–[14]. In the automotive sector, it has been used to raise the sigma level of brushless motor production [15], to reduce welding defects in truck cabin production [16], and to lower painting defects in four-wheeled vehicle production [17], [18], with closer operator supervision and standardized spraying parameters among the main corrective actions in one of these studies [17]. Studies closer to this research have applied Six Sigma to automotive wiring production [19], wire harness tape manufacturing [20], and wiring harness assembly and post-processing in Indonesia [21], [22]. Most of these studies report the technical outcome of defect reduction, whereas fewer examine defects that originate from manual handling on the assembly board, where the corrective levers are work standards, training, supervision, and equipment maintenance rather than machine settings. This distinction matters because the adoption of Lean Six Sigma in the automotive industry still faces organizational barriers, among which resource constraints are the most significant [23]; leadership and management involvement, project infrastructure, and training are critical success factors [24]; and managers need to consider these factors when defining implementation strategies [25]. In labor-intensive wiring harness assembly, the managerial challenge therefore lies not only in measuring defects but also in designing work standards, training, supervision, and maintenance routines that prevent handling-related defects from recurring.

This study applies DMAIC to two handling-related defect types in wiring harness assembly and examines how the findings can be translated into managerial decisions on people, equipment, methods, and materials. The objectives of this study are (1) to assess the baseline quality condition of wiring harness production at PT. XYZ, including process stability and sigma level, (2) to analyze the root causes of the two most frequent and critical defect types using the Six Sigma DMAIC approach, and (3)

to formulate improvement and control actions that management can implement to improve production quality in a sustainable manner.

Methods

Research Design and Object

This study applies a single case study design with a mixed quantitative–qualitative approach at PT. XYZ, an Indonesian manufacturer of wiring harnesses for the automotive industry. The quantitative component covers the Pareto analysis, the p-chart, the chi-square test of monthly differences, and the sigma level, whereas the qualitative component covers the root cause analysis and the formulation of improvement and control actions. Data were gathered through interviews, direct observation of the production process, the company's daily production reports, and documents obtained during the research, and were complemented by a review of books, journal articles, and other relevant publications. The annual defect data for 2022 and 2023 describe the quality problem, whereas the daily production and defect data from August to October 2023 form the basis of the statistical analysis. The improvement actions described in this article were implemented by the company, so the study can also be regarded as an intervention case study.

DMAIC Framework

The data analysis follows the DMAIC stages, which provide a structured route for solving problems and improving the quality of a production process [9]. DMAIC also offers a systematic model that links the measurement of manufacturing process quality with improvement decisions [26]. The stages are explained below.

Define

The Define stage sets the objectives of the Six Sigma quality improvement program. It specifies the quality problem to be solved, the critical defect types, and the strategies and steps required to build quality improvement into the production process [10].

Measure

Measure, the second operational step of Six Sigma, links the Define stage with the stages that follow. In this stage, the stability of the production process is assessed with statistical quality control [12]. Since the daily number of units produced is not constant, a proportion control chart (p-chart) is applied; this chart is widely used to monitor the proportion of nonconforming items in manufacturing [27]. The proportion of defective products for day i is calculated using Equation (1), the center line (CL) using Equation (2), and the upper control limit (UCL) and lower control limit (LCL) for day i using Equations (3) and (4). Because the purpose is to establish a baseline (Phase I), a single center line is calculated from the whole observation period, and the chart is evaluated both for points beyond the control limits and for non-random patterns, such as eight or more consecutive points on one side of the center line [32]. Differences between the monthly proportions are tested with a chi-square test. The baseline capability is expressed as the proportion defective, the number of defective units per million, and the corresponding sigma level, assuming the conventional 1.5σ shift.

$$p_i = \frac{np_i}{n_i} \tag{1}$$

$$\mathrm{CL} = \overline{p} = \frac{\sum np}{\sum n} \tag{2}$$

$$\mathrm{UCL}_i = \overline{p} + 3\sqrt{\frac{\overline{p}(1-\overline{p})}{n_i}} \tag{3}$$

$$\mathrm{LCL}_i = \overline{p} - 3\sqrt{\frac{\overline{p}(1-\overline{p})}{n_i}} \tag{4}$$

where np_i is the number of defective units on day i, n_i is the number of units produced on day i, and the mean proportion is the total number of defective units divided by the total number of units produced in the observation period. A negative LCL is set to zero.

Analyze

Analyze, the third stage, concentrates on the causes of defects. The factors behind each defect are traced with a fishbone (cause-and-effect) diagram [34], which, together with the Pareto chart, is one of the tools most often used in Six Sigma studies [6]. The causes are classified into four groups, commonly called the 4M: man (manpower), machine, method, and material. Figure 1 shows the general structure of the fishbone diagram used in this study.

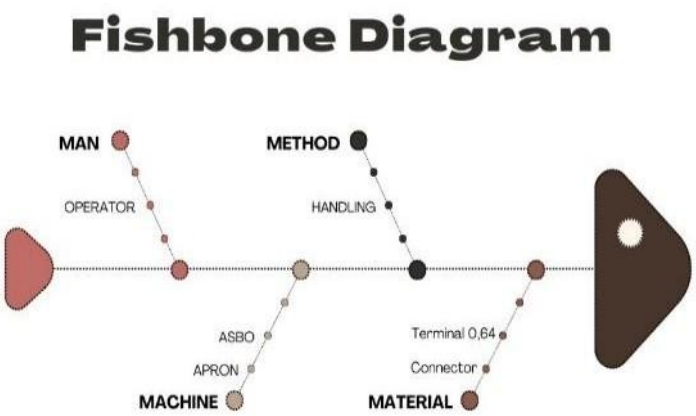


Figure 1. Structure of the fishbone diagram based on the 4M factors

Improve

The Improve stage proposes corrective action plans for quality improvement. These plans are developed with the 5W+1H technique (what, why, where, when, who, and how), and their priority is set according to the causes of each defect [11].

Control

Control, the final operational stage of Six Sigma, documents the results of the quality improvement and disseminates them through standardized work procedures and guidelines, which the company can then use as a benchmark to prevent the same problem from recurring [13]. Sustaining improvement through a repeated plan–do–check–act cycle has been shown to reduce product defects in the automotive components industry [28] and to support continuous improvement through monitoring and supervisory coaching [29].

Results and Discussion

Define

The Define stage identifies the quality problems in wiring harness production at PT. XYZ, namely the defect types that cause products to fail to meet quality standards. The defect types recorded by the company are presented in Table 1.

Table 1. Production defect types and their frequency at PT. XYZ

No.	Defect type	Quantity	Percentage
1	Connector housing breakage	698	16.4%
2	Terminal tip arrangement defect	531	12.5%
3	Mis-location	480	11.3%
4	No taping	465	10.9%
5	Incorrect distance	427	10.0%
6	Stopper attachment defect	389	9.1%
7	Incorrect corrugated tube size	263	6.2%
8	Part attachment defect	161	3.8%
9	Taping defect	111	2.6%
10	Incorrect wiring	92	2.2%
11	Protector attachment defect	79	1.9%
12	Incorrect taping	59	1.4%
13	Defective dimension of band cut	44	1.0%
14	No ID tape	42	1.0%
15	Wire defect	28	0.7%
16	Sealing cover attachment defect	27	0.6%
17	Incorrect branch	27	0.6%
18	Terminal back out	26	0.6%
19	No optional taping	26	0.6%
20	Incorrect optional taping	24	0.6%
21	Incorrect part attachment	20	0.5%
22	Rubber plug attachment defect	20	0.5%
	Others	218	5.1%
	Total	**4,257**	**100.0%**

(Source: company data, processed)

Table 1 and the Pareto chart in Figure 2 show that the two most frequent defect types are connector housing breakage, with 698 defects (16.4%), and terminal tip arrangement defects, with 531 defects (12.5%). Together, these two defects account for 28.9% of all recorded defects. They do not constitute the 'vital few' in the strict Pareto sense, because eight defect categories are needed to reach 80% of all defects (Figure 2). They were nevertheless prioritized for two reasons: they are the most frequent individual defect types, and they are the most critical ones, since connector housing breakage requires the connector to be replaced and a bent terminal must be replaced by the CNC department and can cause a short circuit that may lead to a vehicle fire.

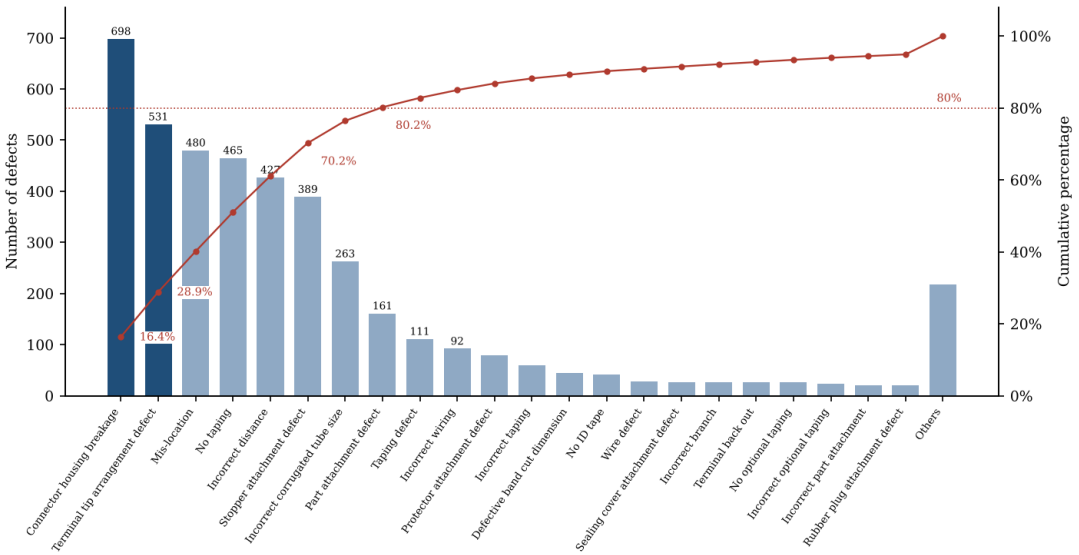


Figure 2. Pareto chart of production defects (cumulative percentage on the right axis)

A connector housing breakage defect is damage to the connector, particularly to its locking part and surface, which prevents the connector from protecting the terminal. This defect affects quality performance because the repair takes long enough to delay production, and the repair cost is high because a considerable amount of material is wasted. A terminal tip arrangement defect occurs when the terminal wire is not straight. A broken or bent terminal can cause a short circuit that may lead to a vehicle fire. If such a defect passes to the customer, it will cause substantial losses for the company.

Based on the observation and the initial analysis, the project scope was defined as reducing these two defect types in the assembly area. The critical-to-quality (CTQ) characteristics are an intact connector housing, particularly its locking part and surface, and a straight, correctly seated terminal tip. Solutions were not defined at this stage; they were derived from the root cause analysis in the Analyze stage.

Measure

The Measure stage uses a control chart to evaluate the stability of the production process and establishes the baseline capability. According to the company records, the annual defect percentage of the observed production plant in 2023 was 1.04%. The daily production and defect data for August, September, and October 2023, which form the basis of the baseline, are presented in Tables 2, 3, and 4. The daily proportions in these tables are considerably higher than the annual company-level rates reported in the Introduction; the two data sources therefore cannot be compared directly, and the baseline below refers only to the daily data of the observed plant.

Table 2. Daily production and defect proportion, August 2023

Date	Production (units)	Defects (units)	Defect proportion
01 Aug 2023	457	39	8.5%
02 Aug 2023	483	33	6.8%
03 Aug 2023	509	35	6.9%
04 Aug 2023	444	27	6.1%
07 Aug 2023	465	31	6.7%
08 Aug 2023	412	20	4.9%
09 Aug 2023	425	19	4.5%
10 Aug 2023	471	23	4.9%
11 Aug 2023	511	30	5.9%

Date	Production (units)	Defects (units)	Defect proportion
14 Aug 2023	447	22	4.9%
15 Aug 2023	469	25	5.3%
16 Aug 2023	481	22	4.6%
17 Aug 2023	402	30	7.5%
18 Aug 2023	381	25	6.6%
21 Aug 2023	369	29	7.9%
22 Aug 2023	372	21	5.6%
23 Aug 2023	401	27	6.7%
24 Aug 2023	419	34	8.1%
25 Aug 2023	392	31	7.9%
28 Aug 2023	336	24	7.1%
29 Aug 2023	350	24	6.9%
30 Aug 2023	374	29	7.8%
31 Aug 2023	380	27	7.1%
Total	**9,750**	**627**	**6.4%**

(Source: company daily production reports, processed)

Table 3. Daily production and defect proportion, September 2023

Date	Production (units)	Defects (units)	Defect proportion
01 Sep 2023	482	36	7.5%
04 Sep 2023	397	40	10.1%
05 Sep 2023	401	32	8.0%
06 Sep 2023	423	30	7.1%
07 Sep 2023	447	37	8.3%
08 Sep 2023	451	44	9.8%
11 Sep 2023	432	41	9.5%
12 Sep 2023	417	35	8.4%
13 Sep 2023	470	39	8.3%
14 Sep 2023	409	28	6.8%
15 Sep 2023	438	29	6.6%
18 Sep 2023	429	27	6.3%
19 Sep 2023	499	42	8.4%
20 Sep 2023	495	42	8.5%
21 Sep 2023	426	36	8.5%
22 Sep 2023	388	29	7.5%
25 Sep 2023	415	35	8.4%
26 Sep 2023	407	31	7.6%
27 Sep 2023	411	30	7.3%
28 Sep 2023	420	31	7.4%
29 Sep 2023	428	28	6.5%
Total	**9,085**	**722**	**7.9%**

(Source: company daily production reports, processed)

Table 4. Daily production and defect proportion, October 2023

Date	Production (units)	Defects (units)	Defect proportion
01 Oct 2023	415	41	9.9%
02 Oct 2023	483	35	7.2%
03 Oct 2023	509	44	8.6%
04 Oct 2023	444	31	7.0%
05 Oct 2023	438	33	7.5%
06 Oct 2023	429	32	7.5%

Date	Production (units)	Defects (units)	Defect proportion
09 Oct 2023	499	48	9.6%
10 Oct 2023	388	32	8.2%
11 Oct 2023	415	32	7.7%
12 Oct 2023	407	36	8.8%
13 Oct 2023	402	34	8.5%
16 Oct 2023	381	28	7.3%
17 Oct 2023	415	41	9.9%
18 Oct 2023	407	36	8.8%
19 Oct 2023	411	37	9.0%
20 Oct 2023	397	33	8.3%
23 Oct 2023	401	36	9.0%
24 Oct 2023	423	33	7.8%
25 Oct 2023	447	39	8.7%
26 Oct 2023	336	29	8.6%
27 Oct 2023	350	27	7.7%
30 Oct 2023	374	32	8.6%
31 Oct 2023	423	29	6.9%
Total	**9,594**	**798**	**8.3%**

(Source: company daily production reports, processed)

The monthly totals and monthly defect proportions are summarized in Table 5. The pooled proportion for the whole period (0.076) is used as the center line of the Phase I chart.

Table 5. Units produced, defective units, and monthly defect proportion, August to October 2023

Month	Units produced (∑n)	Defective units (∑np)	Defect proportion (p)
August 2023	9,750	627	0.064
September 2023	9,085	722	0.079
October 2023	9,594	798	0.083
Total	**28,429**	**2,147**	**0.076**

(Source: company daily production reports, processed)

As an example of the calculation, the defect proportion on 1 August 2023 is obtained from Equation (1):

$$p_{1\ \mathrm{Aug}} = \frac{39}{457} = 0.085$$

The center line for the whole observation period is calculated using Equation (2):

$$\mathrm{CL\ (Aug - Oct)} = \frac{2{,}147}{28{,}429} = 0.076$$

Because the sample size differs every day, the control limits are calculated for each day using Equations (3) and (4). For example, the limits for 1 August 2023 (n = 457) are as follows:

$$\mathrm{UCL\ (1\ Aug)} = 0.076 + 3\sqrt{\frac{0.076(1 - 0.076)}{457}} = 0.113$$

$$\mathrm{LCL\ (1\ Aug)} = 0.076 - 3\sqrt{\frac{0.076(1 - 0.076)}{457}} = 0.039$$

The resulting p-chart for the whole observation period is shown in Figure 3.

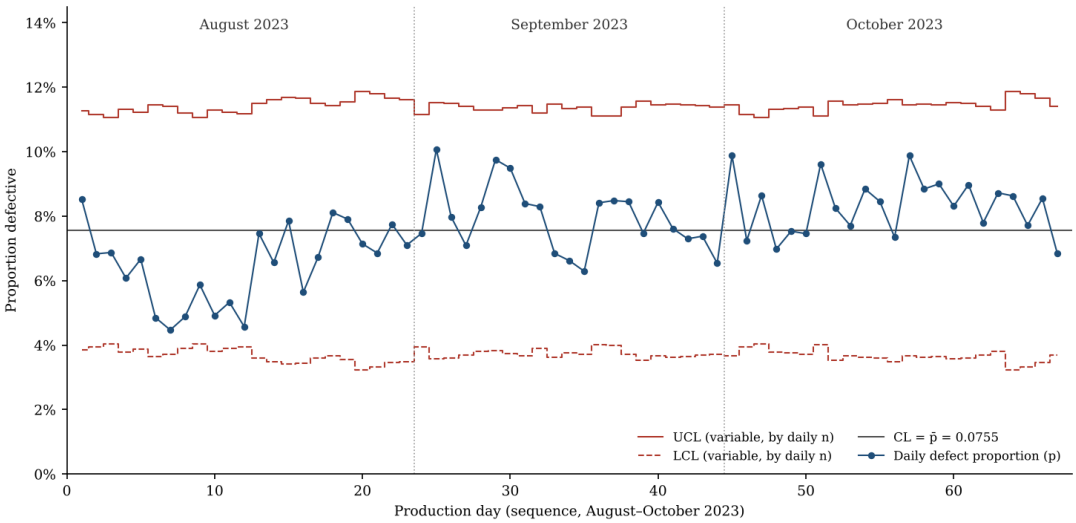


Figure 3. P-chart of the daily defect proportion, August–October 2023 (pooled center line, variable control limits)

Figure 3 shows that none of the 67 daily defect proportions lies outside its control limits. The chart is nevertheless not random: 13 consecutive points from 2 to 18 August lie below the center line, and 10 consecutive points from 17 to 30 October lie above it, both exceeding the common run rule of eight consecutive points on one side of the center line [32]. Consistently, the monthly proportion increased from 0.064 in August to 0.079 in September and 0.083 in October, and the difference between months is statistically significant ($\chi^2 = 27.64$; df = 2; $p < 0.001$). The baseline proportion defective of 7.6% corresponds to about 75,500 defective units per million and a sigma level of about 2.9. These results mean that the defects are not caused by isolated incidents on particular days but by a sustained upward shift in the level of a process that is dominated by common causes. From a management perspective, such a defect level is generated by the work system itself, namely work methods, equipment conditions, and material handling, so it can only be reduced by changing the system rather than by reacting to individual days [33]. This is the focus of the Analyze stage.

Analyze

The Analyze stage identifies the root causes of the defects as the basis for developing and improving the production process. The factors that cause connector housing breakage defects were analyzed using a fishbone diagram [30], [34], as shown in Figure 4. Based on observation and discussions with production personnel, the main suspected cause relates to the machine factor: the connector dangles and touches the floor because the stand of the assembly board (ACB) is not protected, and the damaged apron of the sub-assembly stand causes the connector surface to get caught.

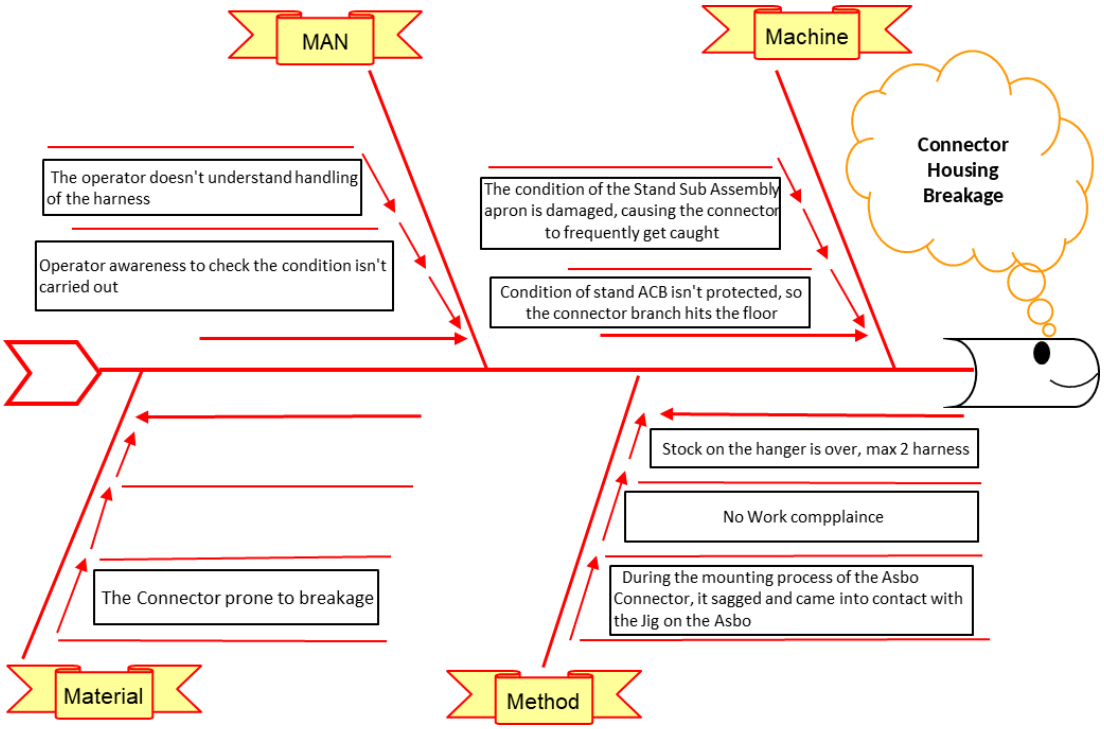


Figure 4. Fishbone diagram of connector housing breakage defects

The same analysis was conducted for terminal tip arrangement defects, as shown in Figure 5. The main suspected causes relate to the man and method factors, namely the way operators insert the terminal wire into the connector. This defect requires particular attention because the repair must be carried out by the CNC department, which replaces the damaged terminal with a new one.

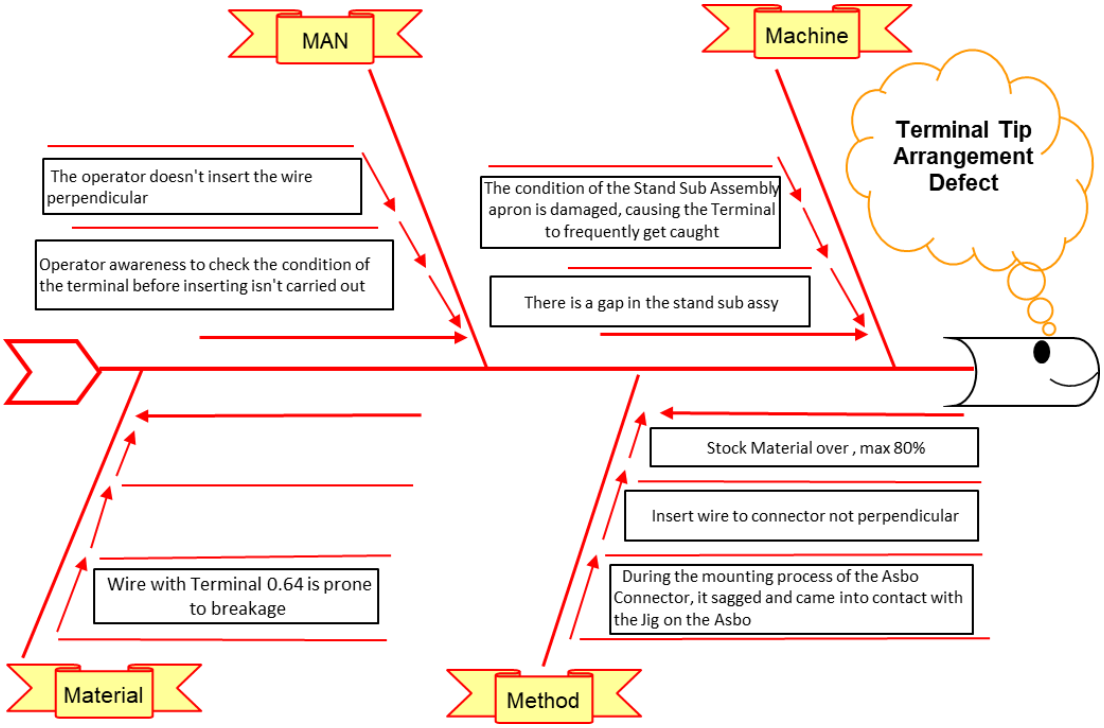


Figure 5. Fishbone diagram of terminal tip arrangement defects

The root causes of both defect types can be summarized according to the 4M factors as follows.

These causes were identified qualitatively and have not yet been weighted with frequency data, for example with a check sheet or stratification by line, shift, or connector type; their validation is therefore noted as a limitation of this study.

a. **Man.** Operators lack understanding of the work process and do not perform self-checks during production. They also lack understanding of how to handle the wire terminals when inserting them into the connectors.

b. **Machine.** Connectors and terminals can hit the sharp and hard side of the assembly board (asbo), which damages the connector and causes connector housing breakage and terminal tip arrangement defects. In addition, torn aprons in the production area cause terminal wires to get caught on the torn side and bend.

c. **Method.** Operators do not follow appropriate working steps. When lifting the wiring harness from the asbo, operators pull the branches forcibly, causing the connectors to collide. Moreover, harnesses are rolled in sizes that do not match the predetermined standard because operators work in a hurry.

d. **Material and upstream process.** Terminals supplied on stock wires from the CNC section are often already bent. This indicates that part of the terminal tip arrangement defects originate upstream in the cutting and crimping process and are only detected in assembly; these defects require inspection at the source and feedback to the CNC section rather than retraining of assembly operators. In addition, certain connector types are more fragile and therefore require special handling in the production process.

Improve

The Improve stage proposes corrective actions for the causes of defects based on the 4M factors analyzed with the fishbone diagrams. The improvement actions are as follows.

a. **Man.** Production operators were retrained on the handling of connectors that frequently become defective, including ensuring that the wiring harness does not dangle and hit the floor when it is lifted. A self-check point was added before the terminal is inserted into the connector, so that operators confirm that the terminal is not bent and insert it perpendicularly.

b. **Machine.** Collisions between connectors and hard objects, such as the jig on the asbo, were prevented by installing protective pads on the asbo erector frame. Torn plastic aprons were replaced, and connector and terminal covers were added.

c. **Method.** New work standards were established for a harness rolling method that reduces the potential for damage to connectors and terminals, and lesson points on correct handling were added in the asbo area.

d. **Material.** Fragile connector types are given special handling, and the stock of connector and terminal material is limited to a maximum of 80% of its capacity to prevent damage caused by overfilling. This 80% limit is a practical threshold that still requires validation.

According to company records, these improvement activities were followed by a decrease in the percentage of defective products of 2.90%. Post-improvement daily data were not included in this study, so this figure could not be tested with a post-improvement p-chart or a two-proportion test and should be interpreted as indicative.

Control

The Control stage ensures that the changes made in the previous stages are maintained so that the goal of improving production quality is achieved. The steps taken at this stage are as follows.

(1) Retraining production operators and line leaders on the revised work processes and work standards, supported by lesson points in the asbo area. This also ensures that new operators understand the changes and do not make work errors that may cause defects.

(2) Conducting regular supervision of operator performance by the production supervisor, including checking daily production reports and monitoring operator compliance. Supervision is carried out every Friday, and if non-compliance is found, a short meeting is held to remind operators of the importance of working according to the standards.

(3) Performing regular maintenance of production equipment, complemented by daily maintenance checks, to ensure that there are no sharp areas on the asbo and no torn aprons in the production area. Any abnormality must be repaired immediately by the maintenance team.

(4) Providing a work difficulty sheet that operators can fill in when they encounter difficulties that affect production quality. The sheets are reported to the quality improvement team and used as a reference for further improvement, so that the company's quality targets can be achieved.

To make these steps measurable, the Control stage should be supported by a control plan that specifies, for each controlled characteristic, the metric (for example, the daily proportion of connector and terminal defects), the measurement method, the frequency, the person responsible, the target, and the reaction plan when a deviation occurs. The p-chart should be continued with control limits recalculated from post-improvement data, and weekly supervision can be complemented by daily layered process audits by team leaders and supervisors. For handling-related defects, error-proofing devices such as terminal protectors or connector jigs are recommended, because the effect of retraining alone tends to fade over time.

Managerial Implications

The findings show that the two prioritized defects at PT. XYZ originate largely from how work is organized and managed. All four root-cause groups relate to managerial levers: workforce competence and discipline, the condition and maintenance of work equipment, the clarity of work standards, and decisions on material handling and stock levels. Because the p-chart shows a process dominated by common causes with a sustained upward shift, quality improvement in labor-intensive assembly operations should be treated as a change to the work system that combines standardized work, structured training, routine supervision, preventive maintenance, and error-proofing, rather than as enforcement of discipline alone [33]. The DMAIC cycle provides managers with a disciplined sequence for converting production data into decisions, while the p-chart offers an early warning signal that a process requires intervention. These results are in line with other DMAIC studies in which operator training and pre-shift briefings were key to reducing defects and rework costs [14], and with wiring harness studies in which corrective actions targeting the root causes lowered defect rates [21], [22]. They differ from those studies in that part of the defects at PT. XYZ originate upstream in the CNC section, so improvement in assembly alone cannot remove them. In automotive painting, closer supervision of operators supported by a competency matrix also helped bring the defect rate below the company's target [17]. Involving operators through lesson points and work difficulty sheets reflects a collaborative approach in which the people closest to the process contribute to problem identification and continuous improvement, supported by supervisory coaching [29]. Because resource constraints are a major barrier to Lean Six Sigma in the automotive industry [23], and leadership involvement and training are among its critical success factors [24], management commitment to providing time, training, and maintenance resources is essential to sustain these results.

Limitations

This study has several limitations. It covers a single company, and the statistical analysis covers three months of production data. The daily defect proportions of the observed plant are considerably higher than the annual company-level rates, and the two sources could not be reconciled with the available data. The root causes were identified qualitatively and were not weighted with frequency data, and part of the terminal defects originate in the upstream CNC process, which was not analyzed. The effect of the improvement actions was reported as a decrease in the defect percentage and was not tested with post-improvement control charts, and no cost-of-quality data were available to justify the actions economically. Future studies could extend the observation period, compare control charts and sigma levels before and after improvement, stratify defects by line, shift, and source, and quantify the cost of poor quality.

Conclusion

This study shows that the annual defect rate of wiring harness production at PT. XYZ increased from 0.61% in 2022 to 0.95% in 2023. In the observed production plant, the baseline proportion defective between August and October 2023 was 7.6%, equivalent to a sigma level of about 2.9; no daily point fell outside the control limits, but the monthly proportion rose significantly, indicating a systemic upward shift in a process dominated by common causes. Connector housing breakage and terminal tip arrangement defects were the two most frequent and critical defect types. Their suspected causes were insufficient operator understanding of the work process, improper and rushed work methods, fragile and upstream-damaged materials and overfilled material stock, and equipment conditions that caused connectors to collide with unprotected parts of the assembly board. The improvement actions formulated through DMAIC, namely retraining production operators, adding protective pads to the equipment, limiting connector and terminal material stock to a maximum of 80%, and establishing new work standards for operator handling, were followed by a reported 2.90% decrease in the percentage of defective products, which still requires statistical verification. These results suggest that Six Sigma DMAIC can serve as a structured quality management approach that links statistical evidence with managerial decisions on people, equipment, methods, and materials in labor-intensive assembly operations.

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