IMPROVING A RAILWAY CONTROL TEST SYSTEM IN PAKISTAN

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ABSTRACT

The focus company is an international Rail Control Solution firm. It has a contract for providing a modern railway signaling system in Pakistan. Significant delays have prolonged the implementation and increased costs. One cause is the testing failure of the Controller Cabinet, and this research concentrates on that.

Six-Sigma methodology is used, with its five phases: define, measure, analyze, improve, and control. The five phases stimulate improvement in the work process, the project's deliverable performance, and quality assurance, which lead to project efficiency and cost effectiveness. The failure rate is reduced to the contract tolerance target. The implementation of these improvements could bring success to the firm's cabinet start-up test, and thus remove the delays and costs.

บทคัดย่อ

บริษัทในการศึกษานี้เป็นผู้จัดทำระบบควบคุมสัญญาณรถไฟ ซึ่งมีสัญญาจัดทำระบบที่ประเทศปากีสถาน เนื่องจากเกิดปัญหาความล่าช้าทำให้ต้องขยายเวลาดำเนินการและทำให้ต้นทุนเพิ่ม สาเหตุอย่างหนึ่งมาจากความผิดพลาดจากการทดสอบตู้ควบคุมสัญญาณ ซึ่งเป็นเป้าหมายในงานวิจัยชิ้นนี้ โดยการใช้วิธี six-sigma ซึ่งประกอบด้วย 5 ขั้นตอน กล่าวคือ กำหนดนิยาม วัด วิเคราะห์ ปรับปรุง และควบคุม ซึ่ง 5 ขั้นตอนนี้ช่วยกระตุ้นให้เกิดการปรับปรุงกระบวนการทำงาน รวมถึงความสามารถในการส่งมอบโครงการ และการประกันคุณภาพ ซึ่งนำไปสู่การเพิ่มประสิทธิภาพและประสิทธิผล

INTRODUCTION

The firm in this research is a manufacturer of trains and their control systems. Its railway section operates in 25 countries, providing trains, engines, operation services, transportation systems and rail control systems. The Thailand part of the firm's Rail Control Section is the focus of this study, and especially the performance of its contract to design,

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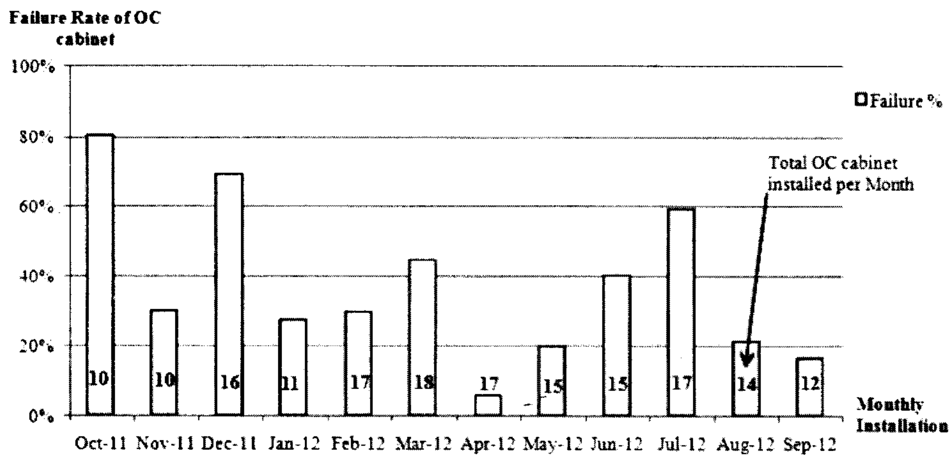
manufacture, supply, install and commission a modern signaling and safety control system in Pakistan, as part of a major modernization of a mainline route and its 31 stations, used by a range of trains from slow freight traffic to intercity high speed services.

The problem is that there have been many delays, which prolong the completion date for the whole line, and increase the firm's costs. The problem arises from the performance of a metal Signal Controller Cabinet, which contains an intricate assembly of electronic devices which communicate with other devices along the railway line. 172 of these expensive cabinets are placed along the line, in stations or trackside cubicles. They ensure safety along the line for level-crossings, tracks, and trains. The contract value for this system is over USD 30 million. Payments to the firm are staged and dependent on meeting timetable dates and quality criteria, especially for start-up tests of the cabinets in the installation stage. The failure rate of the start-up test is shown below (Figure 1).

Figure 1: Failure Rate of Cabinet Testing over One Year



Source: Data from the Test and Commissioning team

The number of cabinets failing the field test is 63 out of 172 cabinets, which is a failure rate of 37%, more than double the 15% tolerance specified in the contract. These failures resulted in Non-Conformity penal costs. Another 273 cabinets await assembly and installation.

The failure problem needs to be thoroughly examined to find a solution. The Six-Sigma method, a 'Lean' concept, is therefore considered as an appropriate tool for this, using its five core phases: Define, Measure, Analyze, Improve, and Control (known by its acronym of DMAIC).

REVIEW OF RELEVANT LITERATURE

Burton and Boeder (2003) described the 'Lean' concept for internalizing quality into a process, especially to eliminate waste and create a continuous flow of work with built-in continuous improvement. Six-Sigma is a Lean application tool, which through its DMAIC offshoot supports the analysis and identification of the critical aspects of a process and its activities. DMAIC also finds the root cause of a problem.

The DMAIC Application Tool

According to George, Rowlands, and Kastel (2004), DMAIC is the most effective tool-kit used by Lean six-sigma practitioners. It is a structured data-based problem solving tool for real problems. It has specific activities in a sequential manner for gathering data, which lead to decision making of solutions (Table 1).

Table 1: DMAIC Process Sequence

Processes	Steps Taken	Reasons	Tools
Define	- Select the product or process that requires improvement. - Collect relevant data. - Sort the data. - Create the as-is map to understand the situation.	- Develop team work and shared ideas. - Confirm opportunity. management/team agreement on the scope. - Agree to the project goal. - Improve the process.	- Financial Analysis - Project Chart - Process Improvement plans
Measure	- Identify the key factors that have the maximum effect on the process. - Collect further data and measure the extent of the effect.	- Confirm that the data is reliable and trustworthy. - Make a decision based on facts and reality. - Make documentation - Select key tasks to be improved.	- Data Collection - Plan - Process observation - Pareto charts - Time series plot - Histograms
Analyze	- Look for patterns in data. - Target areas.	- Find real cause - Improve process speed without harming quality. - Identify critical factors for control.	- Fishbone Analysis - Scatter Plots - Pareto Analysis
Improve	- Identify solution range. - Review existing best practices. - Set criteria for selecting solutions. - Pilot the project solution. - Implement	- Achieve lasting solutions. - Have solutions linked to real causes. - Justify the reason why the solutions are made. - Have everything based on reality	- Pick Chart - Kaizen - Four step rapid setup - Brainstorming - Benchmarking
Control	- Make documentation - Train - Tracking device - Hand-over responsibility	- Prevent back-sliding. - Be alert for future problems - Share experience. - Verify success and sustenance.	- Control charts - Standard Operating Procedures - PDCA cycle

Source: George et al. (2004: p.58-77)

Other Lean Tools

The tools used together with DMAIC are reviewed and defined as follows: Pareto analysis is a statistical tool, also known as the '80-20 Rule', in which within a given population of items, approximately 20 percent of items represent 80 percent of the total 'value', and vice-versa 'Value' may be defined in several ways such as money, usage, or popularity (Muller, 2003). The analysis is a simple systematic technique for prioritizing possible changes by identifying the problems that will be resolved by making these changes.

The Fishbone Analysis is another tool, which systematically sorts ideas into categories to identify potential causes of a problem, in a diagram resembling a fish skeleton. The head is the problem, and the bones show various causes. The categories of causes are generally: manpower, methods, machine, material, and environment, but there can be variations (Gano, 2007).

The 'Gauge Repeatability and Reproducibility' tool is part of Measurement Systems Analysis (MSA) which deals with the problem of measurement error, in projects which need precise measurement (Montgomery, 2005). It incorporates procedures which measure bias, reproducibility, and reliability (Foster, 2006). It places primary importance on test equipment, its consistency and stability.

Another tool used in this research is 'Failure Mode and Effect Analysis' (FMEA). It is used in operations management for analyzing potential failure modes with a classification of the probability and severity of failures. FMEA can identify potential failure based on past experience with similar products or processes (Ambekar, Edlabadkar, and Shrouty, 2013). Pantazopoulos and Tsinopoulos (2005) found FMEA to be a useful tool in reliable engineering for electrical and electronic components as well as in complicated assemblies.

The following Table provides a summary of the Six-sigma usefulness and experience, as captured by recent researchers (Table 2).

Table 2: Summary of Selected Literature

Researchers	Year	Techniques	Information in the research
Corbett	2011	Process Improvement	"**Lean Six Sigma: the contribution to business excellence**". The improvement of the operation and process for business excellence. Lean Six Sigma study shows that the concept is compatible in all business areas.
Jacobsen	2010	Process	"**Quality Revolution Reduces Defects, Drives Improvement sales Growth at 3M**". Data collection and Data analysis is the key for the improvement of the process. They improve the quality by precisely determining the root cause. The result of the study is the reduction of defects in the parts of their product.
Kumar and Sosnoski	2009	Process Improvement	"**Using DMAIC Six Sigma to systematically improve shop floor production quality and cost**". This case applied DMAIC to leverage its potential to realize cost savings and quality improvement. The study proves that the approach effectively improves process, products, profitability, and cost reduction.
Lo, Tsai and Hsien	2009	Quality improvement	"**Six Sigma approach to improve surface lenses in the injection molding process**". In order to control the quality of the production process of lenses, and Quality
			inspection, Six Sigma is applied to the processes. The approach fulfills customer satisfaction with time and condition.
Das, Roy and Antony	2007	Quality Improvement	"**An application of six sigma methodology to reduce lot to lot shade variation of linen fabric**". This study of the weaving industry examines color fading and its cost. Six Sigma solves the problem and reduces the cost.
Knowles, Johnson and Warwood	2004	Quality Improvement	"**Medicated sweet variability: A six sigma application at a UK food manufacturer**". This case applied the six sigma concept to medicated sweet production, with its problem of deviation of the sweet shape. The tool improves production and reduces cost.

Source: Author's compilation

RESEARCH METHODOLOGY

The research process in this study is data collection and analysis, followed by use of the DMAIC approach to solve the problem of the Cabinet start-up test failure. The primary data is the record report of the start-up tests for the cabinets gathered from the site (Figure 1 above showed the failure record). The data is analyzed. Interviews and brainstorming are also used, carried out by experts, with the project core team, the engineer, the product owner, the ITC team, and other necessary people. These key parties are interviewed in order to explore the root causes and the precise implementation of the following applications:

1) The Engineering team who design the Cabinet
2) The ITC team who supervise the assembly of the Cabinet and conduct the start-up test
3) The System integration test team who initiate and design the test and validate the test result
4) Other parties, such as the site manager responsible for installation and safety activities and for reporting all activities at the site, and the product owner who develops generic products, provides advice for dealing with problems, and validates the product design.

Five groups of documents are reviewed from the project experience:

1) **Product Specification Procedure:** Documents concerned with product specification of the system and Cabinet. These include: the overall specification, the product system and operation, product requirement management, product identification, and product design drawing.
2) **Installation Procedure:** Documents relevant to the installation and assembly procedure of the Cabinet, including method of installation, assembly and installation instruction, and wiring instruction.
3) **Test Procedure:** Documents included in all the test activity procedure of the Cabinet, which include the test description, test plan, and test instructions.
4) **Record Template:** Documents concerning the entire template of the record of the Cabinet installation, Cabinet test report, and other checklist sheets.
5) **Daily Report:** Documents reporting significant site activities or problems.

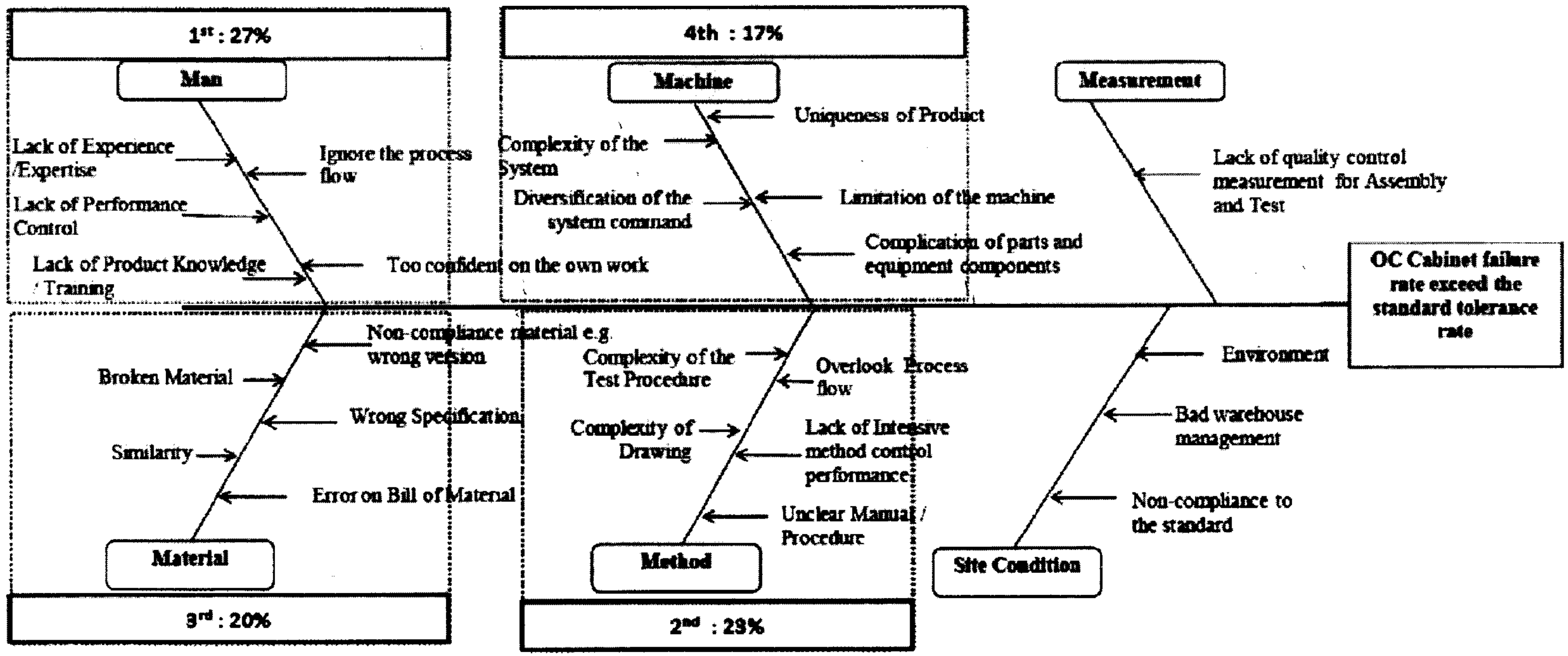
Cause and Effect Diagram of the Problem

This analysis is divided into six categories. A summary of the analysis is that out of a total of 100%, the cause allocation in descending order is:

Man 27%; Method 23%; Material 20%; Machine 17%;
Site Condition 9%; and Measurement 4%.

A summary of the possible causes and effects is shown in the following Fishbone Diagram (Figure 2).

Figure 2: Summary of the Possible Cause-Effect of 63 Cabinets Failing the Start-up Test



Source: Author, compiled from records and interviews

As a summary of the justification for using Six-sigma in this study, the statement by Gygi et al. (2005) is presented here. They stated that Six-sigma is the single most effective problem-solving methodology for improving business and organizational performance, and claimed that there is not a business, technical, or process challenge that cannot be improved by Six-Sigma. So, the DMAIC model is applied here, in its five phases: Define, Measure, Analyze, Improve, Control. The key phase is possibly 'Measure' - the current test system, its criteria and accuracy,

PRESENTATION AND DISCUSSION OF RESULTS

The contract is split into five main stages of progress. The material payment milestones account for 70% of the contract price, of which the Cabinet and its system is the major part. This has a significant effect on the firm's cash flow. The Cabinet needs to pass the basic test in the installation phase. Then, the more complex sub-system test can start. Therefore, initial failure has consequential effects on other tests and delays the project test schedule and later stages.

The DMAIC Define Stage

Three process flowcharts are involved in analyzing and solving the problem at the 'Define' stage. The Design Drawing Flowchart: each Cabinet drawing has to be officially approved by the customer before assembly. Each Cabinet is unique, having its own special features and function. This flowchart was important in the root cause analysis. It was found that complexity of the design, revision of the drawings, and omission of some minor components in the drawings, contributed to the test failure.

The Installation & Assembly Process Flowchart includes the start-up test, so was crucial to the root cause analysis of failure. The findings were that the complexity of the design, the poor handling of resources, and the omission of some steps, resulted in the failure of the cabinet start-up test.

In the Test Process Flowchart, every detail has to be recorded. The test process was important in the root cause analysis. It was found that the complexity of the test description, the poor handling of resources, and the omission of some steps, resulted in the test failures.

The Measure Phase

This Phase analyzes the precision of the test specification and the measurement tools. The findings confirm that in this phase the testers meet the standard for reliability. The result of the GR & R tool shows that Percentage of Repeatability, Percentage of Accuracy, Percentage of Overall Repeatability and Reproducibility, Percentage of Overall

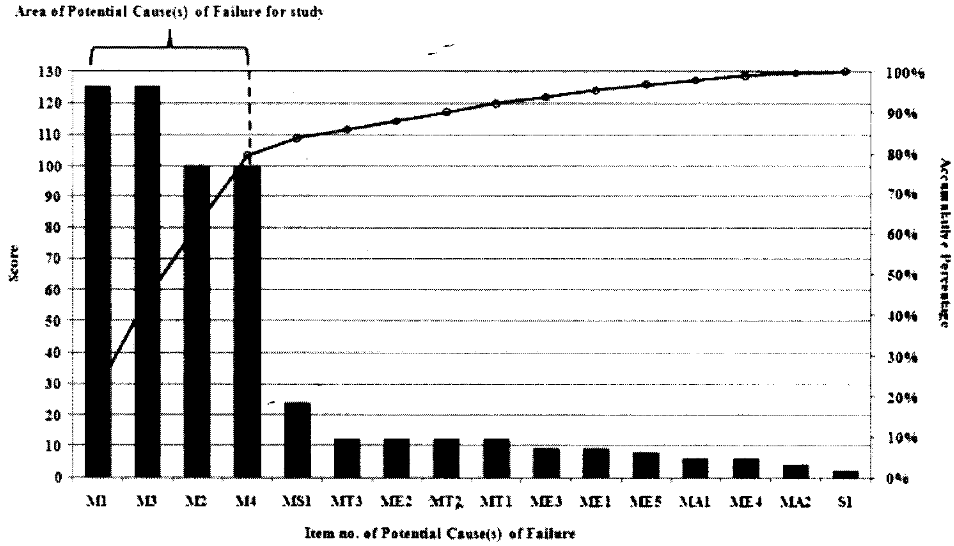
Repeatability and Reproducibility & Accuracy are all 100% guaranteed. Therefore, the measurement tools used are acceptable.

Analyze Phase

The root cause analysis used six categories, but the focus is on four: Method, Man, Material, and Machine as these accounted for 87% of the root causes. The cause and effect matrix, FMEA and Pareto analysis are used. The findings are that the Assembly and Installation processes are critical to the problem.

FMEA measures the Risk Priority Number (RPN) of each factor, the failure level of the failure, from 1 (low) to 5 (high). Pareto Analysis arranged the ranking of the analyzed RPN value of Failure Mode and Effect Analysis for the potential causes of failure, as in Figure 3.

Figure 3: Pareto Analysis of Ranked RPN and Potential Causes of Failure



Source: Author, compiled from company records

Findings from the FMEA revealed 4 critical causes concerned with 'Man', especially the deficiencies in human skill. The employees urgently need more training, for work effectiveness, resource allocation, and performance monitoring.

Improve Phase

The finding was that a root cause was human skill, especially in the Installation and Assembly and Test process. The process, procedure, and documentation need to be reviewed and revised to improve the work organisation and operation in this significant area. Performance evaluation has to be clearly specified. Skill improvement training should focus on the Cabinet installation and assembly and test areas. Lack of resource is a critical issue, so a project manager should plan resource utilization for each function following the work plan. Turnover and utilization also cause lack of resources

Result expected after the improvement

Following the solutions suggested by the team, all the processes, procedures, and documentation involved are reviewed and revised. Training courses enhance learning.

For resource management and performance evaluation, the project manager and line manager will review resource allocation. Performance monitoring is needed to ensure the quality of work to create performance improvement and the standard of self-measurement. Following the improvements, the firm expects to improve the success rate for Cabinet start-up tests.

Control Phase

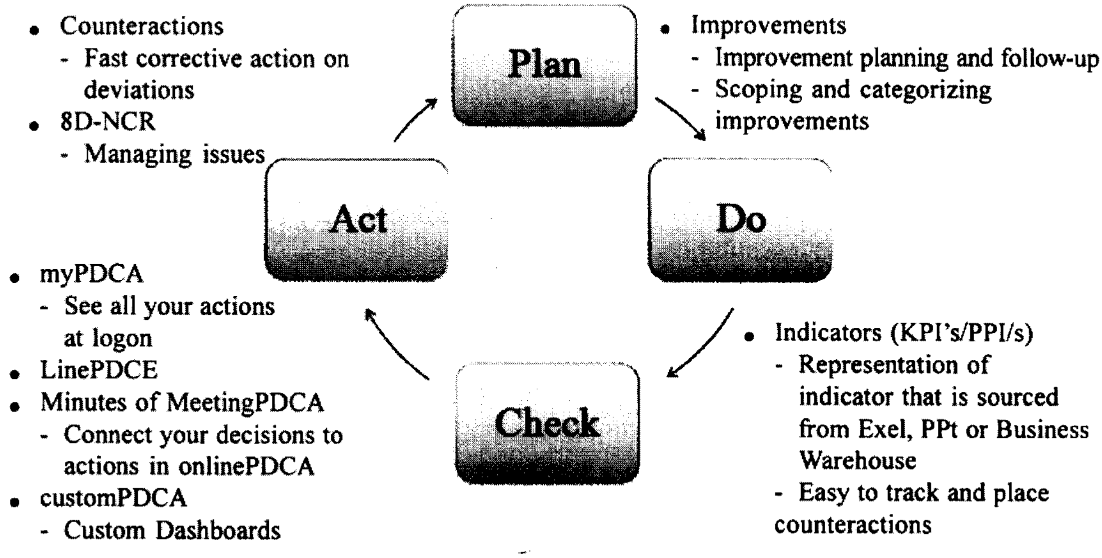
The Control Phase is the development and implementation of the best controls for sustainable and continuous improvement. PDCA (Plan-Do-Check-Action) will be applied as a tracking or a controlling tool for activities in all areas.

In the firm, PDCA is used online. This online PDCA is a Business Management System for planning, tracking and reporting business improvement plans and performances which are appropriate for personal usage, functional usage, and project usage. For the Pakistan project, the KPIs (Key Performance Indicators) of the project and the critical tasks can be tracked, controlled and amended online In addition, this tool can be viewed and shared across the project in order to promote project knowledge management.

In Figure 4, PDCA provides an overview of what is going on and what is to come in the next week for a particular task. It is used to visualize improvements, deliverables, indicators, and counteractions for a coming week. It can produce a customized view of a selected item. It is used when working with specific types of reporting like the Reporting Division at the level of KPIs to top management. It is useful in helpings to plan and conduct a meeting, and for taking notes and minutes directly from online PDCA.

PDCA states problems and goals of a project. It is used when necessary to visualize the problem, goal, target metric, target and savings. A project is broken into small steps related to important milestones. Counteraction helps to get a performance back on track or generally improve it. It is used when something has to be done but is not originally in the plan. It is used to measure a condition and visualize values and changes over time, or to compare and visualize different data over time. Its database provides multi-notification when the target date is due, so all the activity monitored via this tool is needed to set the deadline and the result expected in order to effectively track and evaluate achievement. Performance appraisal can be created by a manager to monitor and evaluate and

Figure 4: Business Management with Online PDCA



Source: the focus firm

sustain best practice. Knowledge sharing across the projects is also promoted through this tool.

To summarise, the DMAIC approach was used systematically solve a failure problem. In the Define Phase, the scope of the specific problem was clarified. The Measure Phase helped to confirm that the data is reliable and trustworthy, by using evaluating tools with the GR & R application. The Analyze Phase was used to dig down to the root cause of the problem, using tools like Fishbone, Pareto Analysis, FMEA and RPN. It found four main causes of the 'Man' factor. These were transformed in the Improve Phase, where solutions were brainstormed by the experts, including knowledge training, human resource management, and performance evaluation. In the Control phase, online PDCA was recommended to monitor and take corrective action and to create sustained improvement through sharing best practice across projects. The implementation of these improvements could bring success to the firm's cabinet start-up test, and thus remove the delays and costs.

SUMMARY AND CONCLUSIONS

This study presents an application of the DMAIC approach to improving the success rate of a Thai firm's Cabinet start-up tests on a main-railway line in Pakistan. Following the recommended improvements, the firm expects to improve its Pakistan project in both deliverable performance and cost effectiveness.

Early Findings show that XYZ project has a 37% failure on the Cabinet star-up test, for 63 Cabinets out of 172, a higher failure rate than the tolerance standard of 15%, causing schedule delays, having to repeat the work and tests, and paying non-conformity penalties. This affected the project's cash flow, and dissatisfied customers. This study identified the root causes of the problem concerned and went on to find the best solution.

Following implementation, the firm will be able to improve the signaling system resulting in the improvement of the project schedule, the reduction of the project's non-conformity cost, compliance with the contract conditions, and customer satisfaction. Moreover, the teamwork together with the improvement on the decision making and the problem-solving by the enhancement of the strategy can create continuous improvement within the organization. Other project teams can adapt this solution in solving other problems.

There are some difficulties predicted for the implementation of the study. To sustain improvement, the project team needs to maintain the best practice and make sure that all the corrective actions are continuously improved. The team should help each other to ensure that the corrective actions is appropriately implemented, otherwise the activity will be useless.

This study of the DMAIC approach provides an opportunity for further execution to prevent recurrent loss in the future. The study of the problems in this project can be an example for further usage and project operation in the future.

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