Journal of Safety Studies
ISSN 2377-3219
2016, Vol. 2, No. 2

Lean Six-Sigma in Aviation Safety: An implementation guide for measuring aviation system's safety performance

Ilias Panagopoulos*, Chris Atkin, Ivan Sikora,
City University London,
Northampton Square, London EC1V 0HB, United Kingdom
Tel: +44-79315-70582
Email: ilias.panagopoulos.1@city.ac.uk

Abstract

The paper introduces a conceptual framework that could improve the safety performance measurement process and ultimately the aviation system safety performance. The framework provides an implementation guide on how organisations could design and develop a proactive, measurement tool for assessing and measuring the Acceptable Level of Safety Performance (ALoSP) at sigma (σ) level, a statistical measurement unit. In fact, the methodology adapts and combines quality management tools, a leading indicators programme and Lean-Six Sigma methodology to formally measure and continuously improve a stable and in-control safety management process by reducing safety defects and variability from core organisational processes and objectives. The implementation guide was empirically tested and validated with data collected and analysed within a period of nine (9) months by the safety department of a complex aviation organisation operating a large transport aircraft fleet.

Keywords: Aviation Safety; Lean Six-Sigma; Measuring Performance

1. Introduction

According to the International Civil Aviation Organization (ICAO) Annex 19 (2013), '*safety is the state in which risks associated with aviation activities are reduced and controlled to an acceptable level'*. Indeed, safety is a system quality stemming from a legal and regulatory framework that stipulates strict and high performance targets as well as a number of activities that must be performed by air operators. According to ICAO Annex 19 each service provider shall, as a minimum:

- Provide continuing monitoring and regular assessment of safety performance
- Ensure remedial action to maintain agreed performance.
- Aim at a continuous performance improvement

At European level, the European Aviation Safety Agency (EASA, 2014), in parallel to management system requirements, outlined its new harmonised approach for establishing a Performance-Based Environment by introducing a clear set of indicators and targets against which the oversight performance of civil aviation authorities is assessed. However, ICAO and EASA do not provide a clear guidance on how stakeholders could proactively measure safety performance. Besides, in aviation industry there is a level of uncertainty as to what extent existing methodologies for measuring performance are suitable for those operators who have already achieved excellent safety records and in-control processes and as such look for further improvements.

1.1. Key Research Questions

Safety performance is the State's or the service provider's safety achievement as defined by its Safety Performance Indicators and Safety Performance Targets (ICAO, 2013). Consequently, this study explores and further investigates the following key research questions:

(1) What methodology could proactively measure system safety performance and improve the safety performance measurement process?

(2) Could a conceptual framework assist the continuous improvement of the safety performance measuring process?

1.1. Aim

For addressing the key research questions, the paper aims to present a conceptual framework that will improve the safety performance measurement process and the aviation system safety performance. Fig. 1 presents the framework, where the Safety-Performance Indicator Lean Sigma (Safety-PILS) model has been embedded within Define –Measure- Analyse-Improve and Control (DMAIC) continuous improvement process.

This integration results in a continuous improvement framework that measures system safety performance and reduces the safety process variability. In addition, the study provides an implementation guide on how air operators could use this framework to design and develop a proactive, performance-based methodology for measuring Acceptable Levels of Safety Performance (ALoSP) at sigma (σ) level, a statistical measurement unit.

Journal of Safety Studies
ISSN 2377-3219
2016, Vol. 2, No. 2

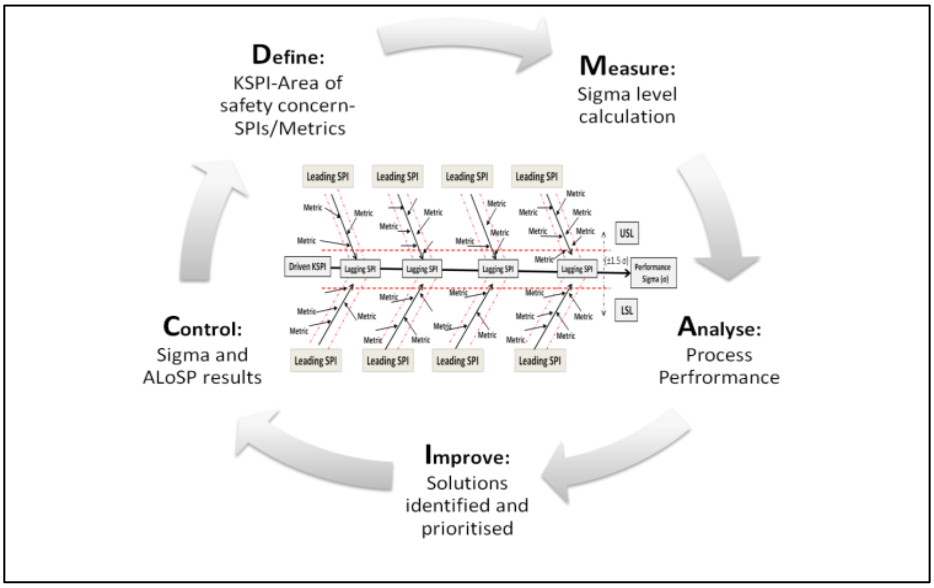

Figure 1. The researcher’s conceptual framework

2. Measuring Safety Performance

An effective performance measurement system should monitor past performance and help to plan desired future performance (Gutierrez et al., 2014). According to Muller (2014), one of the main Safety Management System (SMS) objectives is to measure system effectiveness, improving safety performance and therefore reducing exposure to the risk of having an accident or serious incident. Since most accidents have multiple precursors and cues that an accident is likely to happen, there is a common belief that even a small number of general ‘leading indicators’ can identify increased risk of an imminent accident (Leveson, 2015). Besides, Leveson (2015) discusses how to operationalise leading indicators as shaping and warning signals and through the Systems-Theoretic Accident Model (STAMP) proposes assumptions and their vulnerabilities as a proactive methodology for identifying leading indicators in an aviation system.

Furthermore, Podgorski (2015) suggests that new approaches and methods are needed to ensure management system effectiveness and he proposes a method for ranking and prioritising proactive safety performance indicators related to occupational health and safety based on the utilisation of a certain set of Specific, Measurable, Attainable, Relevant and Timely (SMART) criteria. In addition, Andriulo (2014) proposes a lean safety framework for measuring the effectiveness of a near-miss management system in the automotive industry. Also, Ulfvengren (2014) argues that Lean methodology by integrating quality management with existing management processes would achieve operational effectiveness and could demonstrate safety performance in compliance with new aviation safety regulations. Besides, Verstneten et al (2014) introduced a framework of SPIs for the aviation industry and concluded that unless a process for continuous safety monitoring is in place, the system of SPIs only provides a snapshot view of safety.

In the aviation industry, EASA has recently established the Network of Analysts (NoA) SPI

Sub Group for considering the subject of SPIs (EASp, 2014). Moreover, a Safety Management International Collaboration Group (SM-ICG) was created in February 2009 as a joint activity between key aviation authorities to encourage progress and harmonisation. Although various guidelines have been developed, measuring performance from SPIs will require some time for air operators to determine how SPIs represent safety performance (Roelen, 2012). Also, Karanikas (2016) argues that aviation authorities have not clearly defined the different meanings between 'system effectiveness' and 'effective operation of a system':the former regards the effects of the system on the organisation whereas the latter refers to how much satisfactory a system is operated.

To sum up, in aviation industry the measurement process of a set of pre-defined indicators for measuring system's safety performance has not yet been introduced or standarised. In addition, the development and measurement of proper SPIs is not straightforward and the operational experience for measuring the effectiveness of SMS is very limited, since *'there are many questions yet to be answered on measuring safety performance'* (Roelen, 2012). Consequently, the main challenge remains how to control and maintain performance within agreed safety specification limits and how to develop an objective methodology that will proactively investigate and measure system performance variability (±σ) from target.

3. Lean Six-Sigma for measuring safety performance

Lean-Six Sigma (L6S) has been applied in the manufacturing and healthcare industry since 1990 (Mason, 2015) and is considered as the integration of two management philosophies, Lean and Six Sigma, and has been seen as a robust improvement methodology (Tenera, 2014). According to Harmon (2014), Lean focuses on improving the flow of activities and Six-Sigma focuses on improving the quality and consistency of process outputs. Ulfvengren (2014) in an effort to develop a Safe-Lean concept for an airline that integrates Lean with SMS structures and processes and demonstrates safety performance concluded that, '*what can be really monitored is the normal variation of performance data*.' Nevertheless, this research study argues that Lean itself cannot bring any safety measurement process under statistical control.

Therefore, many organisations, such as Motorola, Samsung, Sony and Honeywell are using six-sigma (6σ) for enhancing safety and as a continuous improvement management tool (Rehman, 2012). Six-Sigma is a statistical measure of excellence in process performance wherein process tolerance corresponds to 6σ with a maximum of 3.4 Defects Per Million Opportunities (DPMO). Consequently, a process performing at 7σ corresponds to 0.019 DPMO, an outcome that may satisfy most aviation safety departments. Besides, Harmon (2014) argues that six-sigma is a good methodology for understanding the measuring process and the use of statistical techniques to analyse the outcomes.

4. The Conceptual framework

The conceptual framework for measuring safety performance composed of the Safety-PILS model embedded within the DMAIC continuous improvement process. The next sections of this chapter are presenting this combined effort along with a practical implementation step guide for measuring system safety performance.

Journal of Safety Studies
ISSN 2377-3219
2016, Vol. 2, No. 2

4.1 The Safety –PILS model

The Safety-PILS model provides guidance on how organisations could design, implement and use a proactive, performance-based measurement tool for assessing and measuring ALoSP. For the purposes of this study, safety performance is measured at sigma (σ) level.

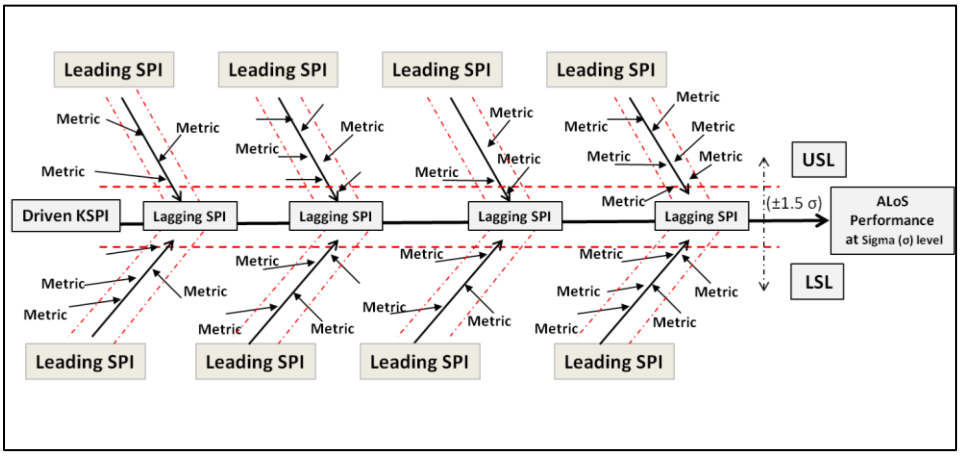

Figure 2. Illustration of the Safety-PILS model, inspired from Ishikawa (1968)

Nevertheless, the Safety-PILS model shown in Fig. 2 provides a holistic view on how organisations could set leading performance indicators and monitor metrics[1] on the top of identified root-causes that affect safety performance or how to set lagging indicators and feedback metrics on the top of safety outcomes (occurrences - effects). In fact, the above model adapts and combines quality management tools, a leading indicators programme and L6S methodology to continuously improve a stable and in-control safety management process. In particular, an Ishikawa-fishbone (Ishikawa, 1968) root-cause and effect diagram is used for establishing leading and lagging performance indicators in an aviation system aiming at within ±1.5 sigma (σ) tolerable safety limits.

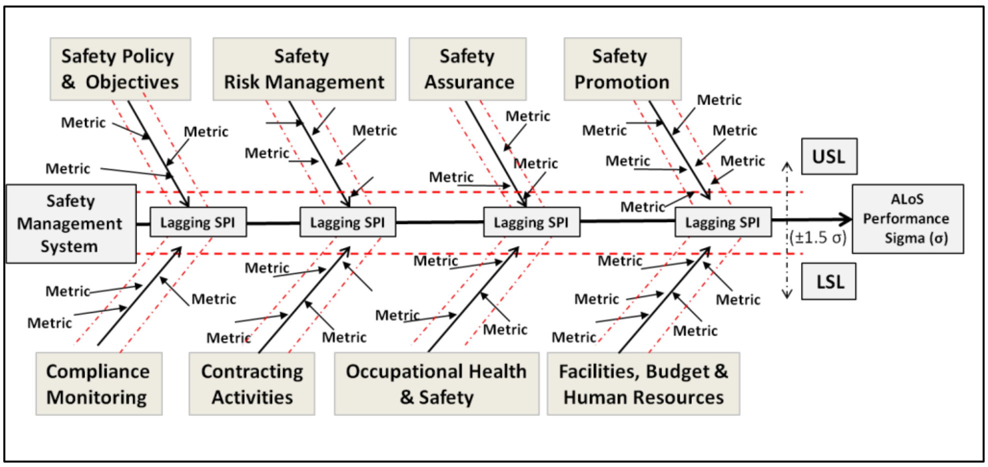

Figure 3. The safety management system performance

[1] The Organisation for Economic Co-operation and Development define metric *'as a system of measurement used to quantify SPIs or how the SPI is being measured'*(OECD,2008)

Nevertheless, the Safety-PILS model aims to control and maintain safety performance within agreed Upper or Lower Specification Limits (i.e. USL, LSL) and to develop an objective methodology that will proactively investigate and measure system performance variability within ±1.5 sigma (σ) from an ALoSP target. In addition, Fig. 3 shows how the overall performance of an integrated safety management system implemented within an aviation organisation could be affected by its components. The intricate relationship during operation of all these components eventually results in the overall safety performance for the organisation's management system, usually captured by indicators relating to safety occurrences. In fact, the core advantage of the Safety-PILS model is that applies the Central Limit Theorem; since it repeatable uses a large size of data and means, the distribution of the sample means will finally approach a normal distribution.

4.2. *The DMAIC process*

Safety-PILS model assists operators to comprehend and design their safety system in accordance with the agreed safety performance targets and specification limits. Accordingly, the next step for the operator is to follow the DMAIC for continuously improving the overall system's safety performance measurement process. Through DMAIC process, the operator could apply L6S methodology for measuring both the performance of each established indicator and system safety performance variability at sigma level from core safety objectives. However, the sequence of DMAIC steps and the times could vary widely, according to the size, the type and the complexity of the project. Since safety measurement is a 'data-driven process', operators should mainly examine whether the data are normalised, the process is in statistical process control and capable to achieve the desired outcome. Indeed, DMAIC is a useful methodology that could assist operators to accomplish this task.

In general, the 'Define' phase rolls out the tools such as the Voice Of the Business (VOB) and project charter which identifies pre-actions in the measurement process. Also, correlation and multiple regression identifies the condition of optimality on root causes and effects in the pre-action process. The 'Measure' phase reveals the continuous assessment of measurement process, with intense brainstorming sessions on the imperative responses. In 'Analyse' phase, the vital root causes that impact the responses are identified. The 'Improve' phase concentrates on optimising the vital root causes which impact the responses by implementing potential solutions. In 'Control' phase, the confirmation run is conducted with optimality conditions and the results are obtained at sigma level. In addition, process variation is eliminated by framing a plan to control the variation within acceptable levels (Srinivasana, 2014).

4.3. Measuring system's safety performance: Implementation guide.

Table 1 shows the implementation step-guide for measuring aviation system's safety performance. The implementation guide is divided in two phases, Phase-I and Phase-II. Phase-I is mainly the utilisation of the Safety-PILS model and Phase-II the practical implementation of the DMAIC process. Both phases are forming the conceptual framework.

Macrothink Institute™

Journal of Safety Studies
ISSN 2377-3219
2016, Vol. 2, No. 2

Table 1. Implementation step guide for measuring system’s safety performance

Phase-I: Safety-PILS model utilisation		
1.	Design Safety-PILS model for VOB	
	-	Define the driven KPI for the VOB
	-	Set the VOB Targets and the LSL-USL based on industry standards
	-	Set SPIs on the VOB- Critical to Safety (CTS) characteristics
	-	Set metrics on each VOB SPI and the associated LSL-USL
2.	Correlation and Multiple Regression Analysis (or Pareto Analysis)	
	-	Identify correlation between cause/effect
Phase-II: Apply Six Sigma-DMAIC methodology		
3.	Data Collection Planning (DCP) for Hypotheses tests	
	-	Hypothesis Testing – Data Normalisation
4.	Control Chart selection - road map	
	-	Control Chart selection for each VOB SPI and Metric
	-	Identify special causes: If none the process is In-Control
5.	Measurement System Analysis (MSA)	
	-	Where does the variation of data comes from?
	-	Is the process Accurate and Precise?
6.	Process Capability	
	-	Is the process capable (i.e. efficient)?
	-	At what sigma level?
7.	Analyse the data	
	-	Identify root cause and attractive areas for improvement
	-	Identify best and feasible solutions
8.	Pilot solutions	
	-	Demonstrate that piloted solution provides a Return of Investment (ROI)
9.	Define Control Plan and Roll-out improvement	
	-	Monitor the Control Plan to sustain the change
10.	Measure total system safety performance	
	-	Voice of the safety Process (VOP)= VOB

5. Phase I: Design Safety-PILS model for VOB

Key terms and concepts in Lean are the Voice of the Customer (VOC) and the Voice of the Business (VOB). VOC reflects the customer needs and the customer perceptions of operator’s products and services, whereas VOB usually refers to what an enterprise strives to achieve, such as key organisational targets and objectives. Since both VOC and VOB identify improvement opportunities and consume outputs from a process, they need to be in harmony (Arafeh, 2015).

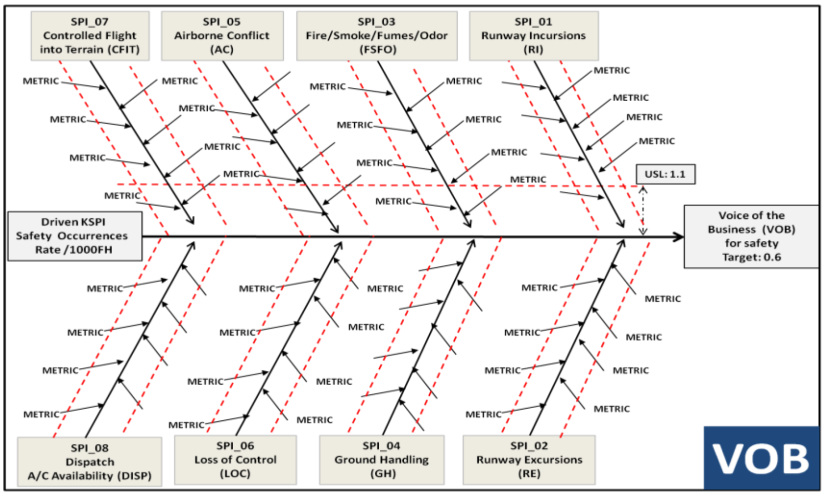

Figure 4. The Voice of the Business (VOB) for aviation safety

Fig. 4 shows how the safety department of a complex air operator utilised the Safety-PILS model for designing the Voice of the Business (VOB) related to flight safety. The driven KSPI has a clear organisational target and USL, meaning to achieve a Safety Occurrence rate/1000 Flying Hours (FH) of 0.6 and not exceeding the rate of 1.1 by the end of 2016. Moreover, all leading and lagging SPIs are normally drawn with their associated specification limits and a clear target. Finally, each SPI consists of a set of monitor and feedback metrics and, each metric should perform within specification limits for achieving its target.

SPI_02: Runway excursions (RE)	SPI_06: Loss of Control (LOC)
Metric 02.1: Deep Landing events	**Metric 06.1:** Stick-shake and alpha floor events
Metric 02.2: Unstable-De-stabilized approaches (all)	**Metric 06.2:** Take off Configuration warnings
Metric 02.3: Unstable-De-stabilized approaches (all) continued for landing	**Metric 06.3:** Low speed during cruise events
Metric 02.4: High speed touchdown events	**Metric 06.4:** Low speed during approach events
Metric 02.5: High speed rejected take-off events	**Metric 06.5:** Percentage of pilot's readiness rate for proficiency
Metric 02.6: Take-off landing events due to contaminated runway surface	**Metric 06.6:** Pilot's utilisation effectiveness
Metric 02.7: Runway and Overrun events due to runway contamination	**Metric 06.7:** Percentage of pilots received upset recovery training
Metric 02.8: Proportion of aerodromes using new reporting criteria for runway surface condition	**Metric 06.8:** % of qualified and current pilot's availability rate

Figure 5. VOB: Indicative Safety Performance Indicators (SPI) & associated Metrics

As an indicative example, Fig. 5 shows two indicators, the SPI_02: Runway excursions (RE) and SPI_06: Loss of Control (LOC) with their associated metrics. In particular, SPI_02 and SPI_06 with the metrics 'Unstable-De-stabilised approaches (all)' and 'Take-off configuration warnings events' have been selected as a research sample for further explaining and validating the conceptual framework implementation guide. The VOB indicators have been selected based on the Pareto Analysis results, past experience and literature review. Also, the study examined the correlation exist among VOB indicators and revealed a moderate to strong correlation, since all examined Pearson's coefficient (R) values were ranging from 0.6-0.8. Finally, the regression analysis revealed that 'Unstable - De-stabilised approaches' is the metric that accounts the most for the variation in the VOB process output.

6. Phase II: Apply Six Sigma DMAIC methodology

Phase II starts with the Data Collection Planning (DCP), the hypothesis testing and control chart selection. During DCP the Safety Office had to decide on what type of data is most appropriate to collect for measuring the VOB SPIs and metrics, what resolution is needed, what statistical tool should be used to interpret the data and what the sample size and frequency should be. For the purpose of this study the VOB sample size was 2.0 and the sampling frequency for collecting data was twice a month. The subgroup size for the VOB was identified as 1.0. The type of the safety data was quantitative-discrete, collected within a period of 6 months, meaning Jan 2016 – Jun 2016, and analysed with Minitab 17 software during Jul-Sep 2016. In addition, the hypothesis summary report of Paired t-tests, STDV and Anderson Darling (AD) normality tests revealed that the data initially followed the normal distribution curve and there was no special cause for any detected variation that needed further investigation (i.e. value $P>0.05$).

Next, the appropriate Statistical Process Control (SPC) Charts for understanding the performance of the examined indicators have been selected. Since, a single chart may not allows the operator to model a process in a way that gives the needed understanding, the safety office implemented multiple charts drawing from the same set of data. The Xbar chart plotted the mean and examined no special causes of variation (i.e. no points outside control limits), meaning that the process was 'in control'. The Moving Range (MR) chart indicated that the average was moving downwards and the R chart plotted the sample range, meaning the extreme max-min values of each examined subgroup. Finally, the control charts and in particular MR charts were considered as effective since the data were normally distributed.

During Measurement System Analysis (MSA) the Gauge R&R–Analysis of Variance (ANOVA) reports revealed that 7.32% of the total variation reported was caused by the gauge. Since this number was lower than 10% was considered acceptable. Also, Part-to-Part variation was 0.38651 which was big enough and therefore, good for the measurement system. The 'Data by operator' graphs revealed the variance recorded for each metric. Although some variation was still apparent, the metrics were measured consistently with each other. Finally, the 'Part operator interaction' graph revealed that the line for each metric followed about same pattern and the averages varied enough that differences were clear, which was also reasonable. To this end, it appeared that the measurement system was adequate for the operator's needs.

One of the next critical steps of Phase II was the Process Capability analysis. Process capability could assist the operator to understand if the measurement process of a particular SPI or metric is capable or efficient (i.e. the process fits within USL/LSL). Besides, to determine the sigma level the particular indicator performs. The analysis revealed that $C_p > C_{pk}$ meaning that the potential process of both metrics was centered. In addition, the C_{pk} was less than 1, meaning that not only a special cause but also a common cause of variation was going to produce unacceptable variation (i.e. defects). C_p=0.17 means that only 17% of the process fit within USL/LSL and C_{pk}=-0.08 means the process was 80% over one specification limit. The control charts revealed that there was no special cause of variation, meaning that this process was in-control. However, neither the actual process nor the potential was capable. At this point the operator had to apply solutions or to take mitigation measures such as, improving oversight through Flight Data Monitoring (FDM), improving the Standard and Operating Procedures (SOPs) related to unstable approaches or take-off configuration warnings, increasing Flight Crew awareness and enhancing Flight Simulator training requirements.

During study period, several intermediate process performance reports of the 'VOB before' implementing solutions took place for re-evaluating the actual and potential capability of the process. In one report, it appeared that the actual capability was still poor with 21.74% of the process being out of specification limits with 217391 DPMO. Nevertheless, the process remained centered since $C_p > C_{pk}$, thus, the most cost effective way to reduce variation was to discover and then eliminate (or reduce) any special causes might appear in the follow-up measurement phase. In fact, the overall actual process appeared to perform between 2-3 sigma level performance (i.e. including 1.5 sigma shift). In addition, by implementing the proposed solutions the potential of the process was to improve since only 1.34% of the process could probably remain outside the specification limits with an expected number of DPMO=13391.

Consequently, the new (i.e. potential) process could perform between 3-4 sigma level performance after implementing solutions, meaning that solutions could achieve 1 sigma process performance improvement comparing to the actual performance. Therefore, the operator proceeded by implementing the proposed solutions. Also, the diagnostic report of the 'VOB before' implementing solutions verified that data were continuing to follow a normal distribution since P value=0.448. Therefore the operator could conclude that the abovementioned C_{pk} results were valid. Besides, in one case the the Xbar-R chart showed four special causes for the existing variation. In fact, the existence of a special cause is not necessary a problem since it can add to or detract from the total process variation.

The process performance report of the VOB that was received right 'after' implementing solutions, re-evaluated the actual and potential capability of the process. It appeared that the actual capability was initially improving, the process was remaining centered and the data were continuing to follow a normal distribution. Besides, the Xbar-R chart showed none special causes for the existing variation.

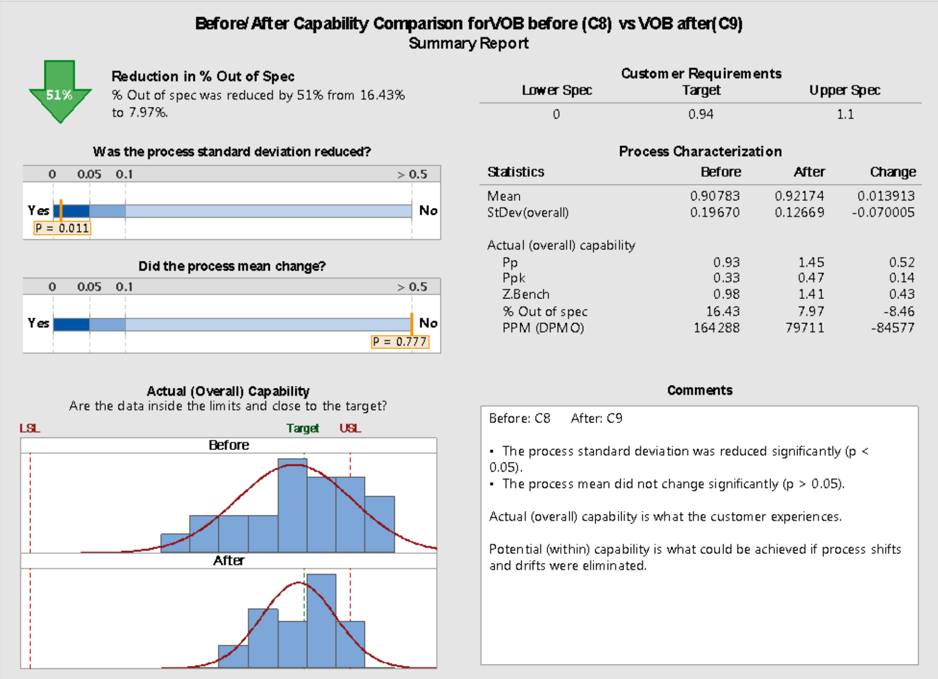

Figure 6. Summary report - capability comparison for VOB before and after.

To conclude with, Fig. 6 shows the final summary report that illustrates the capability comparison for VOB 'before' and 'after' the implementation of solutions, as follows:

- The percentage out of the specification limits has been significantly reduced by 51%, meaning from 16.43% before to 7.97%.
- The STDV (i.e. variation) was significantly reduced by 7%.
- The actual process performance has been increased by 0.52%
- The sigma level has been increased by 43%,
- The DPMO have been reduced by -84577.
- The actual sigma performance was 1.41+1.5 sigma shift which equals to 2.91 sigma level performance.

7. Findings and Recommendations

By the end of Sep 2016 the VOB (i.e. occurrences rate) continued to improve meaning that the percent defective was 0.68% and the percentage yield or acceptance rate was 99.32%. These results indicated that the total system's safety effectiveness was approaching 4 sigma level performance with the potential to have 6210 DPMO (i.e. safety occurrences per one million flying hours). Nevertheless, the study had few limitations. Consequently, the paper recommends the application of the conceptual framework to different settings, different sample and type of SPIs/metrics and the qualitative validation of the results by interviewing Subject Matter Experts (SMEs). As further research the study recommends the application of Genetics Algorithms and Simulation to the implementation guide. In this case, a metaheuristic procedure could sample a set of solutions and select or generate an algorithm that provides a sufficiently good solution to this safety performance optimization problem.

8. Conclusions

In the aviation industry, the process for developing SPIs, measuring safety data and analysing safety performance is neither clear nor yet standarised. The study introduced an integrated, empirical tested conceptual framework that may satisfy Authorities' requirements for establishing a performance-based approach in aviation safety. Furthermore, the study identified and filled the gap existing in the literature and proposed an implementation guide for measuring aviation system safety performance. In particular, the paper introduced the Safety-PILS model that integrates with the DMAIC continuous improvement process. This integration develops a meaningful methodology for measuring performance, though with limitations. The study revealed that the application of L6S methodology can enhance the measuring process. To this end, the proposed guide is a new way of thinking for designing a safety case aims to achieve desired outcomes within agreed specifications limits.

References (APA style)

Andriulo S. & Gnoni M. (2014). Measuring the effectiveness of a near-miss management system: An application in an automotive firm supplier. *Reliability Engineering and System Safety, 132, 154–162.* http://dx.doi.org/10.1016/j.ress.2014.07.022

Arafeh M., (2015). Combining Lean Concepts & Tools with the DMAIC Framework to Improve Processes and Reduce Waste. *American Journal of Operations Research, 5*, 209-221. http://file.scirp.org/pdf/AJOR_2015052614530905.pdf

EASA, (2014). A Harmonised European Approach to a Performance Based Environment (PBE). [Online] Available: https://www.easa.europa.eu/document-library (16 Sep, 2016)

EASp, (2014). European Aviation Safety Plan 2014-2017, [Online] Available: https://www.easa.europa.eu (12 Sep, 2016)

Gutierrez D. M., et al (2014). Evolution of the performance measurement system in the Logistics Department of a broadcasting company: An action research. *International Journal of Production Economics, 160*, 1–12. http://isiarticles.com/ bundles/Article/pre/pdf/41092.pdf

Harmon P. (2014). *Business Process Change*. (3rd ed.). Elsevier (Chapters 5 and 12). Measuring Process Performance, 109-129 and Incremental Improvement with Lean and Six Sigma, 293-325. http://www.sciencedirect.com/science/book/9780128003879.

ICAO (2013). Annex 19. [Online] Available: file:///C:/DocumentsandSettings/Administrator/MyDocuments/Downloads/sms-annex19.pdf (18 Aug, 2016)

Ishikawa, K. (1968). *Guide to Quality Control*. Quality Resources, NY, 1968

Karanikas N., (2016). Critical Review of safety performance metrics. *International Journal Business Performance Management*, Vol. 17, No. 3, 266-285.

Leveson N. G. (2015). A systems approach to risk management through leading safety indicators. *Reliability Engineering and System Safety 136*, 17-34. http://dx.doi.org/10.1016/j.ress.2014.10.008

Mason S.E., Nicolay C.R and Darzi A (2015). The use of Lean and Six Sigma methodologies in surgery: A systematic review. Science Direct, *The surgeon, 13*. http://dx.doi.org/10.1016/j.surge.2014.08.002

Muller R. & Wittmer A. & Drax C. (2014). Aviation Risk and Safety Management- Methods and applications in Aviation Organisations. Springer International Publishing Switzerland.

OECD (2008). Guidance on developing safety performance indicators. Guidance for industry.

Podgorski D. (2015). Measuring operational performance of OSH management system – A demonstration of AHP-based selection of leading key performance indicators. *Safety Science 73*, 146–166. http://dx.doi.org/10.1016/j.ssci.2014.11.018

Rehman L. (2012). Safety Management in a Manufacturing Company: Six Sigma Approach. *Engineering Journal, 4*, 400-407. http://dx.doi.org/10.4236/eng.2012.47053

Roelen A.L.C & Klompstra M.B (2012). The challenges in defining aviation safety performance indicators. [Online] Available: http://www.nlr-atsi.nl (10 Sep, 2016).

Tenera A. & Pinto L.C (2014). A Lean Six Sigma (LSS) project management improvement model. *Procedia, Social and Behavioral Sciences 119*, 912 – 920. http://dx.doi.org/10.1016/j.sbspro.2014.03.102

Ulfvengren P & Corrigan S., (2014). Development and Implementation of a Safety Management System in a Lean Airline. *Cognition, Technology & Work*, *17*, 219-236.

Verstraeten J.G. Roelen A.L.C., Speijker L.J.P (2014). Safety performance indicators for system of organizations in aviation. [Online] Available: https://www.ascos-project.eu downloads/ascos_paper_verstraeten.pdf (19 July, 2016)

Copyright Disclaimer