Measuring the Cost of Quality in an Oil and Gas Value Stream

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Abstract

The cost of quality can be measured by considering the costs of prevention, appraisal and failure related activities. Using the case of Woodside Energy Ltd, a performance measurement system is developed from existing quality objectives and business process maps. The objectives and process maps identify the financial impact of quality-focussed processes and quality-related failures. The results show that cost of quality is dominated by failure costs, that are incurred through activities such as rework and repair. This cost is significant given the cost of downtime in oil and gas production. Moreover the data shows that fluctuations in rework and repair activity from average levels take time to dissipate. By effectively understanding the behaviour of such costs, improvement activities can be undertaken to increase the effectiveness and efficiency of quality-focussed processes.

1. Introduction

The approach of industries ranging from manufacturing, utilities and offshore oil and gas to quality management is governed by the ISO 9000 series of standards (International Standards Organisation 2015). The ISO 9000 Standards define quality as: *"The ability to satisfy the needs of customers and the intended/unintended impact on relevant interested party"*.

The ISO 9000 series addresses all aspects of a quality management system. A requirement of quality management is that measurement and evaluation activities are conducted within a structured framework such as a performance measurement system. Non-financial and financial measures should be considered. The latter provides visibility on the cost of quality while the former can be used where quality costs can't be measured. Under the ISO process, organisations have autonomy in how they measure quality.

The Quality Business Function in Woodside Energy Ltd (Woodside) was established in 2015 with the aim of addressing quality at all levels in the value chain. The team was created with the aspiration to be *"Right first time. Designed, Built, Delivered and Operated as Intended"* (Woodside Energy Ltd 2015). The team has identified a number of improvement opportunities, one of which includes measuring the cost of quality and more broadly, quality performance via a performance measurement system. This paper describes the development of cost of quality measures within a performance measurement system, using the Woodside production value stream as a case study.

1.1 State of the Art

The Balanced Scorecard (BSC) is a popular performance measurement system used by 30-60% of firms and is highly cited in research (Neely et al 2000). The BSC creates balanced and causally linked qualitative and quantitative measures that are derived from strategy. In the long term, the aim of the system is to incorporate double loop learning to review the measures and to determine employee compensation, to encourage strategy aligned behaviours.

The PAF (Prevention-Appraisal-Failure) model is a popular cost of quality approach due to its simplicity and ease of use (Schiffauerova and Thomson 2006). The PAF model separates costs across the value chain into prevention, appraisal and failure activities. Prevention activities aim to prevent defects occurring e.g. quality control through formal assessments of valve suppliers. Appraisal activites aim to maintain quality levels via formal evaluations e.g. formal inspection of plant equipment in an oil and gas asset. Failure activities result from materials/products that don't meet specifications e.g. rework due to incorrect execution of maintenance work orders in a maintenance shutdown.

2. Methodology

Identification of organisation's strategic objectives is the first stage in the implementation of all ISO management systems, from which strategic quality objectives can be determined. Both strategic organisational objectives and strategic quality objectives were available for this project. A high level value stream map of the business is used to identify critical-to-quality activities associated with prevention, appraisal and failure activities.

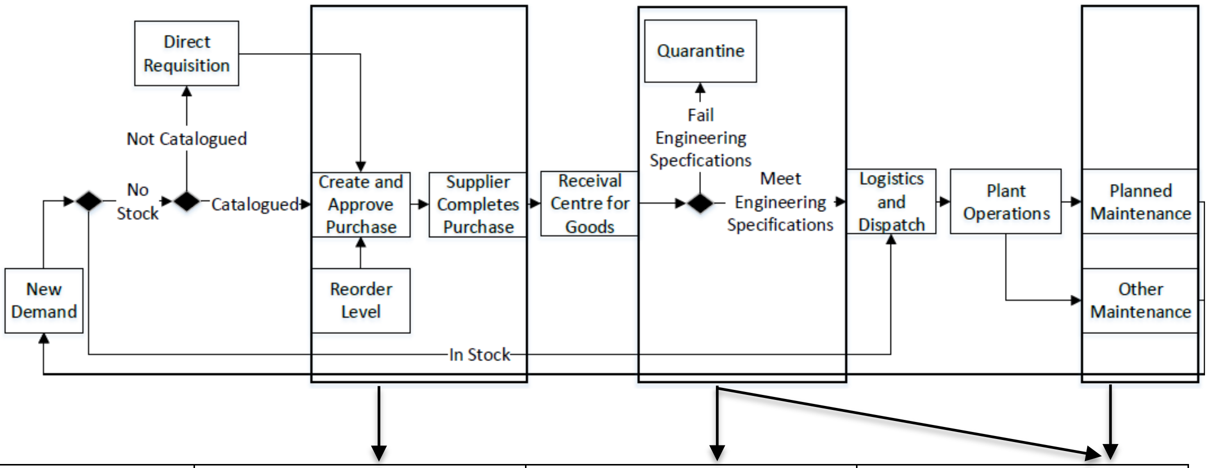
Measures based on these activities are developed and recorded in a database where each measure is associated with a specific strategic quality objective. Each measure has a name, purpose, lead/lag indicator, frequency, performance target, owner, data source and formula. Key measures from the database are organised into a dashboard to display the cost of quality. Historical data is used to visualise the measures over time and a dashboard developed to enable communication of quality measures to stakeholders.

3. Results

From Woodside's strategic quality objectives. a single objective is selected for this study based on discussions with management : "*Cost of quality of equipment delivered*" (Woodside Energy Ltd 2015).

Process mapping of Woodside identifies four areas: exploration, development, production and marketing. Production is chosen as the application area due to its operational significance and availability of data. Within production, discussions with management identified maintenance as the target area due to its impact on Woodside's oil and gas production.

To understand the equipment delivery process, a materials management process map for the maintenance function is created based on discussions with team leads from procurement, logistics, and maintenance. From the process map, we identify measures by establishing critical-to-quality points associated with prevention, appraisal and failure activities as per the PAF model. The process map with critical points and measures is below in Figure 1, where each block in the Figure identifies one of the PAF categories. A total of four key cost of quality measures are developed from Figure 1 and are discussed further below.



PAF CATEGORY	Prevention	Appraisal	Failure
ACTIVITY or PROCESS	Creating and approving purchase orders	Inspecting received items.	Quarantine of inspected items
			Other maintenance i.e. corrective maintenance
MEASURE	Cost of quality assessments for quality critical suppliers	Minimum cost of inspection for items received in the warehouse	Cost of returning items to vendor after inspection
			Rework/repair for equipment failures due to poor quality of equipment

Figure 1 Process Map of Materials Management in Maintenance with Critical Activities Highlighted and Key Measures Identified in a Table

3.1 Prevention

Suppliers are chosen when creating purchase orders based on quality assessments by Woodside. Quality assessments are audits of supplier processes and capabilities along with the level of confidence in their compliance with Woodside requirements. The measure: *"Cost of quality assessments for quality critical suppliers"* should include the labour and material resources used by Woodside to execute these assessments. The quality-critical suppliers are identified by management based on their impact on the strategic quality objective. However there was no data available for calculating the cost of supplier assessments for this project. Furthermore the selection of quality-critical suppliers is subjective and depends on management's understanding of quality and their prior experiences with the supplier.

3.2 Appraisal

The inspection process conducted by inspectors at the warehouse are measured by: *"Minimum cost of inspection for items received in the warehouse"*. Inspectors are paid at a fixed rate which provides the minimum inspection cost from employment (minimum cost = hourly rate × no. of inspectors × hours worked). It is described as a 'minimum cost' as it only includes the labour used for inspection and not other materials required. It also neglects other less formal inspections done at other points in the materials management process.

3.3 Failure

There are two measures for failure, the first being failures identified at the warehouse. Failure at the warehouse is measured by the: *"Cost of returning items to vendor after inspection"*. The cost of returning items is the transportation cost for Woodside to return the items, estimated by multiplying the average return cost per item by the number of returned items. The average return cost per item was provided by Woodside and was calculated by dividing the total transportation cost of returned items with the corresponding quantity during 2015-16. The failure at warehouse measure is a direct failure cost and hidden/opportunity costs from issues like maintenance delays and reordering new materials are excluded.

The second measure relates to failure at plant and is named: *"Rework/repair for equipment failures due to poor quality of equipment"*. Equipment failures in Woodside's plants due to poor equipment quality are recorded as notifications in SAP. The notifications are linked to the cost of work orders completed for the relevant equipment failure which can be added to give rework/repair cost. The measure depends on the accuracy and consistency of reporting root causes for equipment failures. The measure is also a direct failure cost and does not consider hidden/opportunity costs such lost revenue from production delays.

Using measures for the objective of *"Cost of quality of equipment delivered*" in the maintenance area, the cost of quality is calculated by combining prevention, appraisal and failure costs. However for this project, data for prevention costs was not available. The resulting cost of quality plot and a CUSUM plot using the average cost of quality as a reference is shown in Figure 2.

The cost of quality plot shows that failure costs are more significant than appraisal costs. The CUSUM plot shows cumulative deviations from a reference point over time (x-axis). Two turning points are identified at the start of 2013 and middle of 2014 which indicate major rework/repair due to equipment failures at these times. The cost contributions at these times are also observed from the cost of quality. Since mid-2015, the CUSUM plot shows that the cost of quality is beginning to reduce and has followed a downward trend for the past year. Another insight from the CUSUM plot is that there is a time delay following major cost of quality excursions before the cost of quality measure starts to decrease.

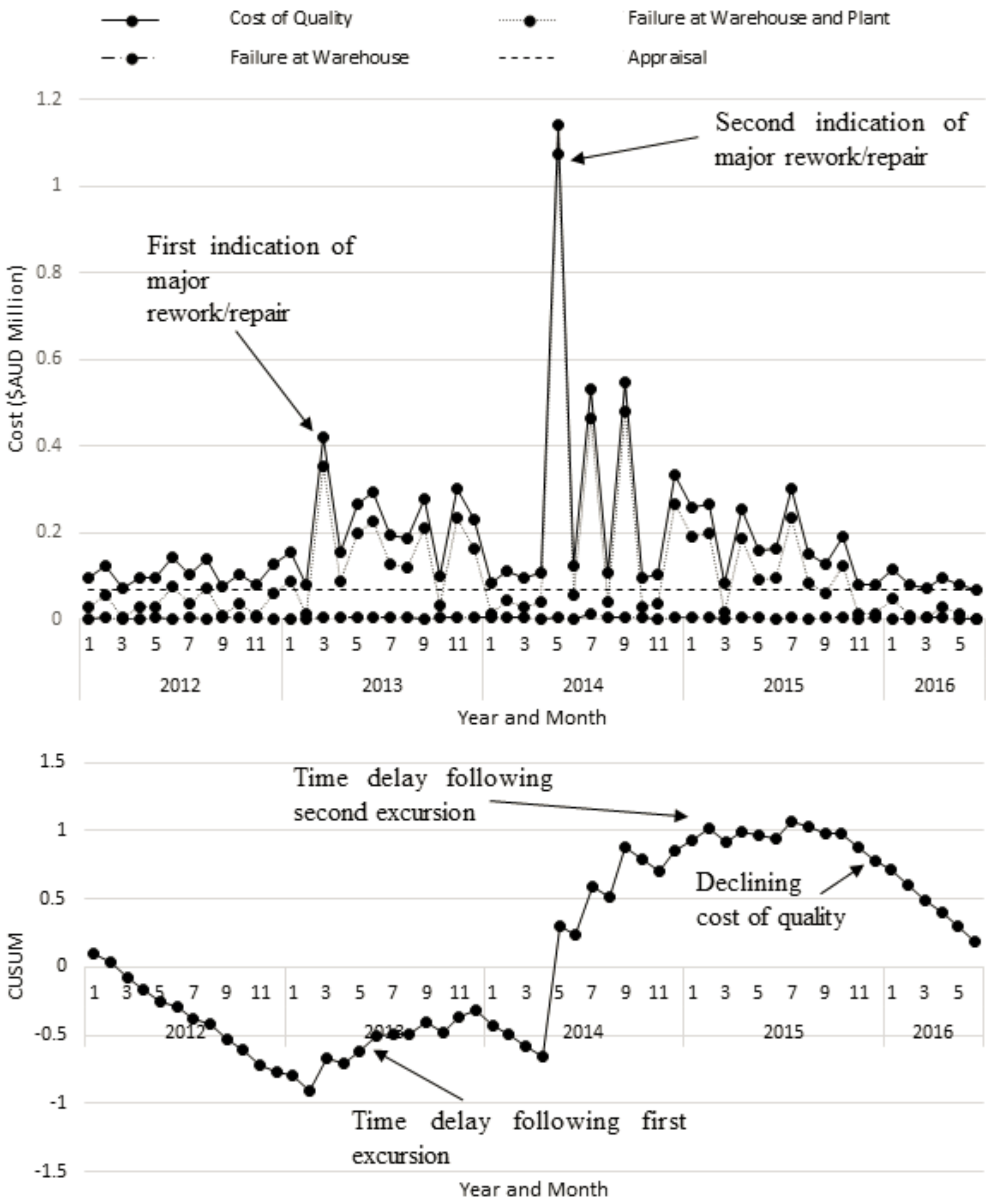


Figure 2 Cost of Quality Plot (top) and CUSUM Plot (bottom) for Cost of Quality of Equipment Delivered in the Maintenance Area

4. Conclusions and Future Work

This work describes how cost of quality is measured via a performance measurement system, where strategic quality objectives identify prevention, appraisal and failure measures. These measures are illustrated in a cost of quality plot with a CUSUM plot that can be used to initiate improvement activities and assess trends. Such a systematic approach provides insight into what influences the cost of quality in an organisation.

For the oil and gas industry, the results show that rework/repair of equipment forms a major component of the cost of quality. Given the importance of downtime in oil and gas production, rework and repair can have a wider impact across the organisation and forms an important focal point. Furthermore the data shows how sudden increases in failure costs can potentially lead to sustained rework/repair in subsequent months.

It is anticipated that this project will lead to further research to expand the scope of measurement into a larger portion of the oil and gas value stream. Furthermore the data can also be analysed to establish clear relationships between measures and how to set performance targets.

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