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A project report on model for calculating cost of poor quality.

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Model for calculating cost of poor quality

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Abstract

This project deals with creation of a Cost of Poor Quality (COPQ) model for Triton Valves Ltd., an auto component manufacturer in Mysore and supplies to many national and international auto makers. The literature pertaining to Quality, Cost of Quality and Cost of Poor Quality is initially discussed. The need for the project as discussed with the management team of the firm is stated and the objective of the project is laid down. The report continues by

identifying the key processes in manufacturing the tyre valves, based upon which the Model for COPQ is built. The various sub-modules in the model - input, calculation and output is explained with relevant figures and calculation examples. The salient features of the model, which prove to be good advantage to the firm is explained. The report concludes by stating several limitations of the project which pave way for the future scope of study.

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Company Introduction

Triton Valves Ltd. is India's largest manufacturer of automotive tyre tube valves, valve cores and accessories. They have been developing high precision products to cater to the needs of diverse clientele across the world. Triton was established by entering into a technical collaboration with Pingcot Bardin SA, a renowned manufacturer of automotive tyre valves based in France. Pingcot Bardin transferred critical manufacturing technology to Triton during the five year collaboration period.

The company has its manufacturing facility located in a 14 acre plot, in Mysore, India. The facility boasts of its state of the art machinery and has a team of dedicated and talented engineers and workforce.

Triton Valves Ltd was incorporated by Mr. M.V.Gokarn, in 1976. Mr. Gokarn was a technocrat entrepreneur with a vision to establish a world-class manufacturing facility in India, pertaining to a wide range of industrial and automotive products. Commercial production of the company commenced in 1978 with an annual capacity of 3 million valves and 4 million valve cores. Triton quickly established a reputation for its quality and customer service and emerged as a strong player in the tyre valve market in India.

Today, Triton has many notable achievements to its credit. It is the market leader in India with over 60% market share, the first in the industry to acquire the QS 9000 and the ISO/TS 16949 certifications. It has the most modern manufacturing facility in India and is also the fastest growing company in the industry.

Triton Valves has invested heavily in building a quality culture in their company. They look to maximise their customer satisfaction by imbuing highest level of quality in all their products and processes. With various Quality certifications and awards to their name, they have also looked to incorporate Six Sigma into their manufacturing process and have a dedicated team for six sigma implementation.

Being the market leader for tyre valves in India, they have a strong client base among the top automobile and tyre manufacturing companies operating in the country. Their reputation of quality and reliability and superior customer service has attracted top firms like Apollo Tyres, Bridgestone India, Ceat Tyres, JK tyres, MRF Tyres, Mahindra & Mahindra, Tata Motors,

TVS-Srichakra Tyres and Wheels India as their OEM customers. (tritonvalves.com/about_us)

Product Profile

The main categories of products that are sold by Triton are –

Valves

Valves are the main products of the company. Tyre valves help to maintain tyre pressure and allows air to be filled or removed from the tyre. A valve also provides a secondary seal and prevents dirt from getting inside. The Valve consists of a rubber tube mounted on a core assembly. Triton manufactures valves for various categories such as motorcycles, cars, trucks, buses, tractors, Airplanes, and more. They have 11 subcategories of valves and an overall more than 60 variants of valves for different uses.

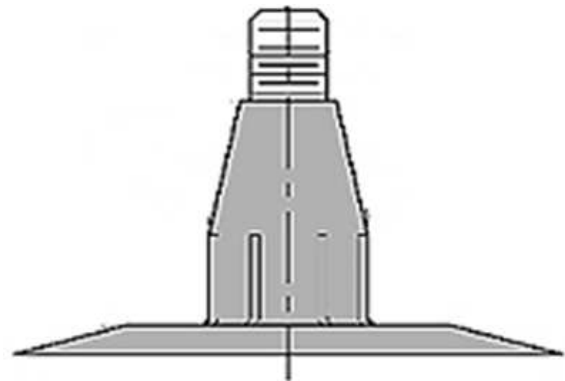


Figure 1 : Valve Schematic

Cores

These are an integral part of the valve assembly for all purposes and are designed by the company itself. It offers two variants the standard bore and the large bore, based on dimensions.



Figure 2 Valve Core

Service Tools

Service tools consist of tools such as Valve Core tightners, Tyre Thread Depth Gauge and Tubeless Snap-in valve puller and pusher.

Adapters & Plugs

Various adaptors have to be used with the valves such as water filling adapter, and envelope adaptors.

Accessories

Accessories consist of the various subparts that are used in the Valve system such as Bridge Washer, Ring Washer, Rubber Washer, Valve cap, Bush, Lock Nut, Hex Nut, Rim Nut and Rubber Base.

AC Valves

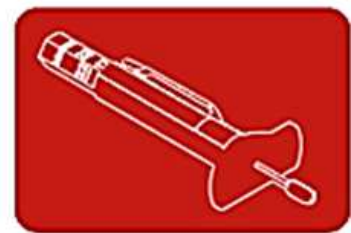
This is Triton's latest product line and has two categories – Automobiles AC valves and HVAC valves. (tritonvalves.com)



VALVES



CORES



SERVICE TOOLS



ADAPTERS & PLUGS



ACCESSORIES



AC PRODUCTS

Figure 3 Triton Product family

Quality policy of Triton

Triton endeavours to design, develop, manufacture and market our products in a cost-effective way to satisfy the quality needs of their customers, comply with the requirements of the Quality Management System and continually improve its effectiveness (tritonvalves.com). The different departments such as Design, Manufacturing and Finance look at continuously improving upon themselves to give the right quality of products as per the requirements of their customers. A quality of near to zero-parts per million defects is strived for in the company.

The objectives of the quality policy of Triton are

1. Adopting, maintaining and improving a Quality Management System as per the requirements of ISO/TS 16949. The ISO/TS16949 is an ISO

technical specification aimed at the development of a quality management system that provides for continual improvement, emphasizing defect prevention and the reduction of variation and waste in the automotive industry supply chain. (iso.org, 2009)

2. Improving processes continually leading to defect prevention, waste reduction and quality improvement.
3. Eliciting commitment and involvement of all the employees to achieve results by their empowerment.

(tritonvalves.com)

A high level of quality is achieved through a quality-first culture across all departments in the company. The Quality Assurance Department uses proven and tested Statistical Process Control and

Analysis techniques to monitor and improve quality of the products. Both manual and automatic (in-machine) testing are conducted at all critical stages, so that defective components do not flow down the value chain. Additionally, a final testing is done again before packaging, which includes a battery of stringent quality tests so that all their products conform to major international standards such as the Tire and Rim Association (TRA) and the European Tyre and Rim Technical Organization (ETRTO).

Cost of poor quality

The Cost of Poor Quality (COPQ) is the cost borne by the company due to having poor quality in its products or process. In the classical Cost of Quality concept, these could be assigned as the Failure costs both internal and external (isixsigma.com). For any company, the aim is to reduce the impact of COPQ as it improves the bottom line and increases the satisfaction of the client with their product.

Literature study

The economic framework for Cost of Quality (COQ) was established by Juran in his book “Leadership for Quality” (Juran J. M., 1951). It was Feigenbaum who divided the total COQ into prevention, appraisal, and internal and external failure (PAFF) categories (Feigenbaum, January 1991). Over time, COQ was replaced by the term cost of poor quality (COPQ). This concept was introduced by H.James Harrington, a quality expert from IBM, in his 1987 book, “Poor Quality Costs”. Juran defines COPQ as the sum of those costs that would vanish if there were no quality problems (Juran, January 1989). Crosby made the differentiation between the cost of conformance and the cost of non-conformance (Crosby, January 1979). Whichever classification is adopted, the current literature suggests that classification and quantification of quality costs is the first step in managing the cost of poor quality. (Teemu Malmi, 2004, pp. 293–317). Reducing a company’s nonvalue creating costs — the cost of poor quality — is one of the best ways of increasing profitability and competitiveness, yet ineffective measurement prevents many businesses realizing the benefits. (Sorqvist, 1997)

The quantification of COPQ is important for further analysis. Ittner has suggested the use of activity-based costing (ABC) concepts in quality improvement for

classification and quantification of quality costs. He advocates applying the ABC approach for defining quality costs by determining activities and classifying them into the essential work and prevention, appraisal and failure categories. (Ittner, 1999). For quantifying the COPQ, according to H.James Harrington, COPQ can be divided into Direct COPQ and Indirect COPQ (Harrington, 1987). **Direct COPQ** can be obtained more directly in quantitative terms from company records. It consists of the following:

- Controllable COPQ are directly controllable costs that make sure that only acceptable quality products and services are delivered to the customer.
- Resultant COPQ are costs resulting from unacceptable quality products and services being delivered to the customer.
- Equipment COPQ are costs incurred to acquire equipment for measuring or controlling the quality of a product or service.

Indirect COPQ is more complex to calculate as it is a delayed result. It is a function of time, effort, and financial costs incurred by the customer. Intangible aspects like brand impact, customer loyalty are important metrics here. These customer costs add up to lost sales and therefore do not appear in the company’s ledger.

The first step in a COPQ project is to identify and quantify the opportunities for improvement. This involves COPQ assessment and selection of the key cost of poor quality elements for improvement. The second step is to understand the cost drivers and the root causes of poor quality. Next, improvement projects are selected based on payback and strategic requirements. Finally, COPQ is used to monitor and measure the continuous improvement process and benefits flow. (Teemu Malmi, 2004)

Need for the project

Triton Valves Ltd., already had a module in place to calculate the COPQ. However, it had the following limitations:

- The existing COPQ model was excel based and hence was not updateable across various

devices, limited collaboration amongst chief managers-in-charge and required the finance manager-in-charge to enter the data offline.

- The existing COPQ model used one month as the period for data collection, calculation and results discussion. This latency pushed the critical decisions to be taken in the month-end and failed to give a break-up of the behaviour of the COPQ value across smaller periods of time. It even did not have the flexibility to change the period to smaller values.
- The existing COPQ model did not cater to all the costs involved.

Hence, the management wanted the project team to study the manufacturing process in depth and develop a refined model that can be applied on a more dynamic and real time basis which would provide a real time snapshot of Cost of Poor quality.

Project scope

The objective of the project is:

“ To develop a more efficient and real time model for calculating the cost of poor quality pertaining to all products manufactured at the company that considers all tangible and intangible factors the value chain”

For the purpose of the project, the project team was assigned three models of Valves, whose complete manufacturing process was to be observed and the new COPQ model was to be developed for the three valve models. The models were selected to ensure that the project team could study all the main process that are involved in the manufacturing process for the entire product families.

The three models that were studied were –

- **TR 78A** : rubber based single bent tube valve for Truck & Bus
- **TR 414** : rubber covered tubeless valve for Passenger Cars
- **TR 29** : rubber based tube valve for Motor Cycles



Figure 4 : TR78A



Figure 5 : TR414



Figure 6 : TR29

Each of these three models undergo certain critical manufacturing processes that were critical in developing the COPQ model. The project team has conducted several visits to the company's manufacturing processes to critically analyse the processes involved and understand the sources of COPQ and wastage.

Key processes in tyre valve manufacturing

The following key processes are critical in the manufacturing of a tyre valve. At each of these stages, significant value addition in terms of the material or labour occurs. These stages are considered as critical stages. Data collection in terms of the defects is to be done for all these stages in the proposed model, so that the net production rejection can be calculated for the required period.

Process - P1

The metal, which is usually brass is cut and shaped into the shape of the valve design. Initially the metal goes through a process where it is cut and shaped into pellets that go as the input to the P1 stage. The P1 process is completely automated. Each sub stage has sensor based quality checks as well as manual random checks. Post the P1 stage, there is a manual inspection stage where the valves are checked for any dimensional imperfections. These inspections are carried out manually on a random sampling basis.

Process – P2

P2 includes treating the rubber to remove impurities and vulcanising it. Then, it is formed into chucks and made into shapes of desired dimensions according to the product line it is being used for.

Process – P3

P3 is the process where the metal valve tubes undergoes chemical treatment that ensure that the bonding between rubber and brass takes place uniformly. This process cleans the metal surface from contaminants and prepares it for next stage. Triton has both a semi-automated and an automated assembly that carries out the entire process of dipping the valves in various chemical baths.

Process – P4

In P4 stage, the machined metal part and the rubber tube are bonded together. This stage uses different machines for different variants like tubeless or tube tyre valves. Two types of machines are used. One uses Injection moulding method and the other uses compression moulding method. Injection moulding is employed for the tubeless variant. Injection moulding gives a more uniform and rapid cure as compared to the compression moulding.

Process – P5

In P5 stage, the core, which is an integral unit of the valve is manufactured. This is the component that is inserted into the valve that helps the valve perform its function of air flow control. This process is also fully automated and has specially designed machines working for it.

Process – P6

At this stage the moulded valve and the core assembly are finally assembled together and sent for final inspection and packing.

Process – P7

This stage involves a final quality check of the finished products before dispatching to packaging and dispatch. The tests conducted at this stage are:

- Pull-out Strength testing – It gauges the strength of a particular specimen through the use of dedicated tension jacks, which are injected into the specimen under testing. (corrosionpedia.com, 2017)
- Bonding testing – It gauges the bonding between the brass metal and the rubber achieved through during manufacturing.
- Flexure testing - Flexure tests are generally used to determine the flexural modulus or flexural strength of a material. When a specimen is placed under flexural loading all three fundamental stresses are present: tensile, compressive and shear, so as to study the behaviour of the product under all these stresses. (testresources.net, 2017)
- Mechanical Endurance testing – It gauges the amount of mechanical pressure the product can handle.

Dedicated tension jacks, bonding testers and flexure testing beams and gauges are some of the tools used here. The process is manually conducted using these tools and defects are sent for rework.

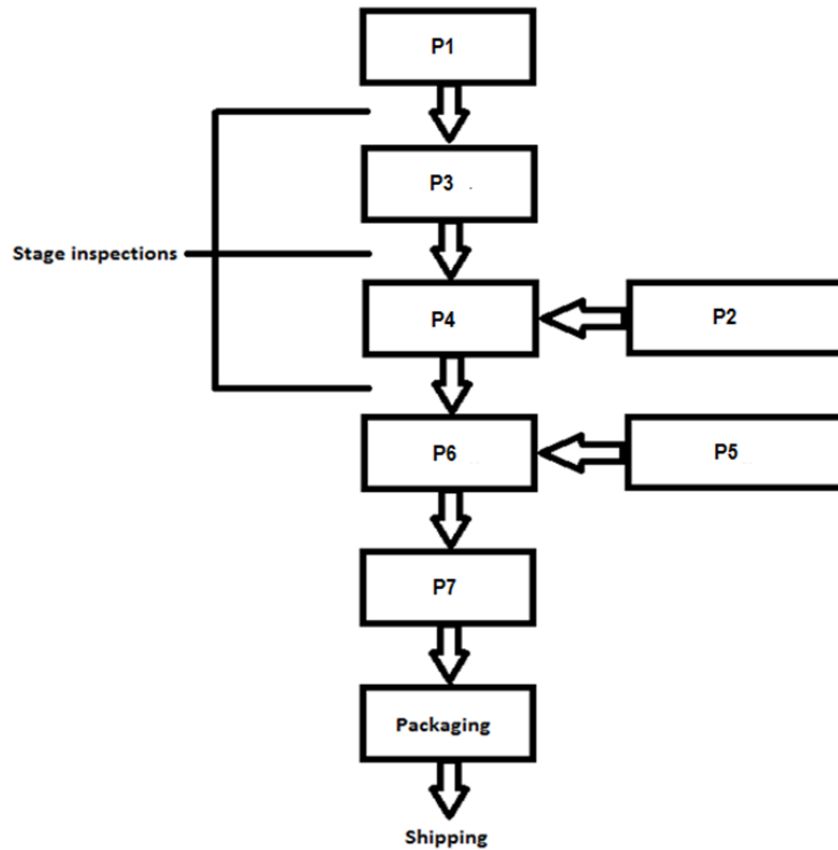


Figure 7 General Process flow

Cost of Poor Quality (COPQ) Model

Introduction

The model proposed to calculate the Net cost of Poor Quality at Triton valves consists of three sub-modules - Data Input sub-module, Calculation sub-module and Results sub-module. Each of these sub-modules are segregated into different entities so as to ensure data security. They are consistent in terms of the data they handle, achieved through real-time linking mechanisms. The entire model is developed using the Google Drive as the cloud platform. This ensures that this data is available across various devices and aids in easy collaboration. Also, the data will be secured and is not vulnerable to any on-site disasters. Each of these sub-modules are explained in detail below.

Data Input sub-module

This sub-module is created by using the Google forms. One form is created for each product. For example, for 3 products - TR29, TR414 and TR78A, three separate google forms are created. Each form consists of various questions, designed based on the critical stages identified. Data about volume of defects in each of the critical stage, and regarding customer rejections

(both rework in Triton and rework on client-site) are collected through these forms.

Its functionality is limited to only entering the data into the system. A user interface is created such that the user is required to fill in answers to several questions pertaining to data collection for that specific product family. No other data will be visible to the user, other than the one he is entering. This ensures that the confidential data is not made publicly visible to all the employees, but is visible to only higher administration employees with suitable permissions for the same. After entering the data, once the user clicks on the "Submit" button, the entered data is extracted into one of the sheets in the Calculation Module.

Usage: The administrator must share the forms to the person (plant supervisor), who can use it to periodically fill in the answers. The period can be hourly, daily, weekly, fortnightly or monthly depending on the requirement of the top management for decision making.

The Google form created for collecting data for defects at critical stages and other customer rejections related is as shown in the next page.

TR 29 defects data collection

* Required

Date *

Date

dd-mm-yyyy

Number of units produced *

Your answer

P1 defects *

Your answer

P3 defects *

Your answer

P4 defects *

Your answer

Transportation costs for bringing the defective units back to the company from the customer's site? *

Your answer

P7 defects *

Your answer

Number of defective units reworked on customer's site? *

Your answer

Number of defective units sent back to the company by the customer? *

Your answer

Number of units scrapped(discarded) on customer's site? *

Your answer

Number of defective units scrapped (discarded) in the company out of the units sent back from the customer? *

Your answer

Travel costs of personnel incurred for reworking on-site? *

Your answer

SUBMIT

Figure 8 Google form for TR29 defects input

Calculations sub-module

The data collected through the input sub-module is linked to this sub-module. This data is used for the calculation of COPQ. This sub-module is created using Google sheets. One sheet is created for each product. For example, for 3 products - TR29, TR414 and TR78A, three separate google sheets are created. In each sheet, the COPQ for that product is calculated finally. Each sheet consists of various sub-sheets:

Introduction to the product

Here the information regarding the critical stages of that product is written down. Also, the percentage of recovery of brass from the discarded valve is written, and taken as constant for all calculations for that particular product.

	A	B	C	D	E
1	PRODUCT NAME	TR 29			
2					
3	CRITICAL STAGES				
4		P1			
5		P3			
6		P4			
7		P6			
8		P7			
9					
10					
11					
12	RECOVERY				
13	Rubber can not be recovered				
14	Only brass is recovered by sending to supplier				
15	% of input cost (brass) that can be recovered	60%			

Figure 9 Calculations sheet - Introduction - TR29

Sub-sheets for all critical stages

For each critical stage identified, a sub-sheet is created. The cost of defects is calculated for each of them. Cost of rejection is calculated as the product of the cost of the product at that stage in the production and the volume of rejections in the period considered.

	A	B	C	D	E	F
1	PROCESS - P1					
2	Value addition Factor	1.603		Input cost	₹ 5.06	
3			% of input cost (brass) that can be recovered	60%		
4						
5	Sl no.	Date	Volume rejected (units)	Cost of rejection	Less: Recovered from supplier	Net cost
6	1	1/1/1900	99	₹ 802.23	₹ 300.29	₹ 501.94

Figure 10 Calculations sheet - P1 defects - TR29

- **Cost of rejection = Input Raw material cost * Value addition till that stage * Volume of rejections**

Out of these rejections, brass cost can be recovered by sending it back to the supplier.

- **Hence, the net cost = Cost of rejection – (% of brass recovered * Input cost)**

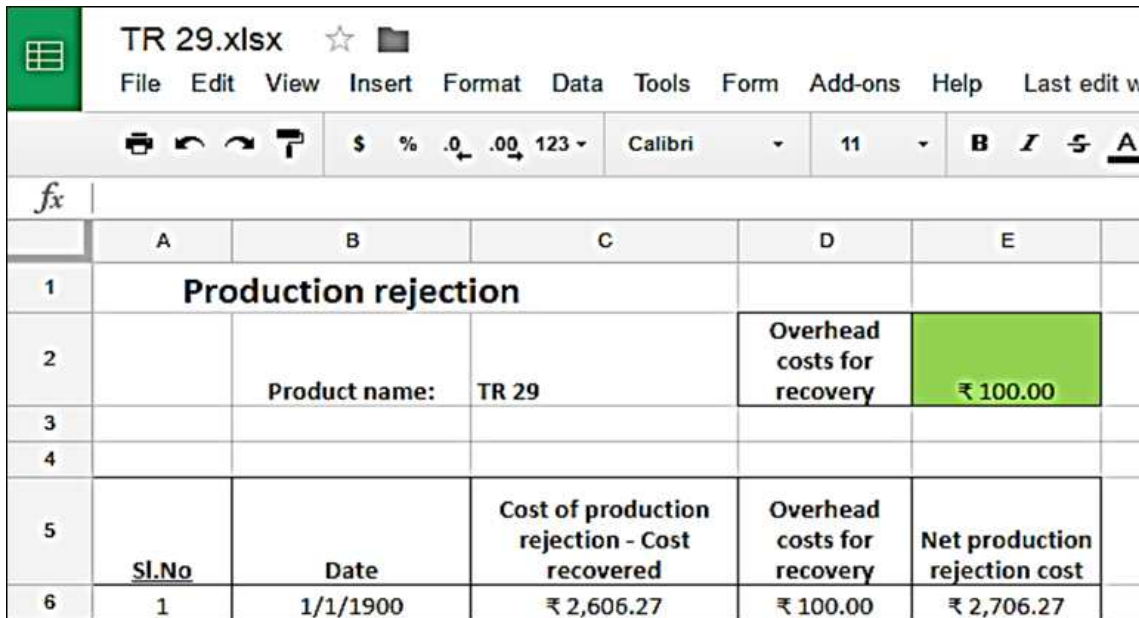
For example, in the above figure, P1 stage is considered. Here,

- Cost of rejection on 1/1/1990 = $5.06 * 1.603 * 99 = 802.23$
- Net cost = $802.23 - (60\% * 5.06) = 501.94$

Production rejection

Production rejection is the total cost of the rejections happenings within the plant, during the production process. The production rejection is found by adding the net costs of rejection pertaining to each critical stage. In order to recover brass from the supplier, there are overhead costs such as transportation etc. These costs are added to the net cost of rejection to obtain the net production rejection cost.

Net cost of production rejection = Sum of net rejection cost at all critical stages + Overhead costs of recovery



	A	B	C	D	E
1	Production rejection				
2		Product name:	TR 29	Overhead costs for recovery	₹ 100.00
3					
4					
5			Cost of production rejection - Cost recovered	Overhead costs for recovery	Net production rejection cost
6	Sl.No	Date			
	1	1/1/1900	₹ 2,606.27	₹ 100.00	₹ 2,706.27

Figure 11 Calculations sheet - Net production rejection -TR29

For example, in the above figure,

$$\begin{aligned} \text{Net cost of production rejection} &= \text{Sum of net rejection cost at all critical stages} + 100 \\ &= 2606.27 + 100 = 2706.27 \end{aligned}$$

Customer rejection

In the COPQ calculation, Customer rejection is one the important aspects to be considered, because it adds to both direct and indirect costs incurred. Total customer rejection cost is sometimes difficult to measure because it is a delayed result of time, effort, and financial costs incurred by the customer. These customer costs add up to lost sales and therefore do not appear in the company's ledger. In this project of COPQ calculation, we have made an effort to consider both direct & indirect costs incurred due to rejection

from the customers of Triton Valves. Direct costs include the cost related to number of rejects by the customers.

Reworked at Triton's factory

At Triton's factory, the rework costs include raw material cost, overhead cost and labour cost. The transportation costs for bringing the rejected products back to the factory are also added to it.

- Cost of rework at Triton = Labour cost + Material cost + Overheads + transportation costs

Reworked at customer's site

Sometimes the rework on the rejected units are done at customer's location itself and hence the rework cost not only includes the raw material and labour costs, but also includes travel and accommodation costs of the service personnel.

- Cost of rework at customer's site = Labour cost + Material cost + Overheads + travel costs

Scraping cost

The products that cannot be reworked are to be

discarded. However, some amount of brass can be recovered from it, and this is reduced from the cost of scrapping.

- Net Cost of scrap = Price of the product – Recovery + Overheads for recovery

Total customer rejection = Cost of rework at Triton + Cost of rework at customer's site + Net cost of scrap

Indirect costs will include the loss of goodwill, due to the delay in meeting the customer's requirement.

Cost of Customer rejection																
Date	Defective units Sent back to the company by customer							Defective units reworked at customer's site							Total Customer Rejection Cost	
	Number of Defective units sent back	Total number of units scrapped	Labour cost	Material cost	Overhead cost	Total cost of rework	Transportation cost	Number of defective units reworked onsite	Total number of units scrapped	Labour cost	Material cost	Overhead cost	Total cost of rework	Travel expense		Cost of scrap
1/1/1900	999	99	₹900.00	₹1,800.00	₹2,700.00	₹5,400.00	₹999.00	999	99	₹900.00	₹1,800.00	₹3,600.00	₹6,300.00	₹999.00	₹594.00	₹14,292.00

Figure 12 Calculations sheet - Customer rejection - TR29

For example, in the above figure,

- Total cost of rework at Triton = 900 + 1800 + 2700 + 999 = 6399
- Cost of rework at customer's site = 900 + 1800 + 3600 + 999 = 7299
- Net Cost of scrap = 594
- Total customer rejection cost = 6399 + 7299 + 594 = 14292

Consolidated COPQ

Here, the total COPQ is calculated. Total COPQ for a product consists of cost of production rejections and customer rejections. As per discussions with senior management, a small percentage of rejections is taken to be "allowed" due to the fact that some rejections are inevitable owing to the machinery used. This allowed rejections is subtracted from the total COPQ to obtain the net COPQ in terms of cost.

Net COPQ in terms of cost = Net cost of Production rejection + Net cost of Customer

Rejection – Allowable cost of rejections

= (1-Rejection % allowed) * (Net cost of Production rejection + Net cost of Customer Rejection)

In terms of percentage with respect to the total production cost,

COPQ (in terms of %) = Net COPQ in terms of cost * 100/ Net production cost

= Net COPQ in terms of cost * 100 / (Input Raw material per unit cost

* Volume of production)

B	C	D	E	F	G	H	I
Total rejection cost (COPQ)							
Date	Production rejection	Customer rejection	Rejection cost	Net rejection cost (COPQ)	Volume of production	Cost of production	%COPQ
1/1/1900	₹ 2,706.27	₹14,292.00	₹16,998.27	₹16,940.47	999999	₹ 10,684,339.32	0.1586

Figure 13 Calculations sheet - Net COPQ - TR29

For example, in the above figure, for a rejections allowed % of 0.34,

Net COPQ in terms of cost =

$$(1-0.34) * (2706.27 + 14292) = 16940.47$$

COPQ (in terms of %) =

$$16940.47 * 100 / (999999 * 5.06) = 0.1586$$

Results sub-module

The top managers, heads of department and other decision makers of Triton valves will be more concerned about what the final value of the COPQ value is for each period considered, rather than the detailed break-ups and calculations of the final value. This kind of abstraction is provided by this sub-module. It consists of only the final values that will be helpful in strategic decision making by the top managers, sparing them of the detailed calculations happening behind it. Also, there are various cost related data that are typically constant for many quarters. These are updated by the finance team only when the market/value chain scenario

changes. The COPQ output and cost-related inputs mentioned above are generally handled by top managers and hence require security, achieved through its segregation from other operational data.

There are 2 sub-sheets in this sub-module - Total COPQ and Costing.

Total COPQ

This sub-sheet calculates final COPQ value. The COPQ values of all the products – TR29, TR414 and TR78A, which were calculated in the Calculation sheets are linked to this sub-sheet. The final COPQ value for the entire product-range is calculated as the sum of the individual COPQ values.

Total COPQ = COPQ of TR29 + COPQ of TR414 + COPQ of TR78A

To obtain the Total COPQ in terms of %, Total COPQ is divided by the Total production cost.

Total COPQ (in terms of %) = Total COPQ in terms of cost / Total production cost

B	C	D	E	F	G	H	I	J	K
Net COPQ									
Date	COPQ - TR29	COPQ - TR78A	COPQ - TR414	Total COPQ	Production cost - TR29	Production cost - TR78A	Production cost - TR414	Total production cost	Net COPQ as % of pdn cost
1/1/1900	₹16,940.47	₹22,616.30	₹ 15,518.65	₹55,075.42	₹10,684,339.32	₹3,457,299.53	₹8,390,397.61	₹22,532,036.45	0.2444

Figure 14 Decision making - Net COPQ

For example, in the above figure, for the date 1/1/1990,

- Total COPQ = 16940 + 22616.30 + 15518.65 = 55075.42
- Total COPQ (in terms of %) = 55075.42 / 22532036.45 = 0.2444

Cost sheet

This sub-sheet consists of the critical stage-wise costing structure for all the products. Each product goes from being a raw material to a finished product. In this case, it starts from brass on one side and rubber on the other side. Value gets added to the raw material at several stages (the stage where significant value addition occurs is taken as the critical stage). Value addition occurs because of the additional labour, material and other overheads (like electricity, solvents) invested upon it.

The cost of the product at each stage is determined by absolute costing. It is the sum of raw material, labour and overheads invested till that stage. The overheads include the costs such as administration, power, manufacturing-related fuels, fluids etc.

The value addition factor (VIF) is the factor which depicts how much value has been added to the raw material to reach the current stage product. It is calculated as,

VIF at stage i = Cost of the product at stage i / Cost of first input raw material

VIF at stage i = Cost of the product at stage i / Cost of first input raw material (Brass

TR 29					
	Input RM	P1	P3	P4	P7
Raw material	₹ 5.06	₹ 5.06	₹ 5.55	₹ 5.55	₹ 5.55
Overhead and Labour cost		₹ 0.77	₹ 1.34	₹ 2.23	₹ 2.63
Fixed Overhead cost		₹ 2.27	₹ 2.50	₹ 2.50	₹ 2.50
	₹ 5.06	₹ 8.10	₹ 9.39	₹ 10.28	₹ 10.68
Value addition Factor	1.000	1.603	1.857	2.034	2.113

Figure 15 Costing for TR 29

TR 78A						
	Input RM	P1a	P1b	P5	P4	P7
Raw material	₹ 16.48	₹ 16.48	₹ 16.48	₹ 16.48	₹ 19.22	₹ 19.22
Over head		₹ 0.66	₹ 1.46	₹ 3.58	₹ 4.33	₹ 6.71
Fixed Overhead cost		₹ 7.42	₹ 7.42	₹ 7.42	₹ 8.65	₹ 8.65
	₹ 16.48	₹ 24.55	₹ 25.35	₹ 27.47	₹ 32.19	₹ 34.57
Value addition Factor	1.000	1.490	1.538	1.667	1.954	2.098

Figure 16 Costing for TR 78A

TR 414					
	Input RM	P1	P4	P6	P7
Raw material	₹ 1.88	₹ 1.88	₹ 2.64	₹ 4.06	₹ 4.06
Over head		₹ 0.26	₹ 2.06	₹ 2.11	₹ 2.50
Fixed Overhead cost		₹ 0.84	₹ 1.19	₹ 1.83	₹ 1.83
	₹ 1.88	₹ 2.98	₹ 5.89	₹ 8.00	₹ 8.39
Value addition Factor	1.000	1.589	3.136	4.263	4.471

Figure 17 Costing for TR 414

For example, in the above figure, for TR414,
The VIF at P1 stage is, 2.98 / 1.88 = 1.589

Salient features of the proposed COPQ Model

The current model developed by the project team to calculate the COPQ has the following salient features:

Google Drive – Cloud based platform

Google Drive, a cloud based platform for collaboration provided by Google Inc., is used extensively in this model. The cloud based nature of the model enhances it through the following features:

- Location-free – Google drive allows users to work from anywhere. As long as the user has an Internet connection, he can access the cloud. Many providers often have apps available to multiple devices, so the user is free to use it on his smartphone or tablet or his desktop computer. This feature allows a work-life balance and maintains productivity rates.
- Backup - Cloud-based backup saves time, avoids larger investments and the need to recruit third-party experts. Choosing cloud backups decrease the size of the firms' data centres. The lowering of the numbers of servers, the software expense, and the staff personnel can significantly reduce IT costs without negatively affecting an organization's IT capabilities.
- Cloud-based workload and file sharing streamline teamwork collaboration, which allows data to be shared, accessed and edited from anywhere. Updates are visible in real-time and are seen by all teammates.
- Maintenance of the servers is easy. Servers are off site, and the providers take care of software updates. There is no need for users to install software on to individual systems and keep up to date with the software as it develops.

(Rajurkar, 2016)

Identification of Critical stages

By carefully studying the various stages of the complete manufacturing process and all the different sub processes, the project team was able to isolate the critical to quality stages that had the most significant impact on the COPQ. These stages are considered for inputting the data and for calculations.

Data security

By making use of a 3 sub-module approach, we were able to enhance the data security aspect of the data inputted into the model. The 3 sub-modules of the model are:

- Input sub-module – Created using Google forms
- Calculation sub-module - Created using Google sheets
- Results sub-module - Created using Google sheets

This 3 sub-module approach allows the administrator to give restricted access to the individual sub-module. Hence, he can effectively bifurcate who can view/change which sub-module. This improves the security of the model, so that only the right person accesses the sub-modules.

Covered all costs across the value chain

All factors that affect the COPQ including Supplier-related, Production-related & Customer-related costs have been incorporated into this model.

COPQ can be obtained for any period of time (hourly/daily/weekly etc)

The model is very flexible and can be used to calculate COPQ for even small (like hourly also) periods of time. As and when the data is inputted, the values are calculated. It can also be used to work in a near-real time basis, by entering the data in that manner.

Easy usage and reproduction

The fundamental benefit of the model is the ease of use and its power of scalability. The model can also be replicated easily for other product lines.

Limitations and Future scope

Even though the proposed COPQ model has several advantages through the salient features mentioned above, it has some limitations, which can be considered for the future scope. They are as below:

- The COPQ model proposed considers the costing for the products based on the Absolute costing method across several activities (process stages). It does not consider all the intangible

costs involved and the opportunity costs involved in poor quality. Hence, these additional costs, which might be dynamic in nature must be captured to make the model optimal.

- Also, the project scope defined had limited the model to only three products – TR29, TR414 and TR78A. Although the major processes involved in manufacturing the valves were considered here, a model consisting of all the valve products, cores and accessories manufactured at Triton Valves Ltd., must be considered so as to obtain an overall picture of the entire COPQ of the facility. In such a scenario, various dependencies between the product categories must be considered to make the model optimal.
- The proposed COPQ model can be extended to form a COQ model which takes into consideration the prevention and appraisal costs in detail other than the internal and external failure costs considered in this model.
- The model uses Google Drive as the cloud-based collaborative platform for capturing data, calculating the COPQ and providing the results. Better storage mechanisms can be achieved through databases like MySQL, which provide more secure querying and processing capabilities. Data visualisation and processing tools like Orange Canvas and Tableau can be used for easier and more effective results interpretation. They also support data mining to uncover underlying patterns in the data captured. Deeper analytics can be performed using them, so that better decisions can be made.

Overall learnings from the project

This project exposed the team to various practical aspects of COQ and COPQ. With respect to tyre valve manufacturing, the team understood the various processes involved in processing across the supply chain. Also, the various critical stages and their importance for calculating the overall COPQ was understood. Various nuances in terms of the costing structure for the various products were understood and integrated to develop the overall model. The team also got an opportunity to utilise their learnings in other management subjects (such as cloud for cross-platform collaboration) into this project.

Conclusions

This project has focussed on creating an efficient, dynamic, secure and user-friendly model to calculate the COPQ pertaining to 3 products - TR29, TR414 and TR78A. The model has been well appreciated by the client – Triton valves Ltd., for its flexibility, thought process involved and satisfying the objectives laid down initially. This model can be made operational in reality by expanding it to include all the products manufactured at Triton, so that the company can get an overall picture of its COPQ. Continuous monitoring of the results obtained through accurate data input across the time period required aids in effective and near real-time decision making.

References

- (n.d.). Retrieved from tritonvalves.com: <http://www.tritonvalves.com/products.html>
- (n.d.). Retrieved from isixsigma.com: <https://www.isixsigma.com/dictionary/cost-of-poor-quality-copq/>
- (2017). Retrieved from corrosionpedia.com: <https://www.corrosionpedia.com/definition/948/pull-out-test>
- Carl Zeiss Industrial Metrology. (n.d.). Retrieved from https://www.zeiss.com/content/dam/Industrial%20Metrology/us/img/Stages/980x308/automotive_copq-a-working-model.pdf
- Crosby, P. B. (January 1979). *Quality is Free: The Art of Making Quality Certain*.
- Feigenbaum, A. V. (January 1991). Total Quality Control. *Harvard business review*.
- Harrington, H. J. (1987). *Poor Quality Costs*. New York: ASQC Quality Press.
- Injection moulding. (n.d.). Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Injection_moulding
- iso.org. (2009). Retrieved from <https://www.iso.org/standard/52844.html>
- Ittner, C. D. (1999). Activity-based Costing Concepts for Quality Improvement. *European Management Journal*, 492-500.

Juran, J. A. (January 1989). *Leadership for Quality*.

Juran, J. M. (1951). *"Quality Control Handbook"*.

Rajurkar, A. (2016 , September 12). *bodhost.com*. Retrieved from <https://www.bodhost.com/blog/features-of-cloud-computing/>

Sorqvist, L. (1997). EFFECTIVE METHODS for measuring the cost of poor quality. *Measuring Business Excellence, Vol. 1 Iss: 2, 50 - 53*.

Teemu Malmi, P. J. (2004). A Collaborative Approach for Managing Project Cost of Poor Quality. *European Accounting Review, Vol. 13*(No. 2), 293–317.

testresources.net. (2017). Retrieved from <http://www.testresources.net/applications/test-types/flexural-test/>

tritonvalves.com/about_us. (n.d.). Retrieved from *tritonvalves.com*: http://www.tritonvalves.com/about_us.html