The Design of QTrac: an automated Quality and Cost Management System for Projects

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Abstract - **The value of Total Quality Management is demonstrated by the fact that quality products and service are non-negotiable as market-entry for organizations to compete globally. Quality costing is a measure of the efficiency of Total Quality Management and the metric that companies employ to measure their gain in profitability from investment in quality management programs. Current financial accounting systems, however, are not designed to measure and report quality related data in a format that allows informed decision-making. Two companies, BIE International and PACE Services, combined their expertise in quality management and cost engineering to design a quality and cost management system that measures and reports quality management and cost data and information. The program is called QTrac for Projects and Manufacturing and is designed as a quality decision-making and cost management system for the project and manufacturing sectors. The objectives of this paper are to present the design strategy of QTrac in response to the critique and limitations of existing quality cost and accounting methodologies.**

Keywords-quality costing, QTrac, quality management, projects

I. INTRODUCTION

The value of Total Quality Management in industry is undeniable in that high quality is non-negotiable as entry to market and opportunity for organizations to compete globally. Quality costing is the metric by which companies measure their gain in profitability and cost savings from investment in quality management programs, products and services. Current financial accounting systems, however, are not designed to measure and report quality related data in a format that allows informed decision-making. In response to this challenge, two companies, BIE International and PACE Services, combined their expertise in quality management and cost engineering to design a quality management and cost system called QTrac: a system to manage quality activities and costs in Projects and Manufacturing. QTrac informs decision-making in quality management and quality costing to achieve risk mitigation, cost reduction and continual improvement.

In 2013 PricewaterhouseCoopers reported that capital project and infrastructure spending is expected to total more than nine trillion dollars by 2025 and that the economic return generated for every dollar spent on a capital project lies between five and twenty five percent [1]. That economic return, however, is eradicated by poor quality in project planning and execution. Furthermore, KPMG found that only thirty-one percent of projects came within ten percent of their original budget and fifty-three percent of the companies surveyed experienced one or more underperforming projects in the past year [2]. The maturity of projects and project management is illustrated by the iron triangle in Figure 1 which shows the inter-relationship of quality, cost and schedule in a project. Schedule and project costs are often unwittingly favoured at the expense of quality and this imbalance will continue to exist as long as the real cost of quality remains hidden among total project costs.

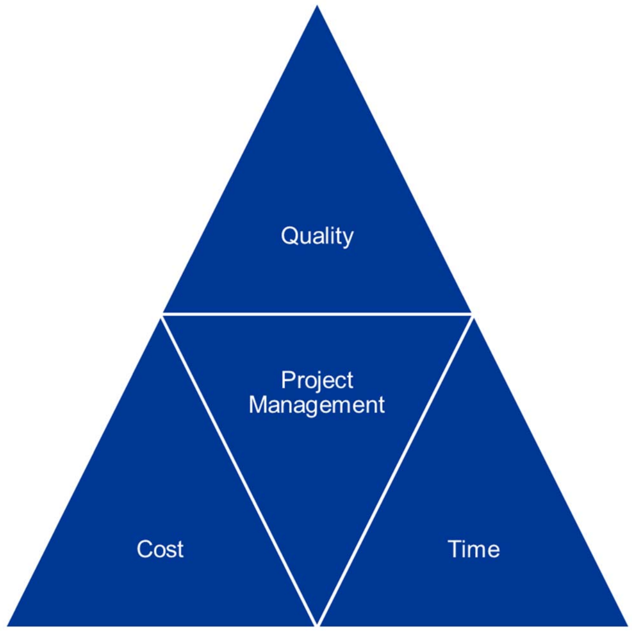

Fig. 1. The iron triangle

The reasons for the hitherto unsuccessful development of an automated quality and cost management system for projects are two-fold. For a quality cost system to be considered a substantive and trusted decision making tool, it is important that these challenges are confronted and addressed both practically and sensibly. The first challenge is that quality costing, as a tool for continual improvement and cost reduction, is contested during implementation due to its apparent subjective, invasive and laborious nature. QTrac addresses this challenge in its marketing and design strategy by several interventions *inter alia* that the software will only be released to mature quality clients during its initial implementation. This strategy ensures that the client understands the value of quality costing and will consequently implement all necessary organisational structures, processes and systems to ensure effective operation of QTrac. The client will also be willing to manage the change associated with its implementation and support the required changes with relevant quality cost training. Secondly, the programme will be tested during its' first release to address all the potential queries that may arise with future implementation and integration with existing systems. Marketing of QTrac, however, is not the focus of this paper and will be addressed by a comprehensive go-to-market strategy and a separate publication.

The second challenge is that quality costing is neither a traditional financial accounting system nor a classic cost allocation methodology. Quality costing is a hybrid costing system that not only extracts and captures direct and hidden quality costs from current accounting systems and cost allocation methods; but also sources the required data by its own design. The objectives of this paper are therefore to present a critique of current quality costing models employed in industry, and to respond to the critique with a discussion of the high-level design and costing philosophy of QTrac.

II. CRITIQUE OF CLASSIC QUALITY COSTING MODELS

A. Critique of Classic Quality Cost Models: an overview

In 1986 Deming argued that measuring quality costs is a waste of time due to hidden and unmeasurable costs and the consequent inaccurate reflection of the process state. Schiffauerova and Thomson [3], however, maintain that customer requirements can only be met through continuous improvement if the cost associated with achieving quality is considered. These opposing views inform the current debate on the extent to which quality costing should be employed by firms in striving for quality improvement, and whether an optimal point of investment versus benefit is achievable - the traditional view being that better quality demands higher cost and vice versa [4].

Current quality cost models may be classified in two primary categories: the most widely known model is the prevention-appraisal-failure (PAF) model as defined in the British Standard BS 6143-1 of 1992 [5]; and the process quality cost model. The PAF model may include or exclude opportunity or intangible costs where these costs can only be estimated [6]. Examples of intangible costs include profits not earned due to lost customers and reduced revenue owing to non-conformances.

In 1979, Philip Crosby modified the PAF classification and presented cost of quality as the sum of the price of conformance and the price of non-conformance - known today as the process cost model and applied in quality costing by Marsh in 1989 [7]. Distinguishing features of the process cost model are that it focuses on processes rather than products, and that it's a simpler cost model than the PAF model in its identification and allocation of cost elements.

Despite the PAF model and the process cost model being the two main approaches to measuring cost of quality (CoQ), neither approach provides an adequate method to allocate overheads to CoQ elements [3,6]. Activity-based costing (ABC) is used by selected authors to overcome this shortcoming [8,9]. Under ABC, accurate costs for various objects are achieved by tracing and assigning resource costs (including overheads) to products (*ibid.*). ABC, however, does not consider process costs or costs external to the process and therefore is not considered a CoQ model. In 1998, Tsai proposed an integrated ABC-CoQ framework as demonstrated in Figure 2 [10]; and ten years later Liu, Cui, Meng and Pan used this model to propose and simulate a CoQ accounting system [11]. Figure 2 proposes ABC consisting of two dimensions: the cost assignment view and the process view. Cost objectives include products, product lines, processes, customers, channels and markets – and create the need for activities. Activities, in turn, create the need for resources which may include people, machines, facilities and utilities as example in the manufacturing sector.

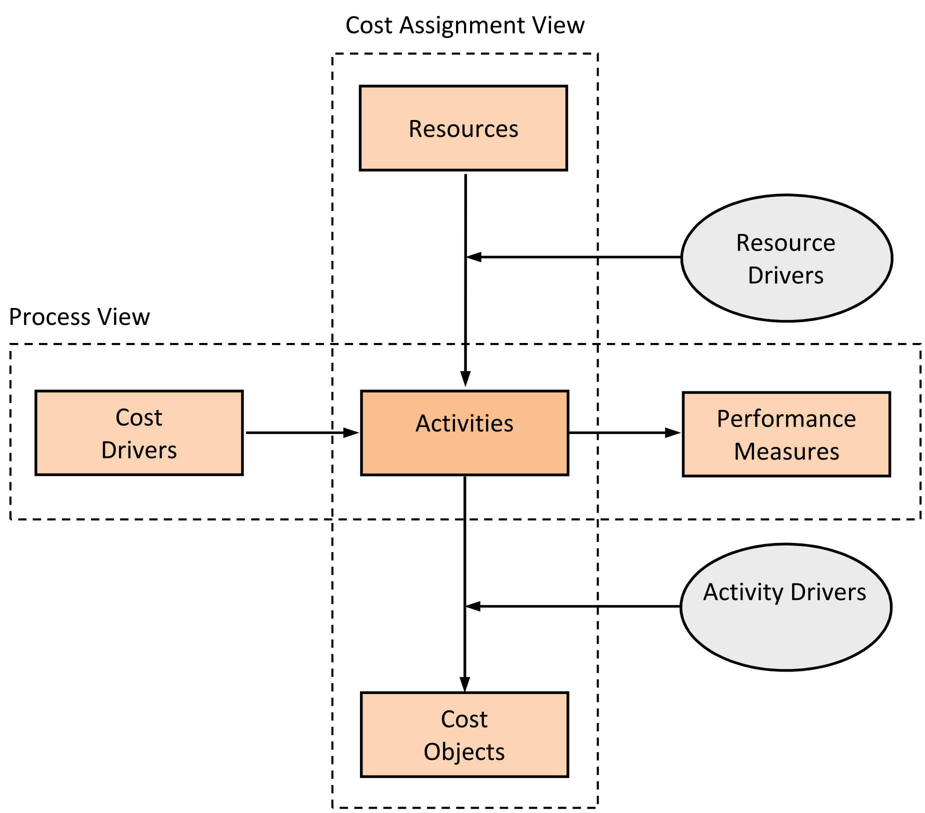

Fig. 2. Two-dimensional ABC-CoQ framework

(adopted from Tsai, 1998:728)

Despite the recognized value of quality costing, CoQ systems are not critic-free and some quality practitioners view quality cost programmes as impediments, rather than contributors, to quality [12,13]. Angell and Chandra [14] and Dale and Wan [15] describe some of the challenges experienced by firms in implementing quality costing including *inter alia* an inappropriate corporate culture and resistance to change; lack of critical support of cross-functional teams; lack of resources with the necessary experience and skills; the incorrect application of quality costing methodology; and errors in data collection. The latter was confirmed in an earlier study by Dale and Plunkett [16] where wide differences between the quality costing models and real world data were found.

Whether a company chooses to implement the PAF model or the process cost model, the chosen method must be tailored to suit a company's requirements and support continual improvement [15, 17]. Ultimately, the success of implementation of any chosen quality cost model is fully dependent on executive support and leadership [18, 19, 20].

B. The PAF Model

Joseph Juran initiated the concept of economies of quality and the graphical form of the cost of quality model in 1951 [3]. Later, in 1956, Armand Feigenbaum proposed the classification of quality costs into the categories of prevention, appraisal and failure costs – generally referred to as the PAF model [21] – and since the time of classification the PAF scheme has been almost universally accepted for quality costing [6]. Consequently, Juran proposed an optimal level of quality based on the relationship between quality costs as indicated in Figure 3 [22]. Feigenbaum's classic CoQ model assumes a trade-off relationship between prevention and appraisal, and failure costs, where the optimal level of quality exists at the intersection of the cost curves to produce a minimum total cost of quality. The premise of this theory is that a hundred per cent conformance to quality costs too much and is therefore impractical and unachievable.

The traditional model, however, does not account for technological improvements or organisational learning, and contradicts the principle of continual improvement. If continual improvement is required in an organisation, no economic level of quality exists and spending on prevention activities can be justified if necessary and supportive of the organisation's strategic objectives [23].

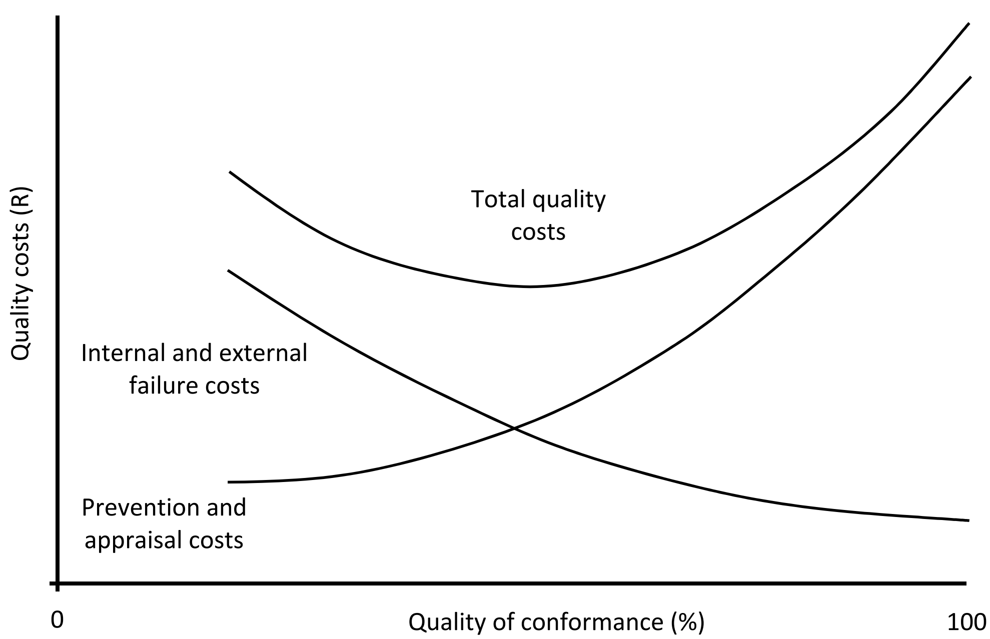

Fig. 3. Classic view of quality costing
(adopted from Juran, 1962)

Quality is often viewed as an attribute with a fixed unit cost [24]. This static formulation of quality, however, is challenged by Freiesleben [12] and Modaress and Ansari [4]. They respectively question the exponential increase of prevention and appraisal costs in Figure 3 and the resultant cost differentials. Freiesleben [12] argues that investment in prevention is subject to diminishing returns because not all root causes of a problem can be detected with the first effort. Organisational learning and technological development may also contribute to quality cost differentials in that the problem detection and solving process is mastered over time - thereby making for a more efficient organisation and requiring less investment in appraisal (*ibid.*). The impact of these developments on quality costing is illustrated in Figure 4 and indicates that the quality cost of detecting root causes is initially high (q_1). As technology development in the company increases from C_1 to C_5, the cost of conformance and the cost of detecting root causes decrease accordingly.

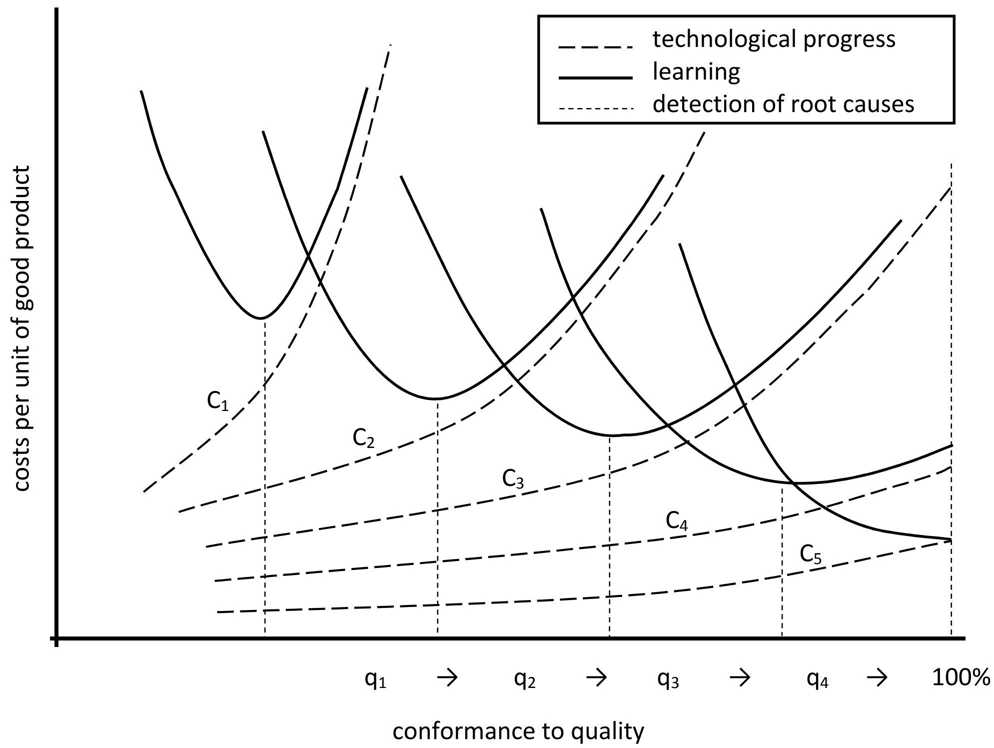

Fig. 4. Development of the costs per unit of good product over time

(adopted from Freiesleben, 2004:965)

Modaress and Ansari [4] agree that a learning curve exists in organisations and that production and production related costs can decline as a result of learning from experience. The traditional quality cost model with exponential increases in prevention and appraisal presupposes a company with a poor quality level or a company just starting to implement a quality improvement programme [12, 6].

In modern quality management, the traditional inspection mode as a measure of appraisal is replaced by the ″establishment of an effective and relatively inexpensive monitoring system, reflecting the insight that quality cannot be guaranteed by ever-increasing inspection, but only by keeping the production process in statistical control and by preventing quality problems from occurring″ [12, p.962]. These arguments on the concept of continual improvement attained by the modern theory of cost of quality are demonstrated in Figure 5.

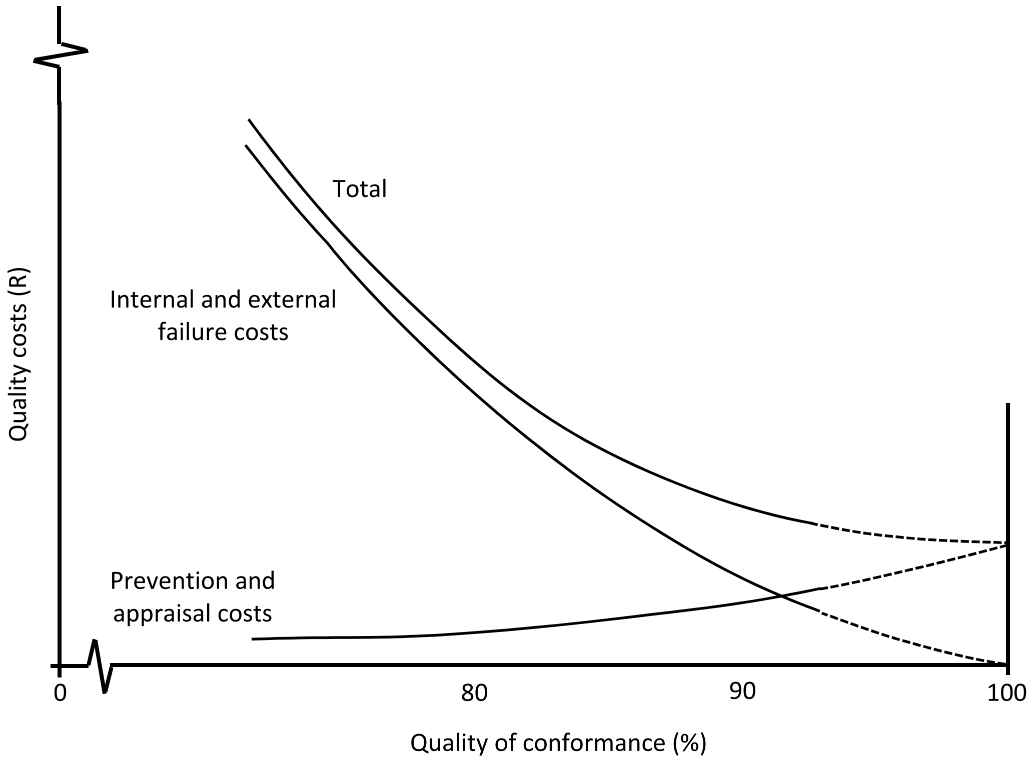

Fig. 5. Modern view of quality costing

(adopted from Schiffauerova and Thomson, 2006:5)

Albeit the PAF model is the most frequently used quality cost model based on documented cases in literature, several practical challenges exist in the design and implementation of the model [3]. Porter and Rayner [25] argue that it is difficult to uniquely classify costs into prevention, appraisal, internal failure, or external failure costs; and Hohner [26] states that appraisal and failure cost categories are non-value-adding activities that detract from productivity and focus on inspection rather than prevention.

A third criticism of the PAF model is that it does not include intangible quality costs. These include *inter alia*:

- opportunity costs including under-utilization of installed capacity, inadequate material handling and poor delivery of service [3];
- the cost of inefficient resource utilization and quality design cost [4];
- profits not earned due to lost customers and reduction in revenue owing to non-conformance [3];
- hidden cost that is inadequately recorded in company accounts and / or failure costs that are never actually discovered [27];
- customer dissatisfaction and the loss of sales due to deviating product standard specifications [24]; and
- the loss of reputation [25].

Chiu and Su [28] and Freiesleben [12] argue that hidden quality costs are often neglected in cost calculations. Hidden costs can further be divided into (i) extra resultant costs and (ii) estimated hidden costs as indicated in Figure 6 [29]. The PAF model that includes opportunity costs or hidden costs is called an opportunity cost or intangible cost model respectively [6]. Giakatis, Enkawa and Washitani [30, p.182] add the dimension of quality loss in prevention and appraisal costs and distinguishes between quality cost and quality loss as follows:

> "…there is quality loss even in prevention and appraisal costs because they are not always so successful. In order to implement a prevention or appraisal activity, a company invests money. If this activity is successful, the company saves money, but if not, the company not only loses the invested money but also sometimes causes further losses. We name these kinds of quality losses prevention loss and appraisal loss, respectively. In addition, there is another important hidden quality loss that is large enough to overlook in rather well-organized manufacturing situation. They are what we name manufacturing loss and design loss. Quality cost is the cost for the company of every effort that sustains or improves the certainty that the product meets or will meet the specified requirements. On the contrary, quality loss is the money spent because a quality cost failed to sustain or improve certainty and hence non-conformances occur".

Goulden and Rawlins [31], from their implementation of the PAF model at GEC Alsthom Engineering Systems Ltd, state that the limitations of the PAF model are evident in two areas: the model itself and the company culture. Issues that arose during implementation were a lack of incentive for change and using quality costing as a punitive measure rather than a quest for long-term process improvement. Goulden and Rawlins argue that the model reinforces the view that the ultimate responsibility for the provision of quality lay with the quality departments, in that prevention is solely associated with the quality assurance department and calibration (*ibid.).*

C. The Process Cost Model

The process cost model focusses on processes rather than products. In the model the price of conformance is the cost involved in making certain that things are done right the first time, which includes actual prevention and appraisal costs; and the price of non-conformance is the money wasted when work fails to conform to customer requirements - which corresponds to actual failure costs [3]. The price of conformance usually represents about three to four percent of sales in well managed companies. The price of non-conformance, on the other hand, typically amounts to twenty percent or more of sales in manufacturing companies, and thirty-five per cent of operating costs in service companies [13]. The benefit of employing the process cost model is that its classification is simpler than that of the PAF model, making the categorization of cost elements easier in both production and service organizations [32]. A further advantage of the model is that discrete processes within a project can be costed, as opposed to costing of the entire project, thereby demanding fewer resources and less time before continual improvement initiatives are identified and implemented [13]. Despite these benefits, the process cost model has not been widely applied in industry.

Porter and Rayner [25] argue that neither Feigenbaum's nor Juran's schemes of quality cost categorisation cope with what is perhaps the greatest waste of resources in any organisation: the amount of management time that is spent on firefighting – performing a task which only exists because somebody did not do the original job right the first time. The cost to the organisation is not just the cost of wasted salaries and overheads, but also the cost of all the things that could have been done in the time saved – new products designed, new customers gained, better management decisions made. In response to these limitations, they propose that cost-benefit models be developed from the process cost model or PAF model that effectively integrate the costs and benefits of total quality management, showing how investment in quality can result in substantial future benefit. The authors, however, do not illustrate the implementation of the cost-benefit model in practice.

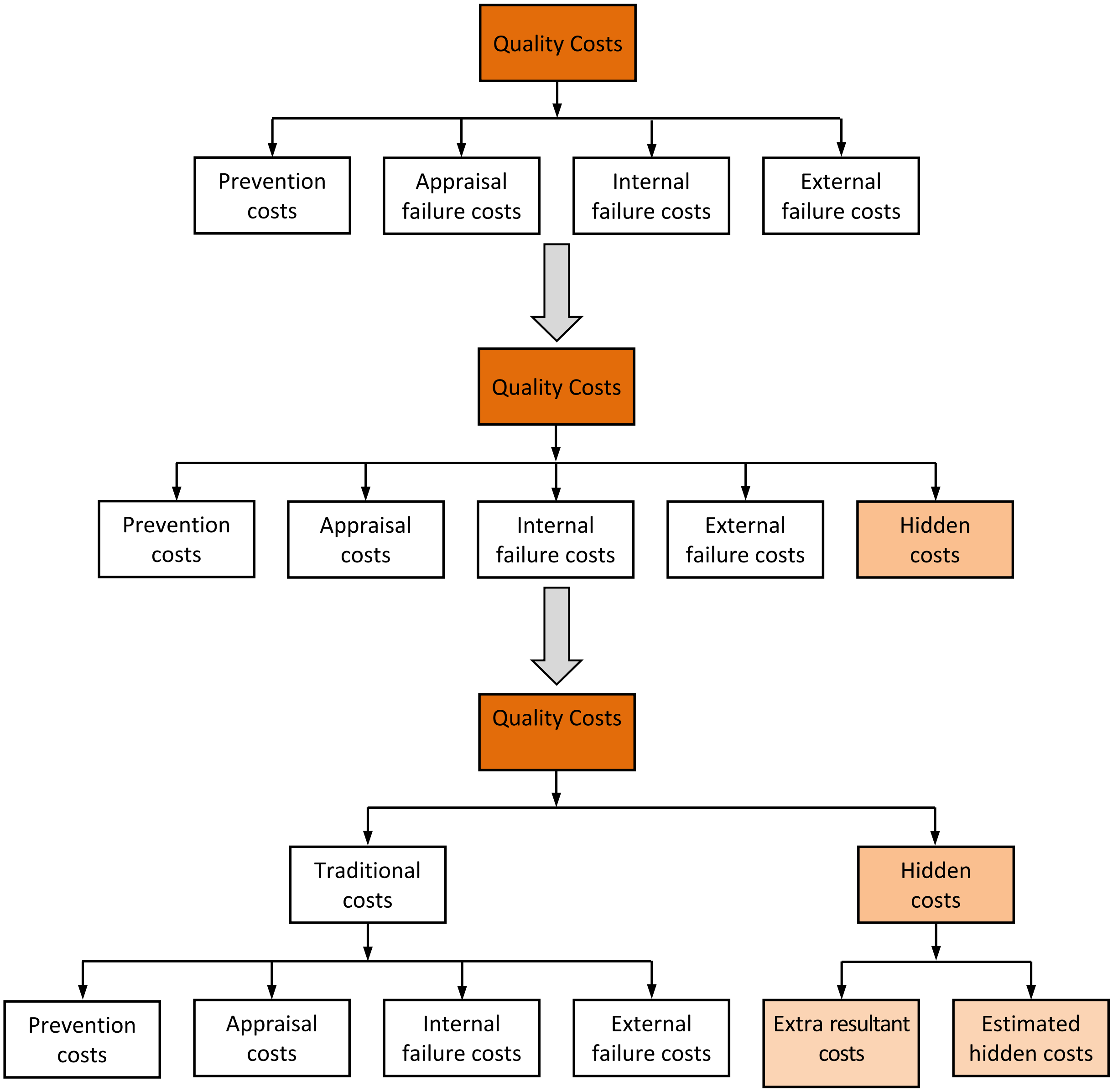

Fig. 6. The division of quality costs
(adopted from Yang, 2008:178)

III. Critique of Traditional Accounting and Cost Engineering Systems

Cost engineering is the discipline devoted to project cost management, including activities such as cost and control estimating, cost control, cost forecasting, investment appraisal, and risk analysis [33]. Cost engineers budget, plan and monitor investment projects, and they seek the optimum balance between cost, quality and time requirements. Today's organizations face growing pressure to control costs and enable responsible financial management of resources. In this environment, an organization is expected to provide services cost-effectively and deliver business value whilst operating within tight budgetary constraints. One way to contain costs is to implement a cost allocation methodology, where business units become directly accountable for the services consumed. Cost engineering was developed in response to the inability of traditional accounting to measure and monitor direct product, process and unit costs. In an extract from the AACE International on Quality Management, Chapter 23, Cokins [34, p.23.4] states the following:

> "….another part of the problem is deficiencies with the financial accounting system. The accountants' traditional general ledger is a wonderful instrument for what it is designed to do: post and bucketize (i.e., categorize) transactions into their specific account balances. But the cost data in this format (e.g., salaries, supplies, depreciation) are structurally deficient for decision support, including measuring cost of quality (COQ). The accounting community has been slow to understand and accept this problem."

But neither traditional accounting nor cost engineering systems are designed to capture the discrete cost elements required for an accurate and reliable quality cost data capture system. As example the cost of conformance requires the capture of costs associated with all quality activities that promote prevention and appraisal of quality such as inspection and vendor assessment. Accounting and cost engineering systems are not designed to identify such discrete costs and at best allocate a budget to the quality management department as a whole. One of the underlying principles of quality costing is that quality activities are not contained by the quality management (QM) department only, but may be exercised by personnel outside the QM department, such as the process of engineering design review. Furthermore, accounting systems do not measure the indirect costs of non-conformance to quality; neither the hidden costs of customer dissatisfaction as example.

Quality cost practitioners argue that neither the PAF nor process cost model provide an adequate method to allocate overheads to cost of quality elements and consequently recommend that activity-based costing or cost allocation used to overcome this shortcoming. Under ABC, accurate costs for various objects are achieved by tracing and assigning resource costs (including overheads) to products. ABC, however, does not consider process costs or costs external to the process and cannot therefore be employed as a proxy for quality costing.

Finally, the success of cost engineering and cost allocation methodologies is confirmed when the total costs allocated within or amongst projects reconcile with the final costs reported by the firm's accounting system. This requirement is not demanded nor true for quality costing since the quality cost system is a sub-system of the total and therefore cannot not be reconciled with the total costs per division or project.

IV. Design strategy of the QTrac cost system

Given the significant and very real limitations of quality cost models combined with the challenges of existing costing systems, it took several years to design, implement and test the quality cost models employed by QTrac. For three years the author designed and tested different quality cost models in Eskom, Africa's largest utility firm, with a team of engineers and quality professionals at various sites and in different divisions. In addition, benchmarking across various sectors and companies revealed that few quality cost models were employed by companies in South Africa: most firms only aim to measure the cost of non-conformance in production or projects. The most effective quality cost model found was a PAF allocation model operated and employed by Timken across its international operations.

After three years, two international companies, namely BIE International and PaCE Services, decided to join their expertise in quality management, quality costing and cost engineering to design the first global quality and cost management system for Projects and Manufacturing. Two years later QTrac for Projects and Manufacturing was released and is the first automated quality management and cost program that can identify and expose the allocation of resources for prevention and appraisal of quality, and recognize ineffective investment in quality in projects. QTrac ensures that the true cost of quality in a project is calculated and provides, perhaps for the first time in the history of quality costing, a metric that can be used for future cost reduction and continual improvement. Figure 7 illustrates how QTrac fits in a project life-cycle.

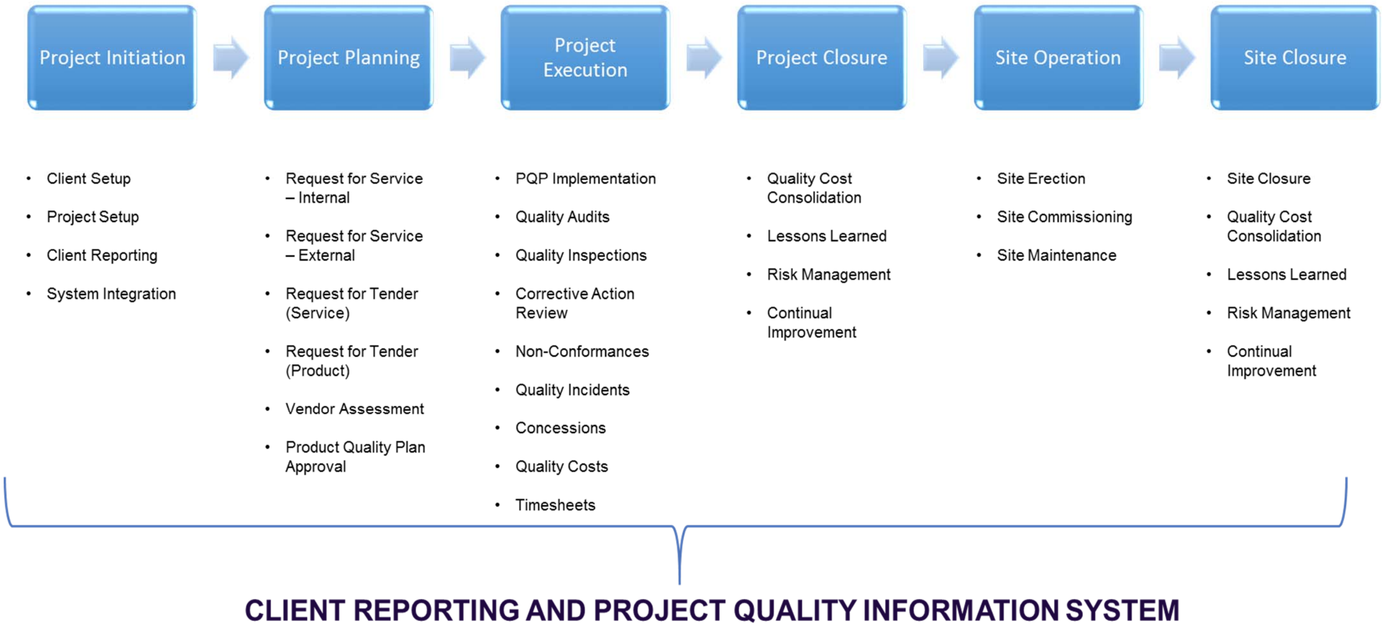

Fig. 7. QTrac in the project life-cycle

The design of QTrac considered the major criticisms of classic quality cost methods which include (1) the incorrect application of quality cost methodologies; (2) lack of data accuracy and reliability; (3) the exclusion of overhead costs; and (4) the exclusion of intangible costs or hidden costs. The first criticism, namely the incorrect application of quality cost methodologies, was addressed with the process design of QTrac. A team of experts with significant experience in engineering, quality management and project and quality costing was selected to model and develop process flows for project quality management. Once the operational processes were established, the quality processes were extracted and standardized across the different stages of project management. Quality processes included *inter alia* vendor assessment, inspection, audits, corrective action reviews and lessons learned. Quality cost models were then integrated with the quality processes to ensure the capture of all relevant quality activities and costs. The standardization of the quality cost processes confirmed that the quality cost methodology originally designed remained consistent and valid across the operations.

The second criticism of data accuracy and cost reliability was mitigated with the design of the input templates of the quality cost system. QTrac promotes data accuracy and cost reliability with predefined parameters during cost entry by employing hard and soft data validations for all input and report parameters. Also, the structure of the input templates was standardized to promote data entry accuracy and user-friendliness. The budget process was used to record the budget at Front End Loading Level 3 which requires a ninety to ninety five percent accuracy as per the Association for the Advancement of Cost Engineering classification. The system minimizes cost estimation - and cost allocation is only considered in the division of overhead costs and external failure costs. Cost data is validated by (1) linking the quality deviation and associated cost with the original quality activity to ensure an audit trail of the cost of non-conformance; and (2) including a document that substantiates the cost amount.

Data accuracy in the design of the costing system was further supported by:

- Clearly defining a task and making classification of work on the timesheet as easy and simple as possible.
- Standardizing all tasks in the system.
- Linking a task in a timesheet directly to a cost category by prior identification of the task as a prevention or appraisal cost.
- Assigning predefined, standardized tasks to the assignee to limit choice of tasks.
- Ensuring transparency in cost collection.

- Providing an audit trail as a proxy for document and data control.
- Ensuring security of attached documents.

It is important to note that one hundred percent data accuracy can never be guaranteed with the use of data entry programs and that data input is always dependent on the professionalism, knowledge and willingness of the quality practitioner using the system. In addition, it is incumbent on the organization to implement the relevant change management, training and processes to promote the accurate and reliable use of the system.

The final criticisms of classic quality cost models are the exclusion of overhead and intangible or hidden costs in the quality cost models. In the design of QTrac overhead costs were considered to form part of the rate charged by personnel for the cost of conformance to quality and may be included as a percentage of personnel hourly rates. The quality defect models, namely incident costing and non-conformance costing, are two primary costs of non-conformance captured by the system. The input forms for both models were designed and tested over a three-year period prior to the design of QTrac in a production environment to ensure their functionality and to determine the challenges of data entry. External failure costs are linked to all deviations in quality and the costs are validated by an enforced link to supporting documentation, as well as approval by senior personnel. The capture and reporting of quality cost data are both transparent and traceable and the QTrac PAF cost philosophy is demonstrated in Figure 8.

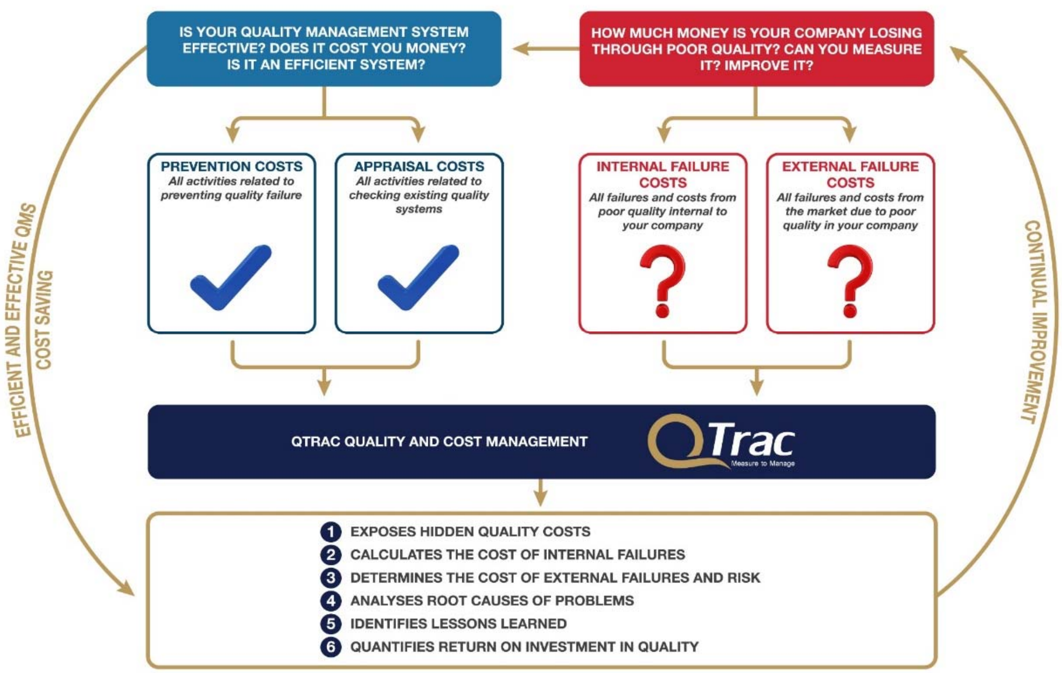

Fig. 8. The QTrac design philosophy

V. CONCLUSION

Case studies demonstrate that quality costing can contribute up to twenty percent of turnover in manufacturing and fifteen percent of total construction costs in projects. To date industry has been unable to measure and apply quality costing effectively and its value has been diluted by the inherent challenges of cost methodology and traditional accounting systems. QTrac offers solution to these challenges as an automated quality and cost management for projects and manufacturing.

The ultimate value of QTrac, however, lies in the conversion of quality cost data to lessons learned which enables improved business and investment decisions and continual improvement. Not only does the contribution of QTrac lie in the decision-making value of the model, but also in the operationalization of the PAF quality cost methodology in project management – the first quality cost model of its kind.

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BIOGRAPHY

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