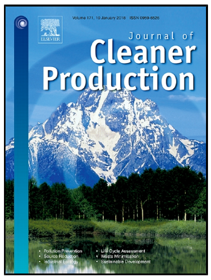

Cost of quality and process model: improving accounting tools for attaining higher environmental efficiency

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Cost of quality and process model: improving accounting tools for attaining higher environmental efficiency

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Abstract

The article, based on a case study of pig farming in France, examines water and air pollution, and finds that, in a traditional system of allocating costs, individual socio-economic actors would shoulder higher repair or restoration costs instead of prevention costs. It shows the importance of prevention for a higher environmental efficiency and adopts a broader view than just the individual economic actor, utilising a process model covering an entire chain of pollution costs (including different stakeholders' objectives and cost structures), beginning with natural resource degradation as an input and ending with the output delivered to "end users" (stakeholders who endure pollution effects). This article suggests a methodological framework that allows a *rapprochement* between socio-economic actors – those polluting and others, suffering pollution in a more economically efficient manner: Cost of quality (CQ) and process model concepts can be used for public decision-making, supplanting standard welfare economics approaches. It is demonstrated here that those concepts can establish a concise and realistic economic basis for natural resource management, and enable better decision-making on efficient investment in environmental protection.

Key words:

Pollution prevention, pollution abatement, environmental cost accounting, cost of quality, process model, quality management.

1. Introduction

A narrow view of environmental issues led to considering them as a battle between business and environmental interests with ensuing power struggles and litigation (Porter & van der

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Linde, 1995) and resulting in heavy cost for the interested parties, society, and the environment.

Different approaches have been tried to measure these costs and discuss how best to reduce them. According to the economic approach of the environment, the choice of disposing waste and remedying the environmental pollution it causes needs to be economically efficient. While there is broad consensus on this basic condition, it is not clear as to which costs should be included, how they would have to be measured (Curkovic et al., 2008), whether certain costs are to be preferred over others, and lastly, what time horizon should be chosen in order to arrive at this objective. Consequently, most economic activities result in untreated pollution, creating deferred economic cost (ecological debt).

Quality Management (QM) has become a mainstream managerial approach for improving products, services, and business processes in order to generate superior customer satisfaction and pursue competitive advantage (Dahlgaard-Park, 2015). This advantage is achieved by the methodical reduction of dissatisfactions, waste and resulting costs. Some researchers have attempted to translate the notion of cost of quality, derived from quality management, to measure the costs associated with the environmental management of companies. These articles describe an environmental management mainly focused on curative actions while quality management considers that preventive actions are more economically efficient.

These approaches have in common their focus on business accounting of an individual entity. Their economic analysis is limited to a single link (polluting company to their customers). Yet this link is part of a much more complex process, and not including upstream pollution “suppliers” that degrade natural environments, and the stakeholders and downstream society that suffer from this degradation.

This article seeks to clarify the efficiency criteria for disposing waste by using the concept of cost of quality (CQ) and process model methodology, derived from quality management.

The article’s findings, based on a literature review and on a pollution cost analysis for pig farming activities, describe inefficient outcomes from environmental and stakeholder perspectives. It is therefore suggested, with the help of the process model and cost of quality concept, to overcome this individualistic perspective with its negative results for all stakeholders concerned and the environment by focusing the actors on reducing the costs of environmental quality of the whole process concerned and by investing on preventive actions.

The proposed methodology has the great advantage of being helpful for resolving environmental problems in a mutually beneficial manner.

The article is divided into six parts: In section 2 the methodology used for the case study is presented: the cost of quality and process model concepts according to quality management are defined. These concepts are at the root of the "cost of environmental quality (CEQ)" methodology utilised here.

Section 3 describes the current economic theory and researches behind waste disposal and its remedy (pollution control), arguing how pollution prevention measures should be regarded in order to occupy a more important place among the different categories of costs of pollution. It is this last insight that makes the quality management concept of "cost of quality" an interesting addition to environmental economic theory and (public) environmental accounting. Following that, the article discusses how cost of quality measures are used in existing studies of environmental cost evaluation.

Section 4 is taken up by an analysis of pollution costs generated by pig farmers in the Southwest of France, where the inefficient relationship between pollution restoration costs and pollution prevention costs becomes clear.

The article's section 5 discusses difficulties and obstacles when applying the cost of quality methodology to environmental process management, and gives suggestions as to how to ameliorate cost accounting tools, so that prevention costs can become a preferred choice over repair/restorative costs.

In a final section, the article discusses the consequences of taking on an overall "cost of quality approach" for negotiations between polluters and polluted, where the realisation of shared interests might change a relationship often characterised by adversity into one of partnership.

2. Methodology

Improving processes by reducing failures and their costs is the most common quality approach to increasing competitiveness and efficiency. These concepts are defined below and then transposed to the environmental field.

2.1 Cost of quality

The origin of the cost of quality (CQ) concept dates back to Juran (1951/1999) and Feigenbaum (1956). The latter proposed its decomposition into the following three costs (Feigenbaum, 1956, p. 99):

> "1. Failure costs (FCs) are caused by defective materials and products that do not meet company quality specifications. They include such loss elements as scrap, spoilage, rework, field complaints, etc." These costs are usually broken down into the external (EFCs) and internal (IFCs) costs of non-compliance.
>
> 2. "Appraisal costs (ACs) include the expenses for maintaining company quality levels by means of formal evaluations of product quality. This involves such cost elements as inspection, test, quality audits, laboratory acceptance examinations, and outside endorsements."
>
> 3. "Prevention costs (PCs) are for the purpose of keeping defects from occurring in the first place. Included here are such costs as quality control engineering, employee quality training, and the quality maintenance of patterns and tools."

In the following, Feigenbaum's quality costs structure (CQ = IFC + EFC + AC + CP) which is generally recognized and accepted (Schiffauerova & Thomson, 2006) will be adopted. The case study will also include in its cost evaluation intangible FCs (Juran, 1951/1999) which take into account the loss of economic opportunities and decreasing revenues owing to failures (Schiffauerova & Thomson, 2006).

The cost of quality concept has been widely applied in the business world to reduce the "hidden plant" consisting of all the activities that do not provide value added to customers or stakeholders.

Management of an activity, process or system is considered efficient when cost of quality is minimal for a given quality requirement. In practice, the main lever to improve efficiency is reducing FCs through developing preventive actions. Cost of quality decreases as PCs increases up to a threshold where it stops decreasing. Gibson, Hoang & Teoh (1991) graphically represented the optimal investment in prevention that has been also used by Finkler (1993). The "cost of environmental quality" is simply the CQ concept applied to environmental management.

2.2 Process model applied to environmental cost evaluation

According to the international definition, a process is an aggregation of “linked activities which transform inputs into outputs” (ISO 9001, 2015, p. XVI). In process management “control shifts from vertical hierarchy to horizontal process flow” (Spencer, 1994, p. 457).

The process approach is a more efficient way for achieving predictable results (ISO 9000, 2015). In the environmental field, the desired result obviously is the reduction of pollution and nuisances. Therefore, the desired environmental outcomes are achieved more efficiently when activities and related resources are managed as a process; hence this article looks at the effects of human activities on the environment as a process. This process must add value (ISO 9000, 2015, Note 4), which in quality management corresponds to the improved satisfaction of customers’ and other stakeholders’ requirements. Therefore, the process of environmental pollution will be defined according to end users’ requirements, and FCs, PCs and the CEQ can be deduced from this framework.

A process model is the preferred model for quality costing within Total Quality Management (Schiffauerova & Thomson, 2006). According to these authors, the process model focuses on process rather than products or services, and process cost is the total cost of conformance and non-conformance for a particular process.

A process is usually described through a process work sheet (Parsley & Corrigan, 1999, adapted from Crosby, 1989). Such a work sheet is used below in the pig farming case study to formalise the pollution process, and it includes the following:

- Definition of the external customers and stakeholders, of their requirements and of the process performance measurements. External failures represent the gap between environmental outputs and their requirements;
- Identification of the suppliers and of their activities (input). Suppliers’ nonconformance to requirements is an internal failure.

In the case study below, the process performances are evaluated in terms of failures and then costs of failures.

2.3. Stakeholders focus

Quality management tools (ISO 9000 standards, models of excellence such as the European Foundation for Quality Management [EFQM] model and the Common Assessment

Framework [CAF]) are not just client-oriented, but include other principal stakeholders as well: personnel and civil society (societal responsibility). The case study below evaluates relevant costs of quality by considering pollution effects on all of the concerned stakeholders. The usefulness of identifying stakeholders' requirements as a tool to measure and improve environmental impacts have been shown for instance by Bouwer Utne (2009).

3. Optimal pollution, welfare economics, and firm environmental cost accounting

3.1 A closer look at the abatement-damage cost relationship

According to established economic theory applied to welfare economics, two different costs of waste disposal (causing pollution) are accounted for: First, there are the costs *caused by* existing pollution, that is, of untreated waste that has been discharged and that is not 'depolluted'. This is the well-known environmental damage curve, expressed in the form of marginal environmental damage. Damage costs therefore would be defined as the quantifiable and non-quantifiable costs that existing pollution that is not cleaned up imposes on economic actors in a given system. Second, total waste disposal costs include the costs incurred for *treating* pollution. In Hussen (2012, p. 186ff), as in many other welfare or environmental economics text books, this cost is called "pollution control (abatement) cost", in the form of marginal abatement cost. The sum of abatement costs and damage costs would make up the total cost of waste disposal causing pollution, and the minimum point of the latter's graphical representation (cf. Fig. 1) would be called the socially "optimal level of pollution" (Hussen, 2012, p. 186-198).

[place Fig. 1 around here]

Thompson (1998), applying the above reasoning to water quality management, further breaks down abatement costs: he calls this cost category the sum of "cleanup and prevention costs", graphically represented in the form of "marginal cost of removal" (Thompson, 1998, p. 170), analogous to marginal abatement cost. The classical approach of opposing damage costs and abatement costs is still considered valid, precisely because it allows finding an "optimal level of pollution" (also cf. Bachmann, 2014, p. 8-10, 15), therefore, obeying the criterion of efficiency (OECD 2013, p. 38-44).

The difference between economic theory and quality management, and the point of this article, lies in a more differentiated assessment of pollution abatement, which, according to welfare economics, includes both restoration and prevention costs, as was shown above, but lumped together indiscriminately. Thus, the valuable insight coming from quality management theory and practice would be to not only make a cost comparison between damage costs caused by pollution and costs of pollution abatement, but crucially, *within* the different cost categories of pollution abatement, between the costs of "depolluting" (cleanup) compared to costs of avoiding the pollution altogether (prevention), even at source.

Pollution prevention, according to Allen & Sinclair Rosselot (1994, p. 4), citing the Illinois Toxic Pollution Prevention Act of 1989, is defined as follows:

> "…in-house practices that reduce, avoid or eliminate the use, generation, disposal, release or manufacture of toxic constituents. It can be achieved through:
>
> 1. input substitution,
> 2. product reformulation,
> 3. production process redesign and modification,
> 4. production process modernization,
> 5. improved operation and maintenance,
> 6. recycling and reuse."

If the objective to be attained is "quality", then the two respective cost categories would be, on the one hand, restorative costs or repair costs that, added to the costs of damage, are called in quality management, "cost of non-quality", and, on the other hand, costs such as prevention and appraisal costs. The activities of "restorative or repair costs" that Allen & Sinclair Rosselot (1994) "expressly excluded" from prevention fall into the quality management category of "repair costs", and thus, "costs of non-quality". The sum of the two cost categories of prevention, appraisal and non-quality costs would make up the total 'cost of quality'. As seen above, for company quality managers and cost accountants, prevention and appraisal costs are considered investments, whereas repair costs are considered (useless) waste, as quality defaults have to be rectified. Thus, while welfare or environmental economics does not distinguish the costs of damage or restoration and the costs of prevention and classifies them together in abatement costs, quality management and lately, business cost accounting literature (cf. e.g., Blocher et al. 2005), insists on their difference: damage or restoration costs are referred to as loss because quality was not produced from the outset without errors and it is necessary to remake what was not done well the first time. Prevention costs, on the other hand, are aimed at eliminating the cause of non-quality for obtaining a lasting quality.

The x-axis that in Fig. 1 reads “waste emission” becomes “(environmental) quality” in quality management, that is, the inverse of waste emission. Thus, whereas in the abatement-damage cost trade-off of Fig 1 the total costs were a function of the level of waste emission (pollution) to be tolerated, the “cost of non-quality”-prevention cost relationship of Fig. 2 depicts total costs as a function of quality, that is to say, the *absence* of failure (i.e., pollution).

[place Fig. 2 around here]

The (marginal) prevention-“non-quality” relationship of quality management is thus nothing other than a more detailed analysis of economic theory’s marginal abatement or pollution control cost curve. The idea of enriching welfare economic theory with concepts from quality management is to make clear the fact that not all pollution abatement costs have equal value, regarding their different effects on the environment, stakeholders and society. Quality management reasoning places a higher value on pollution prevention compared to pollution cleanup, as pollution prevention measures are considered to be more effective than repair measures for attaining the objective of sustainable environmental quality.

In the following section, the current use of quality management concepts in environmental accounting will be discussed.

3.2 Existing studies using cost of quality for environmental cost evaluation

Only few attempts have been made to evaluate the human impact on the environment using CQ or concepts that come close it.

In their overview of studies conducted in the field of environmental management accounting, Berland et al. (2009) mention the classification of environmental costs by Farley et al. (1997), based on five components: evaluation costs (corresponding to ACs), prevention costs, control costs (included in ACs), correction costs (corresponding to FCs) and image costs (also included in FCs). Blocher et al. (2005) discuss four cost categories: PC, AC, IFC, and EFC, an approach directly derived from total quality management and introduced first into environmental cost accounting with e.g., Smith (1990), and Hughes & Willis (1995). The latter recommend investing into PC and AC, in turn leading to a greater reduction of IFC and EFC (cf. also Kitzman, 2001).

The main difficulty encountered in implementing these environmental accounting approaches in companies is the lack of a coherent operational framework to identify and measure the costs, according to Curkovic et al. (2008). Thus, the latter authors detail a list of environmental costs using the four CQ categories mentioned above.

Banasik & Beruvides (2012) expand on this effort and apply the CQ methodology to water utilities. Based on three case studies in the US, the authors conclude that on average, PCs represent 20.3% of the total cost of quality and that FCs could be as high as double the amount of PCs.

The blind spot, however, in all these approaches is their focus on business accounting (for the individual firm). The cost classification adopted in Banasik & Beruvides (2012) reveals the missing items: activities concerning ground water resource protection, resource protection division, conservation costs, water protection, water conservation and costs are accounted for as PCs and borne by the water utilities. Yet these costs are caused by the degradation (or the risk of degradation) of water resources caused by upstream economic actors. Since these actors do not appear in the adopted accounting scheme (which only focuses on water utilities), their liability is not identified.

This pattern was often found in traditional organizations prior to the introduction of quality management, and especially before processes including businesses and their suppliers were formally identified and managed.

Studying the effects of agricultural pollution on water resources in three French *départements* (roughly equivalent to a county in the US and in the UK), Barouch & Claudez (1995) adopt a broader perspective than in the previously mentioned studies by describing the environmental quality chain using a flow chart to formalize the customer-supplier relationship, and they arrive at the conclusion that expenditures for pollution prevention only amount to between 10-20% of the total costs, the rest being comprised of failure costs, that is, costs of non-quality. The theoretical basis of the environmental economics and of the CQ and process model in quality management, however, was not developed. Also, Barouch & Claudez (1995) left open the question of whether similar conclusions could apply to environmental issues other than water resources.

Finally, this article considers that there is an "environmental" process finalized towards end users' requirements, and thus a customer-supplier relationship; yet, pollution is unintentional, it is a side effect of suppliers' activity. In the following, the use of a process model in an environmental context will be discussed and explained.

In summary, environmental costs evaluations using the cost of quality concept are scarce. Studies applying cost of quality evaluation to water pollution highlight the relatively low PC/FC ratio, which describes an environmental management mainly focused on curative actions in the cases studied in the US and in France. Environmental accounting or cost of environmental quality accounting when focusing only on companies results in a transfer of hidden costs. The application of cost of environmental quality to the entire water quality production chain corrects this flaw. The following section discusses, with the help of a case study, how the process model can be applied to various pollution problems and shows how the cost of quality framework can be useful when applied to pollution issues from pig farming.

4. Pollution cost appraisal for pig farming activities in Southwestern France

The ensuing case study discussion is aimed at extending the research by Barouch & Claudez (1995), applying the cost of quality and process model approaches developed there to pollution caused by pig farming.

A significant environmental trend is for organizations to choose suppliers on the basis of environmental criteria by imposing their requirements and applying different selection methods (Govindan et al., 2015). However, unlike commercial relations between organizations where the customer can impose his selection criteria on suppliers, in many situations, no such contractual relationship binds the polluters ("suppliers of pollution") to the stakeholders who suffer them ("end users"), and the regulatory mechanisms sometimes seem inappropriate confronted to the complexity of local situations. The central idea of this case study is to create the conditions for a mutually beneficial contractual relationship between polluters and the victims of pollution by using the CQ and the process model.

4.1 The pig farming context in the Tarn region

At the time of the collection of the data presented below (1998), pork prices had been at their lowest level for twenty years and pig farming had a negative image due to Breton pig farming noted for polluting groundwater and spreading bad odours in the environment so that the development of the entire pig farming industry was at a standstill.

In the Tarn region, unlike in Brittany, pig farms are family sized, less polluting due to their low density and benefit from an exceptional site, the village of Lacaune, where the air is particularly suitable for drying ham, which has helped develop the pork salting tradition in this region dating back to the Middle Ages.

To promote this tradition of quality, the Tarn producers strove to obtain a quality label; if succeeding, this would be likely to lead to a significant increase in demand and doubling Tarn pig production.

This project was instigated six years earlier, but the residents' associations that had formed in the meantime complained that the public administration did not adequately respect regulations on the size of pigsties and that these regulations was poorly designed since they allowed farmers to install pigsties a hundred meters from dwellings regardless of the wind direction.

4.2 Transposing CQ and process approach to evaluate the cost of pollution and nuisances caused by Tarn pigsties

4.2.1 End users' and stakeholders' environmental quality needs

Thus, according to the process management model, end users' needs must be defined at the outset. The main environmental qualities required by end users are the following:

- The residents and the fishing and nature protection associations wanted pollution and nuisances eliminated.
- In a more extended approach, the mayors and the *Conseil Général* (*département* executive) sought economic development and employment. Yet the environmental problems caused by pigsties had contributed to slowing down pig farming related activities and hence the territory's economic development.

4.2.2 Quality (or non-quality) suppliers

Pig farmers are causing environmental failures (pollution and especially odours related to spreading pig manure); yet in a more extended approach, they also are customers pursuing the economic development of their sector blocked for environmental reasons and seeking to resolve this environmental blockage.

4.2.3 The formalisation of the environmental process

The following table, adapted from Crosby's process model worksheet (Parsley & Corrigan, 1999; Crosby, 1989) sums up the situation:

[insert Table 1 around here]

According to this model, the end users' requirements pull the process. The gap between inputs, outputs and finally, end users' requirements is a non-quality (a failure) that will be measured in the next section. Both farmers and polluted environment – upstream suppliers - are responsible for these non-qualities.

4.2.4 CEQ Evaluation

The table below (table 2) was obtained from evaluating the economic consequences of pig farming nuisances and pollution. The currency used at the time (francs) has been converted to euros. Note that these data should be multiplied by the inflation coefficient (1.27) to get today's corresponding value. As stated in the first part, "cost of environmental quality" is the CQ applied to the process of environmental pollution that is analysed here.

[insert Table 2 around here]

4.2.5 Details of this calculation

<u>Internal failure costs: €160,000 p.a (€45,000 + €90,000 + €22,000 + €2,000)</u>

Internal failure costs = investments made by farmers to reduce odours = cost of landfill material + cost of reduction of manure odours + cost of oxygenation

- **2 investments of landfill material** on average per year over the last 3 years, usually through the cooperative: cost of the two equipments (€450,000) depreciated over 10 years: **€45,000 p.a**. This figure is slightly overestimated as this amount also partly concerns cattle breeders who use some of this material.

- Half of the breeders use **bacteria to liquefy and reduce manure odours**: the cost of the bacteria (1.2c / or 1.5c per kg) for (approx) 60,000 pigs x 100kg in average/pig**: €90,000**.

This figure is overestimated because part of this investment is the dilution of slurry for non-environmental reasons.

- 15 farms are equipped with **oxygenation:** the cost of oxygenation is between 0.75c to 3c / kg depending on the size of the tanks (we chose an average of 1.8c) x 12,000 pigs x 100 kg / pig: **€22,000**.

- **Spray misting**: 1 farm: **€2,000** p.a.

The latter actions have been considered as FCs because they consist of curative actions aiming at reducing the odours of manure. A preventive action would be for instance pig farming on straw which suppress odours.

External failure cost (EFC) estimate: €4.25M (€ 30,000 + €15,000 + € 3.4M + € 805,000)

Pigsties EFC = cost of legal proceedings + cost of depollution after an accident occurred + cost of nuisances + losses of economic activities

a) Cost of legal proceedings: €30,000

Cost of proceedings by resident **(**€7,500 x 2) **+** cost of legal proceedings for farmers (€7,500 x 2) = **€30,000**
Comment: This figure may be overestimated because such proceedings do not occur every year.

b) Costs of depollution: €15,000
- **Cost of eliminating accidental pollution**: €7,500
- **Cost of re-stocking the river with fish after pollution**: €7,500

c) Cost caused by nuisances = cost of loss of enjoyment + cost of depreciation of the property: €3.4M
Loss of enjoyment: 10 “black spots” (villages where odours generated local opposition)
x average value of property (€68,000) x annual value of the enjoyment (5%) x average number of properties per village (100) (corresponding to 300/400 residents) = €**3.4M**

Comment: There is an obvious difficulty in calculating this failure cost leading to significant simplifications.

The cost of depreciation of the property (20% from notarial sources) was not added because the average number of annual transactions could not be obtained.
Therefore, the cost of nuisance proposed here is underestimated.

d) Estimate of loss of economic activity: €805,000

- **Cost of the loss of jobs**: job creation for young farmers. The number of pig farms not taken over in one year (3) x cost of an unemployed person €15,000 = ***€45,000***
- **Obstacle to the development of their village** due to the presence of pig farms: number of municipalities affected in their development (one) x average value of building plot (€20,000) x number of building plots (15) x depreciation rate (20%, from notarial sources, see just above) = ***€60,000***

Comment: it is assumed that this is an annual flow which may be exaggerated: thus the cost of failure may be overestimated.

- **Loss to the development of the farming economy**: number of development projects or installations blocked (4) x average turnover of new pigsties (€174,000 in 1998) = ***€700,000***

Comment: the gains related to restoring the pig farming image have not been evaluated. Thus, the potential benefits related to restarting the industry are probably underestimated.

Prevention costs = cost of public investment for water protection equipment among farmers: €300,000

- **P.M.P.O**. (Plan for Pollution Control): A public plan aiming to upgrade livestock farmers' water protection equipment: **€300,000** per year (public services source).

The costs detailed above are annual costs. Yet a few costs were observed when the data was collected where it was not certain that they occurred every year, for instance legal procedures or accidental pollution treatment.

To these costs should be added the PCs that are not quantifiable at this stage:

- Impact study costs.
- The cost of information on preventive actions.
- The cost of meetings and consultations.

4.2.6 Analysis of costs and their comparison

PCs are around €300,000, making them 7.9% of the €3.84M for direct FCs and 6.1% of the €4.21M for the total CEQ. Significantly, most internal FCs and PCs were incurred in the last 3/4 years reflecting the rise in environmental concerns amongst farmers and the development of national policies aimed at water resources protection from pig pollution. These figures show that PCs are clearly much lower than FCs. Note that the PCs were ascribable to water pollution prevention, whereas in Tarn most FCs relate to odours. No ACs were identified in this situation.

4.2.7 Lessons learnt from the case study

In sum, the process model shows clearly how an environmental input is transformed into an environmental and social output, and the dissatisfactions and the costs which go along with this process. The low ratio of PCs/CEQ, the conflictual situation on the field and the lack of proper management of this process indicate that its maturity is 1 (basic) according to an AFNOR (2005) typology from 1 (basic) to 5 (excellent).

Collaboration between environmental quality suppliers and users is thus encouraged by the potential gains from reducing external and internal FCs. In France, the case of Evian has been the most prominent in this respect (cf. Defrance, 2015): the company created partnerships with local farms and villages, leading to contractual relationships that help implementing less polluting agricultural practices. The Evian company paid out financial compensation in return for reduced pollution by agriculture and other activities. This has enabled the firm to keep its "Natural Mineral Water" label, underwritten by French legislation. Out of the total budget of around €700,000 p. a. allocated to the project by different stakeholders, two thirds of this sum was borne by Evian. The investment into pollution prevention was judged to be much more cost-efficient for the firm than bearing restoration costs or shouldering the risk of losing the "Natural Mineral Water" label, which for a worldwide brand could run into hundreds of millions of Euros.

5. Discussion: Five difficulties must be overcome when measuring CEQ

Implementing the CEQ and process model concepts into environmental processes supposes to overcome the following difficulties.

First, necessary economic information is not always readily available. Data are generally not organized according to CEQ measurement needs. Further, these are generally dispersed among various actors (public services, private businesses, individuals) and thus difficult to collect in full. Finally, not all costs are measurable and this research thus limited itself to the quantifiable aspects of external environmental 'non-quality'. For instance, the bad image of pig farming resulting from its pollution and nuisances has not been quantified, even though this cost may be significant.

Second, measurements are sometimes imprecise and agreements with the relevant stakeholders may be needed in order to identify a shared and useful evaluation. Third, it may be difficult to assign a particular environmental cost to a (non-quality) supplier. For instance, Barouch & Claudez (1995) use a percentage given by local experts to evaluate the agricultural pollution impact compared to other sources of pollution.

Furthermore, it may be difficult to include all the curative or preventive actions in the economic sphere as some behaviours may be motivated by personal (for instance ethical), and not economic reasons.

Consequently, some CEQ elements could not be evaluated and the CEQ measurements proposed here are therefore based on approximations, meaning that the above-measured FCs are very likely to be underestimated. PCs can be more easily identified, as these are largely present in business accounts or public budgets. Although approximate at this stage, these data bring to light the hidden costs of the environmental quality process and the challenges to be met to define efficient environmental policies.

The difficulties in evaluating cost of quality are not specific to the environmental processes studied here. The problem also exists in private companies for the following reasons: lack of cooperation between a company's different organizational units, difficulties in accessing precise financial data, cost of quality program personalization, difficulty in standardizing the cost of quality approach across companies (Rasamie & Kanapathy, 2011). Moreover, some costs are hidden (Deming, 1993) and do not appear in company information systems (Savall & Zardet, 2001).

The last difficulty to discuss concerns pollution restoration costs that, compared to prevention costs, seem to be easier to account for and to budget: Restoration costs are reactive, locally circumscribed, and planned and executed for the short term, and therefore they will not bind excessive amounts of capital, in turn minimizing short-term costs for individual economic actors responsible for cleanup on a local scale.

In the absence of a clear description and evaluation of the process that links environmental quality suppliers and end users, the restoration of environmental quality degraded by man – which constitutes a failure cost (a loss) – is accounted for as increased activity for businesses and supplementary wealth for a country. That mistake is caused by the partitioning between the actors sharing the same environmental process. Consequently, what is destroyed by an economic agent is restored by another one and the country is supposedly richer.

This leads to the commonly observed phenomenon of costs of pollution being externalised from polluters to economic actors suffering from that pollution, or even society in its entirety. Therefore, "optimal pollution", the seemingly rational solution from the current standpoint of short-term and direct cost evaluation, leads to excessive pollution from a national, regional and global view of sustainable development, and to deferred economic cost.

6. Conclusion and perspectives for future research

6.1 Conclusion

Environmental issues are often considered as a battle between business and environmental interests. This situation was also observed in the Tarn study.

Analysing the problem under the very different and therefore innovative perspective employed here (environmental process overall cost of quality), might help transform the usually conflictual situations of "polluter-polluted" into a mutually beneficial game (in the sense of Porter & van der Linde, 1995). The methodology proposed here is to reframe the environmental problems according to the cost of quality and process model concepts. Natural environments link suppliers and end users of environmental quality. In this article, cost of quality is applied to a specific environmental issue: pig farming pollution and nuisances. The environmental process under observation consists of independent or non-cooperative entities that generally ignore their common interests: in traditional management, businesses and their suppliers often find themselves in similar situations. Consequently, the hidden costs produced by suppliers are assumed by intermediate and end users. Using a process analysis focused on stakeholders' requirements, this approach brings clarity, unveils the concealed liabilities and estimates the global costs of an environmental process.

Viewing prevention costs in relationship with failure costs (PC/FC) or overall costs (PCs/CEQ), these ratios are good indicators of the success of environmental policies: in studies using CEQ measurement for a single company, as well as in this case study, the situations were clearly oriented towards curative actions (not preventive actions) and lacked the appropriate supplier/customer process management tools.

The absence of shared specifications and objectives between suppliers, customers and stakeholders of environmental quality as they exist in the economic market today creates uncertainty that prevents actors from choosing effective strategies. For instance, pig farmers who invested in the fight against bad odours did not satisfy local residents since common specifications were not previously agreed upon and these farmers were therefore doubly penalized in their efforts. Quality management costs and process tools could be this common language and these specifications that will help all stakeholders to focus on the aim of reducing the FCs and CEQ for the benefit of all.

To sum up, CEQ evaluation based on a process model can, on the one hand, help provide comprehensive environmental cost measurement and ratios. Firstly, CEQ performance indicators associated to process model establish a concise economic basis for natural resource management. Further, PC/FC and PC/CEQ ratios can provide a better picture of the overall situation of waste disposal (either curative or preventive). Thirdly, the overall efficiency of the proposed environmental management strategy can be assessed: with decreasing CEQ, the environmental management process attains both a higher degree of maturity, and becomes more sustainable. A higher state of maturity would, for instance, be observed when numerous mutually beneficial relationships between environmental quality suppliers, users, stakeholders and the society are being established and managed, which is coherent with the seventh principle of ISO 9000 (2015) and with Quality Excellence models.

On the other hand, CEQ enables better decision-making on efficient investments in environmental protection, as assessment of returns on investment (ROI) is more detailed, and thus, objective. Unlike welfare economics applied to the environment, this approach clearly distinguishes between restoration costs and prevention costs and therefore makes it possible to identify more precisely the optimum efficiency of environmental protection.

The originality of this research lies not only in providing a more adequate means of monetary measurement, and thus rendering the issues related to the degradation of natural resources more visible to managers, but also in putting forward a consensual (not an adversarial) goal:

to reduce environment-related global FCs. All these possibilities and objectives have been out of the reach of traditional public environmental accounting tools.

Lastly, it should not be forgotten that CEQ is in the hands of the economic actors concerned, who will be able to identify and allocate costs, and thus returns on investment. Government agencies will be able to undertake an economic evaluation as a necessary precondition for creating and promulgating new laws and regulations.

Classic approaches define environmental value by creating either theoretical markets (e.g., Halcon, 2012) or an artificial value for natural assets (e.g., Costanza et al., 2014). This article's approach based on real end users' and stakeholders' requirements and on tools commonly used by businesses (cost of quality, process management) does neither, making it both pragmatic and workable.

6.2 Perspectives for future research

In the absence of a clear description and evaluation of the chain that links environmental quality suppliers and end users, the restoration of environmental quality degraded by man – which this article contended constitutes a failure cost (a loss) – enters national accounts as increased activity for businesses, and thus forms part of a country's wealth creation. This may explain difficulties in improving the environment. Correcting this common mistake would lead to re-evaluating the GDP accordingly.

Halevy & Naveh (2000) are the first to extend the concept of the 'cost of non-quality' to national accounts. Their work based on Israel's GDP shows that an estimated 30% of the national product is wasted due to poor workmanship and planning (i.e., failure costs). However, their study does not take into account environmental FCs.

The proposed model may be applied to studies of economic sectors such as water supply and treatment.

The European Environment Agency (2014) evaluated the cost of atmospheric pollution caused by 10,000 companies in the EU in 2012 at €169bn (an external failure cost). Future research could be dedicated to developing a more accurate version of the GDP where environmental EFCs and IFCs are identified as a loss and not a gain.

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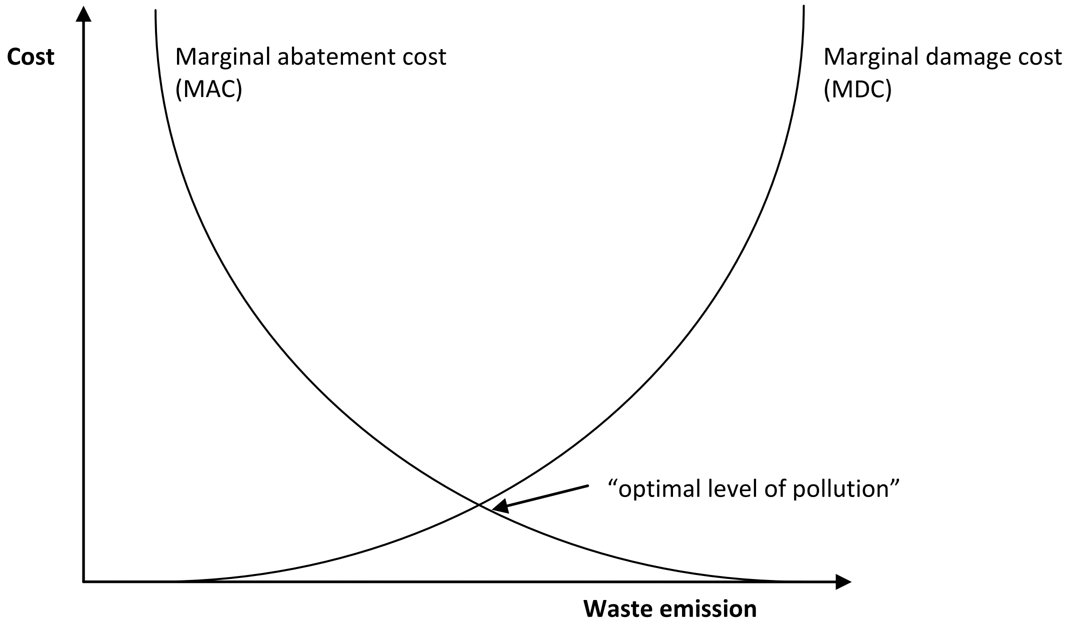

Fig. 1: The abatement cost – environmental damage relationship (cf. e.g. Hussen, 2012)

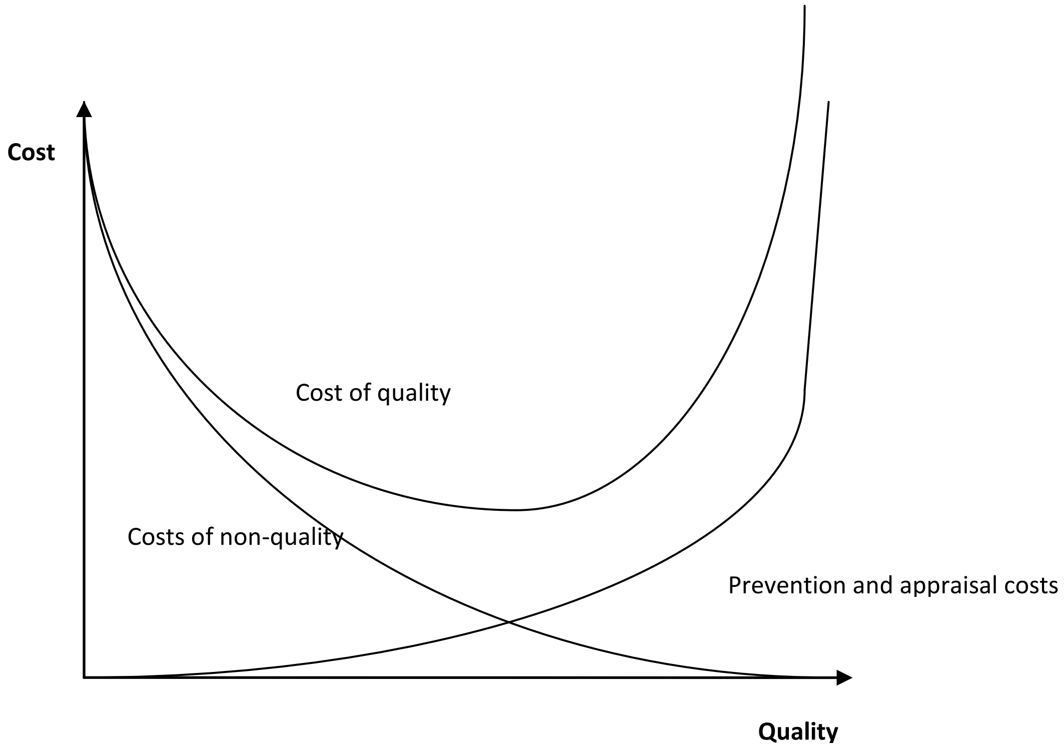

Fig. 2: ‘Cost of non-quality’ vs. prevention cost in quality management (cf. e.g. Finkler 1993)

Table 1. Process model describing the customer-supplier environmental quality chain for pig farming pollution and nuisances

Upstream Suppliers	**Inputs**	**Intermediate Requirements**	**Intermediate "Suppliers"**	**Outcomes**	**External (End Users') requirements**	**End Users**
Pig Farmers	Pig Manure	State regulations	River, Air (polluted by input)	<u>Environmental outcomes</u> Odours Water pollution	Absence of odours Absence of water pollution	Residents Nature protection associations Fishing associations
				<u>Socio-economic outcomes</u> Opposition to pig farm pollution causing: Decrease of pig farming and economic development	Economic development Employment Pig industry development	*Conseil Général* Mayors of villages close to pig farms Pig Farmers

Process Performance criteria (gap between requirements and inputs/outcomes)	**Measurements**
<u>Quality</u>	Number of internal and external failures
<u>Cost</u>	Cost of failures and cost of environmental quality

Table 2. Evaluation of the annual CEQ related to pig farming pollution and nuisances in the Tarn region

Process Stakeholders	*Type of quality cost*	*Itemized failures and costs (€000s)*	*CEQ (€000s)*
Cost borne by Suppliers			
Farmers	**Internal failure cost**	Equipment to bury liquid manure: 45 Use of bacteria to liquefy manure and reduce odours: 90 Manure oxygenation: 22 Spraying, vaporization: 2	Costs of odour suppression **160**
Costs borne by End users			
Residents, Residents Defence associations	**External failure costs**	Legal proceedings: 30 Accidental pollution and restocking the river with fish: 15 Loss of enjoyment for houses situated close to the pigsties: 3400	Pollution and nuisance costs **3445**
Costs borne by Society			
Young farmers	**External failure cost**	Cost of farmers' employment: 45	**45**
Villages Regions	**External failure costs**	Cost of slowing down of villages development: 60 Economic losses caused by the slowing down of farming creation and/or development: 700	**760**
Ministry of Agriculture	**Prevention costs**	Improvement actions to help farmers achieve water protection standards: 300	**300**
			Total CEQ (1998) €4.71M