Beyond Environmental Management to Quantifiable Pollution Management

A thesis submitted to the University of Wales for the Degree of

Doctor of Philosophy

By

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Declaration / Statements

DECLARATION

This work has not been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed ....(Candidate)

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STATEMENT 1

This thesis is the results of my own investigations, except where otherwise stated.

Other sources are acknowledged by footnotes giving explicit references. A bibliography is appended.

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Summary

Stakeholders increasingly have a heightened expectation of organisational commitment to good environmental and societal practice. Proponents of the link between environmental and financial performance have argued that pollution reduction provides future cost savings by increasing efficiency, reducing compliance costs, and minimising future liabilities. Environmental management systems such as BS EN ISO 14001:1996 or the Eco-Management and Audit Scheme (EMAS) do not require organisations to comment on overall environmental performance. BS EN ISO 14001: 1996 simply advocates that the organisation should have viewed each particular function of the business process and applied a self- formulated quantitative / qualitative analysis to the function in question, providing no incentive to add a level of independently verifiable transparency to the analysis process.

This thesis investigates whether it is possible to develop an environmental management system that is capable of delivering a quantitative social / economic statement based on the pollutant aspects / effects of the organisation.

A model for quantitative pollution management (QPM) is developed, and a scoring mechanism is defined which enables an indicator of pollution performance to be derived. This indicator reviews the organisation as a whole system, as well as commenting on its constituent parts. The indicator is based upon evaluation of five areas, those of management /leadership, inputs, controls, activities, and outputs. The model is tested in industry by an audit of a manufacturing organisation in South Wales, and a numeric QPM indicator is derived. The numeric QPM indicator is subsequently considered by means of a qualitative interpretation of the quantitative indicator score. The qualitative interpretation is then considered against the impression of the organisation gained by the author during the conduct of the audit.

Potential future work in relation to QPM is considered, and the possible application of the concepts of fuzzy logic to QPM is given.

Chapter 2 Design of the Environmental Management System

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Chapter 1

Introduction – Literature Review

Chapter Summary

This chapter introduces the fundamental concepts that underpin the potential and implementation of quantitative pollution management (QPM) as a management tool. It identifies the aims and objectives of this work, and provides an introductory literature review.

1.1 Introduction

A quality management system (QMS) does not in itself decide the technical or commercial specification of a product, but establishes disciplines that assist in the consistent meeting of requirements. An environmental management system (EMS) requires in the main that an organisation identifies and registers its environmental effects, while promoting continual environmental improvement, but does not need to comment on overall environmental performance. The hypothesis that is central to this work is that it is possible to develop an environmental management system that is capable of delivering a quantitative social / economic statement based on the pollutant aspects / effects of the organisation. The United States Environmental Protection Agency (US EPA) defines pollution as "any substance introduced into the environment that adversely affects the usefulness of a resource". This definition automatically implies a quantifiable effect basis for justification of pollutant monitoring.

The subjective assessment of environmental effects that is required by BS EN ISO 14001: 1996 does not focus attention on the overall environmental performance of the organisation. It simply advocates that it should have viewed each particular function of the business process and apply a self-formulated quantitative / qualitative analysis to the function in question. This requirement for 'self formulation' provides no incentive to add a level of independently verifiable transparency to the analysis process (lack of transparency provides no incentive to the manufacturer to consider anything other than end-of-pipe solutions). As has been shown by Rechem International

Ltd (Jones, 1995) over the past decade, sector acceptance by the public, the regulatory authorities and other stakeholders can be directly related to the levels of transparency, scientific uncertainty and traceability of the individual steps of the process. The study by Grayson (2003) considers that stakeholders have a heightened expectation of organisations' commitment to good environmental and societal practice.

As within an organisation the ranges of synthetic pathways and end products increase, and the use of novel intermediates becomes more prevalent, overall environmental performance is of critical importance (James, 1994). Quantifiable pollution management (QPM) is intended to provide a social and behavioural indicator of the manufacturing performance. It allows the customer and the public to be informed (by a quantitative indicator) of the organisation's overall environmental performance, considered against the possible pollution involved in the manufacturing process, and its effects, in a way that has taken into account not only process inputs and outputs, but the controls exerting influence on the process and the mechanisms involved in production.

Proponents of the link between environmental and financial performance have argued that pollution reduction provides future cost savings by increasing efficiency, reducing compliance costs, and minimising future liabilities (Porter and Van der Linde, 1995; Reinhardt, 1999). Porter and Van der Linde (1995) considered that opportunities for profitable pollution reduction exist because managers often lack the skills and experience to understand the full cost of pollution (Jaffe *et al.*, 1995). Hart (1997) proposed that excess returns (i.e. profits above industry average) result from differences in the underlying environmental capabilities of firms. Managers may possess unique resources or capabilities that allow them to employ profitable environmental strategies that are difficult to imitate. The study of empirical "pays to be green" literature (King and Lennox, 2000) has supported the occurrence of a positive relationship between pollution reduction and financial gain by relying on correlative studies of environmental and financial performance.

Event studies are a means of demonstrating that 'greening' can cause changes in stock / share price following an environmental related event. By isolating an environmental event within a narrow time frame, event studies establish causes for important differences between firms that cannot otherwise be reconciled. The limitation with event studies is that they may study the effect of events on an organisation that are only partially environmental in nature, and do not facilitate benchmark comparison. In some cases research has sought to avoid this problem by using published results such as the annual release of toxic emission data through the US EPA's Toxic Release Inventory (TRI) programme as the event. Polluting firms were found to have lost market value in a one-day window following the release of TRI information (Hamilton, 1995; Konar and Cohen, 1997; Khanna *et al.*, 1998). Given the complexity of analysing TRI data, it seems possible that same-day stock price movements may reflect contemporaneously reported pollution rankings.

1.2 Pollution

In using the US EPA definition of pollution (see section 1.0), difficulty arises in quantification of the subjective term "usefulness". Usefulness does not have an absolute value; it is a ranged term. Usefulness cannot be considered as constant, and membership values for the range between 'useful' and 'useless' are uncertain.

The effects of pollution may be primary, or the pollutants may interact after release with moisture, other pollutants, or sunlight (or more than one of these). Pollution may be local, regional or global in scale. The effects may be direct, indirect or cumulative and felt immediately or after a delay, intermittently or constantly. Until a threshold is reached, pollution may not appear to be a problem (Barrow, 1997). Until a threshold is reached the environment may render the material harmless. Once the threshold is exceeded the absorptive capacity may gradually or suddenly collapse. Gradual dose response relationships for pollutant effects can make identification of effects difficult. These complex interactions of pollutant scenarios form the background of the considerations underpinning the development of the pollution indicator advocated in Chapter 4.

1.3 Current Environmental Management System Development

In the early 1980's the United Nations Environment Programme (UNEP) saw environmental management as the control of all human activities that have significant impact on the environment (Toolba, 1982). The two current published environmental management system standards are the BS EN ISO

14000: 1996 family of standards, and the Eco-Management and Audit Scheme (EMAS), Council Regulation 761/2001 EC. Both of these are voluntary standards to which an organisation may choose to become certified / verified by means of third party confirmation audit. There is a marked difference in the reporting philosophy of both standards, which results in organisations having to internally identify their own organisational reasons for wishing to achieve either standard (Harmer, 1997; Barker, 2000).

Environmental management can be described as a methodology by which organisations acting in a structured manner assess their operations to ensure that they are functioning in an environmentally legitimate way (Whitelaw, 1997). They define the impacts of their activities on the natural environment, subsequently proposing actions (within defined timescales) to minimise or reduce those impacts that they consider (under criteria defined by themselves) as harmful. An environmental management system is a management system that aims to encourage an organisation to control its environmental impacts and reduce such impacts continuously. It is unfortunate that the opportunity afforded to the technical standards committees responsible for the development of the two recognised environmental management systems operating within the European Union (EU) to introduce management principles and methodologies for positive pollution management were not taken. Overall environmental performance is not commented upon within either standard. Process techniques or strategic decisions that would derive environmental benefit from the application of Best Practicable Environmental Option (BPEO) or Best Available Techniques Not Entailing Excessive Cost

(BATNEEC) - implying straight financial cost are not included as requirements.

1.4 BS EN ISO 14000: 1996

In August 1991 the International Standards Organisation (ISO) established a Strategic Advisory Group on the Environment (SAGE) to assess the need for international environmental management standards and to recommend an overall strategic plan for such standards. The SAGE remit required the investigation of the promotion of a common approach to environmental management, of enhancement of an organisation's ability to attain and measure environmental performance, and of ways to facilitate trade and remove trade barriers. In 1992, based on SAGE findings, ISO formed Technical Committee TC-207 who formulated the standard BS EN ISO 14001. BS EN ISO 14001: 1996 superseded BS 7750: Environmental Management System 1992 in September 1996, although agreement was reached to allow certification against the draft standard DIS / ISO 14001 from December 1995. The speed of development to this stage was remarkable compared to that for the development of quality assurance standards. For example the BS EN ISO 9000: 1994 series, which drew its origins from the 1959 American Department of Defense standard Mil Q 9858A, evolved through the 1968 NATO Allied Quality Assurance Publication (AQAP), to the United Kingdom (UK) equivalent of AQAP-1 (Def. Stan. 05-08) in 1970 to the publication in 1972 by the British Standards Institution of BS 4981, 'A guide to Quality Assurance'. In 1979, BSI published BS 5750 in three parts, revising the standard in 1984, and again in 1987, finally arriving at the current quality system standards in accordance with the International Organisation for Standardisation (ISO) of BS EN ISO 9000: 1994. A subsequent review took place, and the new standards, the BS EN ISO 9000: 2000 series as scheduled were released in late 2000. The revised standard BS EN ISO 9001:2000 proposes a view of environmental concern new to a quality standard previously focussed on repeatability and traceability. ISO Technical Committee TC 176 (Quality Management)) appear to have taken account of the increasing amount of environmental importance proposed by TC 207 (Environment).

It may be judged that it was the speed of development of BS EN ISO 14001: 1996 that denied the evolution of an environmental management system that was able to set out appropriate environmental performance guidelines. No maximum levels of volatile organic compounds (VOCs) emitted to atmosphere, no maximum volumes of effluent, and no maximum tonnage of waste sent to landfill are quoted. The individuals and committees responsible for the drafting of the Standard, having had prior experience of writing BS 7750: 1992 (ISO 14001's predecessor), recognised that every organisation is unique, every business is different; therefore to set or prescribe absolute levels would be an impossible undertaking. It avoids the possibility for comment on the existing environmental situation of the organisation by an emphasis on the recognition and registering of environmental aspects. Accreditation to the standard confirms that the organisation has viewed its environmental aspects, and is demonstrably aware of any applicable environmental legislation. It is the term "accredited" that is key to understanding the philosophy of ISO

14001: 1996. It is necessary for the management system to conform to the required elements of the standard. However these elements are non-flexible, having been devised by the ISO Technical Committee TC 207 as generically acceptable factors for conformance. The standard itself is devoid of any mechanism for comment on environmental performance (other than the requirement for developing environmental targets and objectives) allowing accreditation by attribute, i.e. the system conforms Yes / No?

The robustness of the accreditation procedure itself appears somewhat deficient, as there is no specific requirement for a benchmark environmental review of the operation under scrutiny. However, in practice, this is carried out by many organisations that intend to seek certification (Phillips, 2000), as it is a fundamental exercise that allows a baseline evaluation of the environmental performance of the organisation to be established.

Although enabling a defined approach to an environmental management system, BS EN ISO 14001:1996 does not reflect the concept of QPM for the purpose of this study, as the management system does not achieve a holistic interpretation of the organisation, and does not give a quantitative or qualitative statement of organisational environmental performance.

1.5 The Eco-Management and Audit Scheme (EMAS) 761/2001 EEC

The Eco-Management and Audit Scheme (the EMAS Regulation) was originally published in its entirety in Official Journal L168 dated 10 July 1993, and was formally launched in the UK in April 1995. The regulation was amended in March 2001 to promote a coherent approach between the legislative instruments developed at Community level in the field of environmental protection. The foresight of the EU provided an opportunity for organisations to demonstrate, in a very public way, their achievements with respect to environmental issues detailed in published EMAS brochures. It was hoped that the release of detailed information based on a publicly available, third party validated, environmental policy statement would induce companies not just to achieve legal compliance, but also to go beyond minimum legal requirement. The uptake of EMAS as a management standard within the UK has been very poor in comparison with that of BS EN ISO 14001 (ENDS, June 2000). This has been due not only to the organisational sector applicability of EMAS, but also to the increased visibility for performance evaluation inherent in the regulation.

There is no written requirement in BS EN ISO 14001 or EMAS for an organisation to be legally compliant, although a plethora of environmental legislation exists and is continuously being added to. Both BS EN ISO 14001 and EMAS require the formulation of a register of applicable environmental legislation to be constructed and maintained. Both standards, however, do not require continuous legality of operations to maintain certification / verification. However the "Polluter Pays Principle", Best Practicable Environmental Option (BPEO) and Best Available Technique Not Entailing Excessive Cost (BATNEEC), derived from the Environmental Protection Act 1990, all lead to the supposition that the ethos of the legislation lends itself to the inclusion of an additional factor, such as the availability of a quantitative indication of pollution management. The European Commission published the long awaited paper on environmental liability in February 2000 (ENDS, February 2000). The document proposes that there be strict liability both for "traditional" damage to people and property, and for damage to the environment – defined in this context as reduced biodiversity and generation of contaminated sites.

The certification of BS EN ISO 14000:1996 and the verification of EMAS are conducted through registered organisations under the direction, administration and guidance of the United Kingdom Accreditation Service (UKAS). Directed by specifications laid out in BS EN ISO 10011:2000, auditors with sector expertise for the particular industry involved perform system and organisational audits for conformance against the requisite standard, recommending registration by UKAS of conforming systems based on individual sector performance.

EMAS does not reflect the complete concept of QPM, although differing from BS EN ISO 14001:1996 by the introduction of a verifiable environmental statement, it does not lead to a quantitative or qualitative statement of environmental performance, as it considers compliance as opposed to performance.

1.6 Environmental Performance Indicators

Prior to the ability of Certification bodies to accredit an EMS, SGS Yarsley ICS Ltd. launched the "Green Dove" award (SGS ICS 1996), which gave indication of compliance with what was then BS 7750 (evolving into BS EN ISO 14000:1996). This strategic movement away from other UKAS Certified bodies to introduce an award and visible conformance indicator for environmental management in industry, which is still used, addressed a perceived need to visibly demonstrate organisational environmental management. The award is currently granted to organisations upon certification to BS EN ISO 14000:1996. The further development of an indicator aligned to a management system is demonstrated by the use of the "Green Globe" in the tourism industry (Keegan, 1998).

Individuals, however, exhibit different preferences for various aspects of our environment, and the measurement of preferences has historically proven to be a difficult task. The market-based price mechanism illustrates a typical environmental consumer choice. Tropical forests may be used to illustrate this by the use of a valuation contingent based on their existence, rather than their resource usage (Barrow, 1997) as alternative consideration may be given to the opportunity costs from economic activities that do not occur as a consequence of management to conserve the scarce resources. A pricing structure that is based on a comprehensive understanding of the identifiable environmental costs, such as effective waste management, rather than the more amorphous issues of pricing sites of special scientific interest (SSSI's), allows the general public to demonstrate their environmental stance by exercising their power as purchasers.

The need for exposure of environmental effects in a way which responds to the views and concerns of society ($Rothermund_a$, 1997) ensuring that everyone understands both the benefits and costs of organisational activities ($Rothermund_b$, 1997), is a key element that is currently absent from many organisations. The measurement and reporting of unit emissions (Herkstroter, 1998) allows a balance to be drawn against many human activities that hitherto have brought huge benefits in terms of economic and social development. The Co-Operative Bank recently became a customer in the new "Green Electricity" market (ENDS, December 1998), buying power from the Renewable Energy Company, generated *via* a sewage sludge incinerator, as a direct response to the Government's Advisory Committee on Business and the Environment (ACBE) call for increased industrial use of renewable energy (ENDS report 279; ENDS Report 284). This is a clear demonstration by the Co-Operative Bank of its attempt to reduce overall environmental impact with a strategic purchasing decision made within the organisation, having an impact outside its operations. These industry-wide environmental initiatives are worthy of further consideration in the study of QPM as they detail environmental considerations undertaken by organisations against traditional market options.

1.7 BS EN ISO 14031:2000 'Environmental Management – Environmental Performance Evaluation – Guidelines'

The attempt by ISO to produce a standard on environmental performance evaluation (EPE), prepared under the secretariat of the American National Standards Institute (ANSI), was published as a standard in 2000. It was prepared by the ISO TEC 207 / SC 4 leadership, based on the discussions and decisions of the 1997-04-20/24 meetings of the sub-committee and its working groups in Kyoto. The draft EPE guidelines, while introducing Environmental Performance Indicators (EPI's) and Environmental Condition Indicators (ECI's), only achieve an internal reporting function for management information. This lacks the structure that would allow external evaluation for visible conformance, being an internally focussed system.

The EPE Process model is an internal management process that uses a selection of indicators to provide information comparing an organisation's past and present environmental performance with its environmental performance criteria, based on the 'Plan, Do, Check, Act' or 'PDCA' Cycle of W. Edwards Demming (Kolaric, 1995). The standard describes two general categories of indicators of EPI's and ECI's; these are enhanced by a further division of EPI's to Management Performance Indicators (MPI's) and Operational Performance Indicators (OPI's). EPI's are intended to provide information about management efforts to influence the environmental performance of the organisation's operations, while providing information about the actual performance of the organisation's operations. ECI's are intended as a form of indicator that will provide information about the condition of the environment. ECI's are intended to provide information about the local, regional, national or global condition of the environment. The condition of the environment may change from time to time or with specific events. While ECI's are not measures of impact on the environment, changes in ECI's can provide useful information on relationships between the condition of the environment and an organisation's activities, products or services.

In considering BS EN ISO 14031:2000 for inclusion in the study of QPM, it is important to realise that environmental performance evaluation (EPE) has not been prescribed by BS EN ISO 14031:2000 in terms of defined criteria, resulting in an organisationally specific selection of relevant determinants when it is applied. No methodology has been given for analysing and converting data and assessing information, and no quantitative or qualitative outcome publication format is shown for the derived data.

1.8 The United Kingdom (UK) Environment Agency (EA) Operator and Pollution Risk Appraisal (OPRA)

The Operator and Pollution Risk Appraisal (OPRA), Version 2 1997, represents a move toward risk based assessment and regulation by the EA. OPRA is based on rigorous principles and includes sophisticated thinking. It is not intended for detailed assessment of process risk or operator performance but to provide an objective and consistent assessment of the environmental risk from an Integrated Pollution Control (IPC) process. The basic premise of OPRA is to define the main factors affecting risk and to perform a simple yet robust analysis of these, in order to enable a score to be determined as a regular part of inspection visits. By targeting inspection effort toward the higher risk processes (based on OPRA results), the EA intends to improve the effectiveness and efficiency of its own activities.

OPRA contains two elements, Operator Performance Appraisal (OPA) and Pollution Hazard Appraisal (PHA). Each element performs an evaluation of seven predetermined factors (known as attributes) to determine operator performance and pollution hazard. Both the OPA and PHA scores are combined to produce the OPRA rating. The OPA weighting factors reflect the importance placed on the issues of operation, management and training, and plant maintenance. The occurrence of incidents is important, but is considered by OPRA to be an output or consequence of the above issues.

In considering the inclusion of OPRA toward the study of QPM, it is important to note that the PHA weighting factors reflect the fact that each of the selected attributes belongs to a chain of interactive issues, which lead to the risk of harm to the environment. Each attribute is therefore considered important. The current weighting factors are therefore effectively equal. The limiting factor of OPRA is due to the model being designed and applicable to only IPC authorised organisations.

The introduction by the EA of local Environment Agency plans (LEAPS), which make public the targets that an area needs to achieve, and any areas of weakness (Gray, 1997) would produce a much broader scope of application for participants if aligned to the methodology of OPRA.

1.9 The Global Reporting Initiative (GRI)

The Global Reporting Initiative (GRI) is a long-term, multi-stakeholder, international undertaking with a mission to develop and disseminate globally applicable sustainability reporting guidelines for voluntary use by organisations reporting on the economic, environmental and social dimensions of their activities, products and services. The GRI was originally convened by CERES (Coalition for Environmentally Responsible Economies) in partnership with UNEP (United Nations Environment Programme). The GRI consider that the long-term objective of developing "generally accepted sustainability accounting principles" requires both a robust product incorporating the best available techniques, and a stable process through which continuous learning can occur. In its view of environmental performance GRI considers that organisations create environmental impacts at various levels, including local, national, regional, and international. Some are well understood, while others present substantial measurement challenges owing to their complexity, uncertainty and synergies.

Environmental reporting has reached a level of emerging common practices based on a shared understanding of environmental processes. The repeated appearance of certain environmental categories, aspects and indicators provides a foundation for a common information base. However, organisational differences remain and are reflected in the variety of indicators used by reporting organisations. GRI distinguishes two types of indicator: generally applicable and organisation-specific. Indicators noted as 'generally applicable' are relevant to all organisations. Organisation specific indicators, while critical to an understanding of the performance of the organisations to which they apply, may not be relevant to all organisations. These indicators are derived from attributes such as the organisation's industry sector and geographic location, and from the concerns of stakeholders.

The GRI considers indicators under the following category headings:

Energy (Joules)

Materials (Tonnes or kilograms)

Water (Litres or cubic metres)

Emissions, Effluents, and Waste (Tonnes or kilograms)

Transport

Suppliers

Products and Services

Land Use / Biodiversity

Compliance

Any raw performance data is collected in terms of absolute figures. These can be *via* a monetary measurement or *via* physical measurement for a given period of the operation. Absolute figures provide information on the size of an impact, or on the quality or value of an achievement.

In consideration of the study of QPM, it is important to utilise the types of indicator used in environmental reporting, and to take note of the repeated appearance of certain environmental categories, aspects and indicators to reflect the fact that organisations create environmental impacts at various levels, including local, national, regional, and international.

1.10 Environmental "Name and Shame"

The production and publishing on the internet by Friends of the Earth of a name and shame list entitled "Britain's filthiest factories" (ENDS February 1999; FoE, 1999), ranked individual organisations by annual emissions of "recognised" carcinogens. The top 10 sites accounted for 84% of the 13,088 tonnes of carcinogens identified on the Chemical Release Inventory (CRI) database. The Chemical Industries Association (CIA) expressed concern at FoE's use of the word "carcinogen" while Associated Octel pointed out that the World Health Organisation's International Agency for Research on Cancer (IARC) regarded two of the substances used (lead and ethyl chloride) to be "unclassifiable" because of "inadequate" evidence of carcinogenicity in humans. The inadequacy of information has given a direct indication of the increased requirement for quantifiable pollution indicators, not only for customer / consumer choice, but as a means to disprove allegation and rumour.

The United Kingdom (UK) Environment Agency (EA) proposed in 1999 to publish performance league tables (Gallagher, 1999), that would detail the amount of enforcement action it had taken. These would tell the public where responsibility lay for major pollution damage, and would be coupled with an encouragement to the Courts to impose larger fines for environmental damage (ENDS report 287).

In addition to the study by James (1994) which considered the external transparency of the environmental performance by an organisation, both the

Friends of the Earth 'name and shame list' and the EA proposal of performance league tables introduce an important factor to the study of QPM by showing that a clear and meaningful outcome indicator which defines the environmental performance of an organisation is required.

1.11 Derivation of the Management System Boundaries

The management system reporting scope is aimed at the production of a quantitative indicator of pollution management. Using the "simple process" model (Fig. 1.1) detailed in BS 7850 Part 1, it is possible to view a process in its simplest terms. Where multiple activities or physical facilities produce or provide a particular product or service, the organisation should take them into account when evaluating environmental performance.

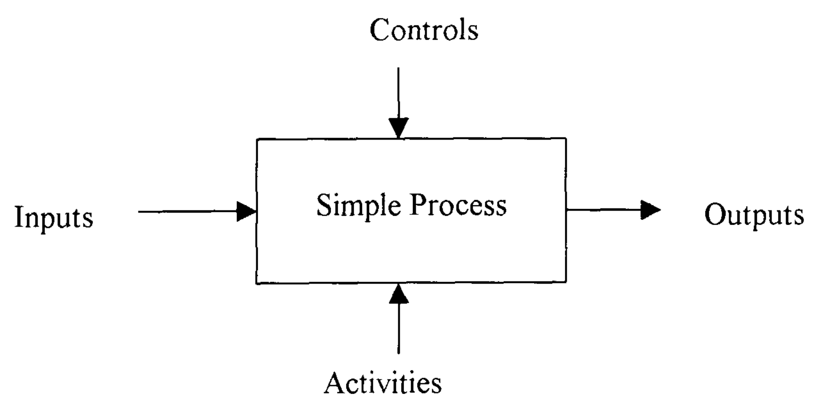

Fig. 1.1 "Simple Process" Model BS 7850: 1992

The four critical areas of Inputs, Controls, Activities and Outputs are to be considered individually. The inputs to any production system enable source reduction of pollutants. When less waste is being produced, less needs to be captured. The activities involved in the sourcing of raw materials / production parts and equipment are critical in this area, and account should be taken of opportunities for resource conservation, or through implementation of better process control, and increased efficiency with which resources such as water or energy are used. Using less energy is pollution prevention, because fuel is conserved, and at the same time, pollutant emissions that would have resulted from the production and use of the energy are not produced as outputs.

The evaluation of both "process orientated" and " product and service orientated" criteria assist in the identification of how companies assess environmental performance. It is necessary for the traditional measures of corporate economic performance to be extended to include their environmental performance (Beaumond *et al.*, 1994). When evaluating internal environmental assessment, environmental cost function should reflect the impact on the environment (Muska, 1999) requiring a fundamental change in philosophy from a focus on short-term profitability to longer-term measures on return on investments (Shen and Yu, 1999). The additional requirement for consideration of the 'throughput' in terms of basic housekeeping measures can range from a base level to those that include design for the environment (DfE).

In most production processes, there are two outputs, the product and the waste. They should both be disposed of in the safest and most environmentally acceptable way possible. Waste is a measure of organisational inefficiency. The level of pollution reduction that maximises the difference between the benefits and costs of cutting back waste release is known as the "optimal level of pollution abatement". Many environmental managers have made this 'value judgement' by speculation (Ortorlano, 1997; Arnold, 1995). The aggregate level of waste tends to fluctuate with economic upsurge (Beaumond *et al.*, 1994). This is indicated by the increase in waste management companies, whose methods of operation head upward in the hierarchy of waste management options (Fig. 1.2).

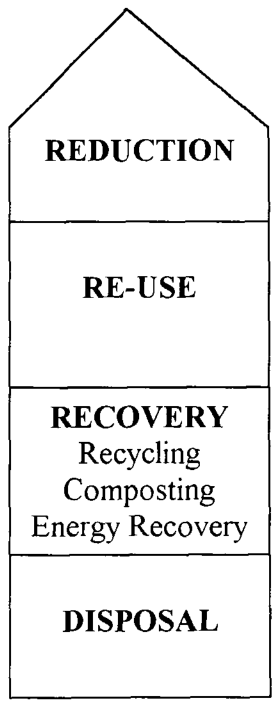

Fig. 1.2 The hierarchy of waste management. Williams. (1998)

The analysis of any production system (inventory analysis) ends, in general, in a comprehensive inventory table including possibly hundreds of different environmental interactions (Hofstetter *et al.*, 2000). This vast amount of information on resources used, substances emitted to air, water or soil, and noise and radiation will, in most studies, not easily lend itself to ranking and assessing alternatives. SETAC (1993) classifies environmental interventions into impact categories according to their mode of action. The SETAC characterisation step quantifies these contributions per impact category, resulting in a 'category indicator'. For example: CO_2 emissions to air are called environmental interventions; CO_2 contributes to the impact category "global warming"; a product system usually emits different gases contributing to global warming (e.g. CO_2, CH4, etc.). The category indicator is calculated by multiplying each intervention adding to global warming with its "Global Warming Potential" (GWP). The research literature notes some 20 impact categories (Heijungs *et al.*, 1992).

Use of life cycle assessment (LCA) as a decision support tool is a damage–oriented approach, where interventions are assessed according to their modelled damage potential towards the environment (Hofstetter *et al.*, 2000). The damage potential is expressed in explicitly defined safeguard subjects and quantified in respective damage indicators. In the example of CO_2, human health as well as ecosystem quality may be selected as environmental safeguard subjects, as they are both affected by the consequences of global warming. These consequences are modelled and quantified in two damage indicators, one indicating the damage to human health, the other to the eco-system quality. Such damage-orientated approaches end up with three damage indicators (compared to 10-20 impact categories) in former approaches (Goedkoop *et al.*, 1998). In a final step these damage indicators may be aggregated to a single (eco) index. However, depending on the degree of correlation between the damage indicators, high correlation would not change the rankings between product alternatives, and modelling and quantification of one of the damage indicators would be sufficient for the assessment of alternatives. If the correlation is low, decision-makers have to add additional information on the importance of the selected safeguard subjects. A related proposal is the dominance analysis suggested by Lundie and Huppes (1999). Their approach uses statistical analysis based on the normalised category indicators according to CML methodology (Heijungs *et al.*, 1992).

1.12 Investor Responsibility Research Centre (IRRC)

The IRRC has reported on corporate governance and social responsibility from its headquarters in Washington DC, USA since 1972. The approach taken towards gathering and presenting environmental information through their Corporate Environmental Profile Directory (CEPD) ensures that information is obtained in a way that maximises the consistency and the comparability of the information gathered, securing information on environmental compliance, incidents, toxic chemical emissions, permit restrictions, and waste clean-up responsibilities, as discussed below.

The IRRC has developed an Emissions Efficiency Index® (IRRC, 2001) as a normalising tool for analysing an organisation's progress in reducing emissions of selected toxic chemicals associated with their manufacturing process. The index expresses the amount of reported Toxic Release Inventory

(TRI) releases and transfers in pounds per thousand dollars ($) of domestic revenue.

$$\text{Sample IRRC Environmental Index} = \frac{\text{TRI (Environmental Statute Unit) (i.e. Toxic releases in pounds for a given year)}}{\text{Domestic or Total Revenues (i.e. in thousands of dollars for that year)}}$$

While there is no certainty that a pattern of increasing emissions per dollar of revenue produced will result in greater financial risks, the proliferation of environmental regulation and litigation strongly suggests that organisations that are able to generate revenue with lower levels of regulated pollutant emissions will tend to have fewer future environmental liabilities. In addition, some investors may view trends in absolute or size adjusted emissions as a measure of the effectiveness of the organisation's environmental stewardship. There are several important limitations inherent in the toxic chemical data taken from the TRI. This information is self reported by organisations, and no mechanism exists to ensure the accuracy of the records. Organisations are not required to measure their releases and transfers, but only to make estimates based on available data. As no methodology is prescribed, organisations use differing methods for estimating emissions. Revisions have taken place of early estimates, and ambiguity remains over exactly what portion of certain complex chemical mixtures found in some industrial process wastes is acceptable.

In the absence of consistent, publicly available environmental data in Japan, corporate environmental reports are a primary source for assessing organisational environmental performance (NTTDATAIMC, 2001). In a survey of 88 organisations, 90% provided information about environmental objectives and achievements, including related costs, in their environmental reports. Yet only 55% reported CO_2 emissions. The study shows levels of disclosure and environmental reporting through data on greenhouse gas emissions, management systems, training, and other data elements.

1.13 HMIP - Emissions, Efficiencies and Economics, "The 3 E's Methodology"

The 3 E's methodology (HMIP, 1996) is a structured systematic review technique, which aims to improve environmental performance and economics through process optimisation. It may be applied to any flow or batch process, although it was developed initially for processes regulated under IPC. Essentially an improvement project, the methodology may be revisited at any stage of the life cycle of a project. The stages of the review are clearly defined as:

- Planning
- Review
- Implementation of proposals

With specified benefit objectives of:

- Reduced emissions
- Improved process efficiency
- Improved economics

- Improved management control

Although not intended to determine a quantitative or qualitative indication of pollution performance other than for fiscal comparisons, it does develop associated benefits for the organisation in terms of:

- Emission identification
- Utility usage
- Material / utilities usage per unit of output
- Better understanding of the process and BATNEEC

1.14 Quality Awards

The European Foundation for Quality Management (EFQM) Business Excellence Model is the most widely applied model in Europe used to measure and manage total quality management (Westlund, 2001). The EFQM model is based on the underlying idea that customer satisfaction, employee satisfaction, and beneficial impacts on society will ultimately imply excellent business results. Another basic principle is that the EFQM approach enables the description of cause and effect relationships. There are two main criteria used, the 'enabler' elements consider business management, and the 'results' criteria describe what the organisation has achieved. Environmental issues are dealt with in both criteria, but have their most significant role within one of the results categories, namely society results.

The Malcolm Baldrige National Quality Improvement Act, signed by President Reagan in 1987, established an annual USA quality award (Kolaric, 1995). Award applications are examined in seven major categories with a maximum total score of 1000 points, and evaluated on three dimensions, approach, deployment and results.

In utilising concepts from both EFQM and the Malcolm Baldrige National Quality Award, the study of QPM will benefit by considering a holistic view of the organisation, juxtaposing total quality excellence and environmental performance in pursuit of a final numeric indicator of performance measured against prescribed criteria.

1.15 Balanced Scorecard

Balanced scorecard is a methodology for strategic control using a multidimensional framework for describing, implementing and managing strategy through all levels of an organisation. Introduced by Kaplan and Norton (1992), balanced scorecard benefits an organisation by providing both relevant and balanced information in a concise manner (Mooraj *et. al.*, 1999). This 'balance' enables organisations to clarify their vision and strategy by translating them with a tool that effectively communicates strategic intent, and motivates and tracks performance against strategic goals. Balanced scorecard is more than an assorted collection of financial and non-financial measures (Jones, 2001) as it structures an organisation's focus on the cause and effect relationships which interact between the four 'perspectives', considered by Kaplan and Norton (1992) (Fig. 1.3).

The cyclical process of the balanced scorecard allows comparison with Dr. W. Edwards Demming's Plan / Do / Check / Act (PDCA) cycle (Kolaric, 1995). Balanced scorecard is based on performance metrics that are continually tracked over time to look for trends, good and bad practice, and areas for improvement.

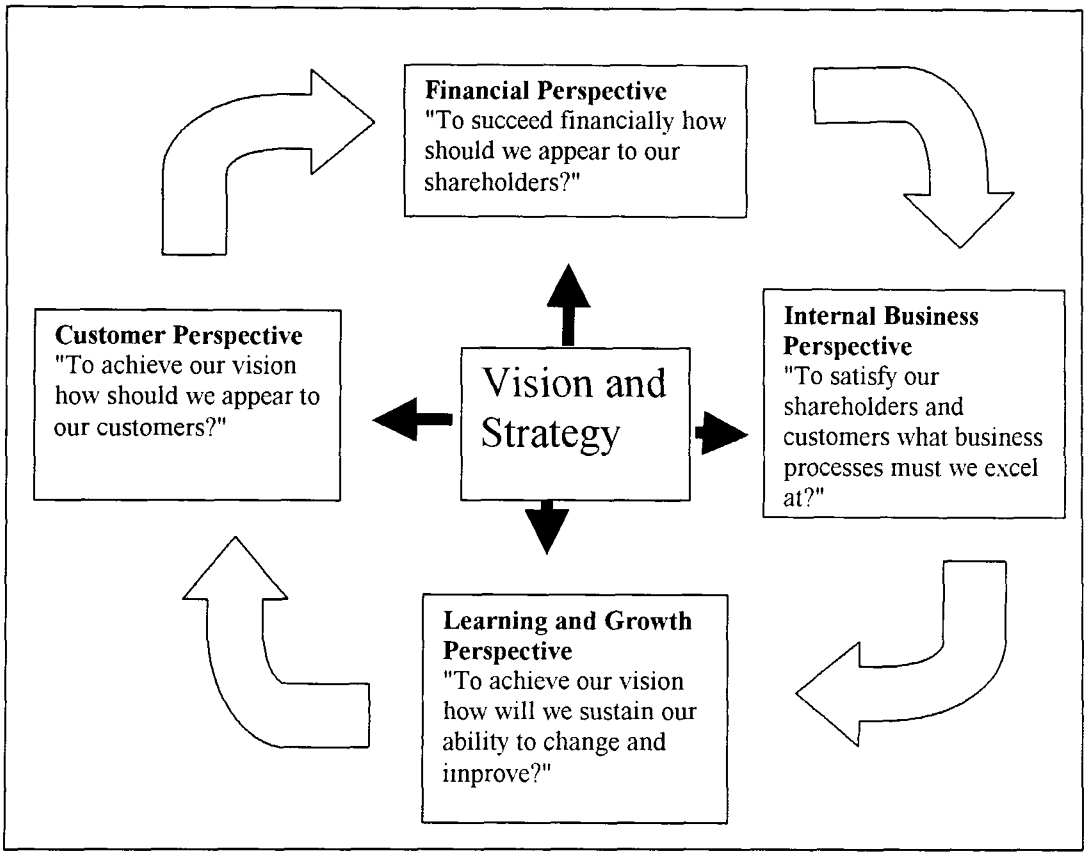

Fig.1.3 The Balanced Scorecard Perspectives. (Adapted from "The Balanced Scorecard", Kaplan and Norton. Harvard Business School, 1996.)

The balanced scorecard invites managers take a wider view of the organisation, and by focussing energies, attention and measures on all four of the perspectives, organisations become driven by their mission, rather than by short-term financial performance. Crucial to achieving this is the application of measures to company strategy. Instead of strategic decision making being considered as beyond measurement, the balanced scorecard strengthens the argument that strategy should be central to any process of measurement (Norreklit, 2000).

Kaplan and Norton (1996) consider that there are three key elements that contribute to the success of the balanced scorecard. These are

- Cause and Effect Relationships
- Performance Drivers
- Linkages to Financial Measures

Cause and Effect Relationships - Kaplan and Norton consider that each measure selected for a balanced scorecard, rather than being isolated or 'stand alone', should be part of a chain of cause and effect relationships the resultant network of which reflect the strategy.

Performance Drivers - Kaplan and Norton advocate that a balanced scorecard should have a combination of "lead" and "lag" indicators. The (1992) study considers that measures common to organisations within an industry sector are known as "lag indicators". e.g. market share. "Lead indicators" are drivers of performance and tend to be unique as they reflect differing strategies, and are company (and strategy) specific.

Linkages to Financial Measures - The frequent pursuit of single change programmes such as quality, customer satisfaction or re-engineering are considered by Kaplan and Norton as strategic issues. However they should be translated into measures that are ultimately linked to financial indicators rather than pursued indiscriminately.

The intent and practical applications of balanced scorecard stems from similar precepts to the management by objectives (MBO) introduced in the late 1950's by Peter Drucker (Dinesh, 1998). It is the concept of the individual elements of an organisation considered as part of a chain of cause and effect relationships, the resultant network of which reflects the strategy of the organisation which make this methodology a consideration for inclusion in the author's study toward QPM. The study of QPM would benefit from the inclusion of performance metrics that are continually tracked over time to look for trends, good and bad practice, and areas for improvement. This would enable managers to take a wider view of the individual components of an organisation.

1.16 Aims and Objectives of the Programme of Research

The aim of this research is to develop and apply a model for environmental management from which quantifiable indication of overall environmental performance for an organisation may be derived. This innovative study will assist in allowing environmental performance to become a strategic factor in business planning. Direct comparisons may be made between the operational characteristics of organisations, and how those organisations impact on the environment *via* pollution, providing direct business benefits to organisations that manage their business and protect the environment.

Following the development of a quantifiable pollution indicator, customers / consumers would be able to make a purchase decision that takes into account environmental concerns. These unique QPM indicators will assist in promoting a sustainable management strategy with preventative approaches to pollution. Under these circumstances, a QPM indicator would allow industrial and regulatory strategies to be implemented beyond the traditional boundaries of pollution control and waste management. It would give a broader perspective on performance, and encourage application of preventive technologies to reduce pollutant and waste loads, while also promoting environmentally friendly products and services through openly available quantitative indicators. The derived indicator will be limited to the state of a particular process at a given point in time, and as such will need recalculation over given time intervals. This methodology enables the organisation to demonstrate improvement, if applicable. Monitoring tools should in any case be an aid to strategy formulation, not a determinant of it (Escoubes, 1999).

1.17 Summary

The thesis which is central to this work is that is possible to develop an environmental management system that is capable of delivering a quantifiable social / economic statement based on the pollutant aspects / effects of the organisation. In the literature survey, the links between environmental performance and financial performance are considered. Several research methods are described which consider pollution performance. However it is clear that no single method wholly reflects quantitative pollution management (QPM) for the purposes of this study. The basis for QPM can be derived from either of the certified EMS. However, neither BS EN ISO 14001:1996 nor EMAS actually considers any form of quantitative output.

BS 14031:2000 achieves an internal reporting function for management information. However, this lacks the structure of externality for visible conformance, being an internally focussed system. Environmental performance evaluation (EPE) has not been prescribed by BS EN ISO 14031:2000 in terms of defined criteria, resulting in an organisationally specific selection of relevant determinants. This international standard does not prescribe a methodology for analysing and converting data and assessing information, and no quantitative or qualitative outcome publication format is shown for the derived data.

The EA OPRA methodology is not intended for detailed assessment of process risk or operator performance but to provide an objective and consistent assessment of the environmental risk from an Integrated Pollution Control (IPC) process. The methodology involved in the GRI reporting guideline is based on the collection of absolute figures. From absolute figures relative figures (ratios) may be derived which allow comparisons of products or processes with each other, and allow comparability of different scales of operation relative to a specific activity (e.g. kilograms of product per litre of water used). Relative ratios can include a consideration of actual pollution performance considered against the potential for pollution within an organisation. QPM may therefore be constructed as a relative ratio of actual performance against potential for pollution, derived from a combination of absolute figures obtained from environmental indicators.

The EFQM model provides a conceptual platform for the evaluation of a company for actual and perceived performance, using both enabling management and actual results, which assist the evaluation of 'cause and effect' relationships. The Malcolm Baldrige Award uses a concept based on seven major categories, each assessed under three dimensions on the precept of 'promoting awareness, recognising achievements and publicising strategies'. Both awards are concerned with the implementation of a company wide system, and use a self-assessment process prior to examination.

The derivation of the management reporting system from which this thesis regarding QPM may be accomplished will consider factors emerging from BS EN ISO 14000 series, EMAS, BS 14031, GRI, OPRA, EFQM and the Malcolm Baldrige Award.

1.18 Outline of Thesis

The author's study of QPM is offered in the following chapters that are detailed below.

Chapter 2 considers the selection of the metrics necessary for the design of the quantitative pollution management (QPM) system. The Chapter identifies the required metrics and discusses their inclusion in the QPM management system.

Chapter 3 considers the author's methodology in deriving the initial model for QPM. It provides a brief overview of the prototyping, application and evaluation of QPM

Chapter 4 considers the derivation of the initial model for QPM, and the weightings of the individual, and combined categories in achieving the indicator of pollution performance. The Chapter also considers the audit guidelines for the assessment of QPM.

Chapter 5 offers the initial audit of Tubex Ltd. for QPM, and the derivation of the initial QPM indicator. The Chapter also considers a qualitative interpretation of the quantitative indicator.

Chapter 6 reviews the author's study of QPM, and shows the contributions afforded by the study. The Chapter also considers the possibility of further work on the initial model

Chapter 2

Design of the Environmental Management System

Chapter Summary

This chapter considers the metrics necessary for the design of the quantitative pollution management (QPM) system. It identifies the metrics and discusses their inclusion.

2.1 Introduction

A strategic response to corporate environmental performance requires a consideration of what and how to measure. This chapter considers how the pollution performance of the organisation may be quantified in practice, which is the aim of this study. Annex VI of the EMAS regulation details direct environmental aspects (activities over which an organisation has management control) and indirect environmental aspects (from significant activities, products or services over which an organisation may not have management control). Environmental performance indicators are generally based on an "input-output" model of companies (Escoubes, 1999). Consumption and emissions dominate the metrics used for the determination of environmental performance. The technical and operational indicators in BS EN ISO 14031, based on the simple process model illustrated in BS 7850 (see Fig.1.1) are intended to be used as an internal tool for the determination of organisational environmental performance against the criteria set by management. The contribution afforded by the author's unique study of Quantitative Pollution Management (QPM) is that QPM will be able to be used as both a determinant of internal performance and for extrinsic verification of performance.

The reporting mechanism for environmental data needs to consider four main issues (Brownley, 1997):

i. Audience
ii. Measurement tools
iii. Degree of disclosure
iv. Tracking environmental performance throughout the organisation

i. Audience

The consideration of the target audience is a key factor in determining the reporting mechanism for QPM. The assessment and voluntary disclosure of environmental performance by an organisation gains industrial advantage at the risk of greater external scrutiny (Meyers, 1999; Jones, 1995). The corporate culture that guides decision-making becomes open to increased examination. Unsolicited analysis may be rigorous and swift, coming from independent reviewers as well as interested stakeholders. Sophisticated analysis techniques are well established with public interest groups. For example, the production and publishing on the Internet by Friends of the Earth of a name and shame list entitled "Britain's filthiest factories" (ENDS February 1999; FoE, 1999), ranked individual organisations by annual emissions of "recognised" carcinogens. Corporate activities will be revealed to emerging, in addition to traditional, audiences. If QPM is used as a model for quantifying pollution performance, stakeholders will be able to assure themselves of the organisational commitment to the environment by using the quantitative / qualitative indicator.

ii. Measurement Tools

The organisational use of QPM requires the development of tools and processes for the measurement of year on year progress according to specified indices, and for communicating performance against those indices in a meaningful way. This has the advantage for the organisation of providing a single index, which may be easily understood by both corporate management and external stakeholders, which is able to identify areas in need of improvement or corrective action, and provide a means for benchmarking. Modelling of environmental waste management systems, as opposed to the modelling of the particular components of the system, has been attempted since the late 1980's (Wang, 2001). A common shortcoming of statistical models is the implication that the conditions producing existing outputs will be appropriate in areas (or time periods) other than those where data for statistical analyses were obtained. Such contextual factors include socio-economic, demographic, and operational aspects of the existing systems. Statistical models largely ignore the 'inner workings' or interactions between the various components of a system. The derivation and use of 3D numerical models for pollution studies are based upon the solution of basic flow and dispersion of pollutants. The quality of the input data is often not sufficient to justify the application of the very complex numerical tools. Alternatives are parametised semi empirical models that make use of priori assumptions about the flow and dispersion conditions (Berkowicz, 2000).

The environmental dimension of quality is measured and defined in accordance with one, or both, of the following two paradigms (Westlund, 2001):

i. Dimensions which are absolute, e.g. measurements, such as chlorine emissions

ii. Dimensions which are perceived, e.g. by market, by stakeholders etc.

Both paradigms are important. However the linkages to perceived dimensions make it crucial to identify those areas that have an impact on stakeholder behaviour and evaluations. To address the perceived dimension paradigm, the QPM method developed in this study will consider factors additional to operational performance, by evaluating the decision-making process and organisational management.

By focussing attention on specific areas of performance, performance indicators can be used to shape what issues are thought about. For example, a survey that measures asthma rates within a particular locality or age group indicates that this outcome is of importance to the agency that mandated its introduction; by the action of measurement it makes the institutional performance on this issue public. By focussing attention on their performance indicator results, governments may impose a policy agenda on institutions by embedding assumptions related to purposes, goals or values into the selection and structure of indicators (Barnetson *et al.*, 2000). Performance indicators may transfer the power to set priorities and goals to those who create and control the documentary decision-making systems (Newson, 1994). Through the inclusion of performance indicators that demonstrate the positive outcomes of a policy agenda, and by the exclusion of performance indicators that demonstrate the negative outcomes, evidence is able to be generated that legitimises a particular policy agenda. Consequently, the use of performance indicators affects how institutions and policies are evaluated, as the power to delineate what evidence is considered relevant is shifted to those who create and control the performance indicator systems.

Performance indicators are occasionally complicated, and often controversial. In general terms they consist of a ratio, which comprises a numerator and a denominator. A robust indicator requires general agreement about the values that go into both of these. Additionally performance indicators need consensus that a higher ratio is 'better' or 'worse' than a lower ratio. The interpretation of indicators is generally at least as complex as their construction.

iii. Degree of Disclosure

It is necessary for the traditional measures of corporate economic performance to be extended to include organisational environmental performance (Beaumont *et al.,* 1994). The Department of the Environment, Food and Rural Affairs (DEFRA) guide to Integrated Pollution Prevention and Control (IPPC) outlines requirements for IPPC authorised organisations to consider Best Available Techniques (BAT), together with a consideration of local circumstances. The author's QPM study is intended to provide a quantitative / qualitative indicator that will enable all organisations to produce an individual evaluation of organisational performance which is in addition to the end-of-pipe reporting of emissions, allowing consideration of the organisational perspective as a whole.

Increasingly, organisations are not only expected to act in a responsible manner, but are asked to demonstrate this publicly (KPMG, 1999). This is particularly true in the environmental field, where growing public awareness and concern have fuelled the environmental movement. Company stakeholders, however, include many groups with differing priorities –

employees, shareholders, banks and insurers, customers, local communities, and the general public. The KPMG study considers that the response of organisations has been to extend public reporting to non-financial information, initially in the field of environment, and more recently to social and ethical issues, concluding that once organisations see their competitors producing such reports the pressure increases for them to report similar outputs.

Recent developments in communication have given a shorter lead-time, and larger audience for the reporting of environmental matters. Organisations now recognise the need for a proactive approach to environmental risk management and wish to demonstrate this to the relevant stakeholder groups (James, 1995). In addition to these pressures, a number of countries (Denmark, Norway, Netherlands, Sweden and UK) have a mandatory reporting requirement as well as voluntary reporting as a requirement of the Eco Management and Audit Scheme (EMAS).

2.2 Characteristics of QPM as Management System Deliverables

Via the delivery of a quantifiable social - economic statement based on the pollutant aspects / effects of an organisation, QPM is intended to produce a direct indicator of pollution performance by that organisation.

The contribution afforded by the QPM indicator will enable organisations to establish:

a. Common language and conceptual framework for the management of pollution by the organisation

b. Direct benchmark for organisational pollution performance evaluation
c. Temporal performance comparison using defined criteria
d. Comparisons with environmental performances of other organisations of a similar or diverse nature.

2.3 Measurement Metrics

Using the US EPA definition of pollution (See Chapter 1) as the central statement within an environmental management system (EMS) intended to deliver a statement of environmental performance implies that a greater understanding of the evaluation of environmental performance is needed. This understanding may be achieved through assessment of internal management processes to provide reliable and verifiable information on an ongoing basis. The measurement metrics used in this context must extend beyond the traditional focus on failure rates and end-of-pipe controls. End-of-pipe measures are limited to tracking costs, emissions, or other outputs, and fail to measure adequately the efficiency or effectiveness of the underlying process. They do not consider how the organisation approaches pollution management, and the extent of the deployment of management implementation – vertically through all levels of the organisation, and horizontally to all areas and activities. Post performance or results metrics consider what the organisation has achieved.

The US EPA definition of pollution does not rate the impact effects of pollution; the severity may vary according to factors such as toxicity, flow rate, frequency, bioaccumulation, etc. Source–Pathway–Receptor analysis provides a potential methodology for systematic analysis for assessing the hazard of pollution (Watts, 1997). Evaluation of operational performance by King and Lennox (2000) allows for differences in toxicity between emitted chemicals by weighting each by its toxicity against the reportable quantities database in the U.S. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, 1980) Statute using:

$$\mathrm{E}_{it} = \sum_{\forall c} w_c e_{cit} \qquad (2-1)$$

Where E_{it} is the aggregate emission for facility i in year t, w_c is the toxicity weight for chemical c in year t, e_{cit} is the mass in the year of emissions of chemical c. Relative environmental performance at the facility level is measured by estimating the production function relationship between facility size and aggregate toxic emissions for each four digit Standard Industrial Classification (SIC) code within each year using standard ordinary least squares regression. The relative environmental performance of a facility (RE_{it}) is given by the standardised residual, or deviation, between observed and predicted emissions given the facility's size and industry sector. The methodology developed by King and Lennox (2000) is limited to emissions that have a membership function within the CERCLA statute, and are reliant on post-event performance. BS EN ISO 14031:2000 defines the characteristics of data for indicators used in environmental performance evaluation as shown in Table 2.1.

2.4 Environmental Indicators

Direct measures or calculations:	Basic data or information
Relative measures or calculations:	Data or information compared to or in relation to, another parameter
Indexed:	Describing data or information converted to units or to a form which relates the information to a chosen standard or baseline
Aggregated	Describing data or information of the same type, but from different sources, collected and expressed as a combined value
Weighted:	Describing data or information modified by applying a factor related to its significance

Table. 2.1 Characteristics of data for indicators used in environmental performance evaluation.

2.5 Leading and Lagging Indicators

Environmental indicators can be broadly classed into two types of measures: end of process measures, otherwise known as 'lagging' indicators and in-process measures, otherwise known as 'lead' indicators (GRI, 2000). Most environmental metrics programmes will contain both types of measures.

	Lagging Indicators	Leading Indicators
Type of measure	End-of-process or output indicators	In-process or management indicators
Approach	Quantitative	Quantitative and qualitative
Example	Tonnes of toxic chemicals released to air, water, or land per unit time	Percentage of facility conducting self audit
Strength	Easy to quantify and understand: generally preferred by the public and regulators	Reflect current or future rather than past performance
Weakness	Time lag in feedback loop: root causes not always identified	May not address all stakeholder concerns; can be difficult to quantify and evaluate; hard to build support for use

Table. 2.2. Comparison of characteristics of leading and lagging indicators (GRI. 2000)

The reporting of indicator results within the GRI as absolute figures enables the organisational environmental characteristics to become apparent. The principal advantage of using lagging indicators is that they are usually readily quantifiable and understandable, and the data is often collected for other business purposes. The main disadvantage is that they lag behind or reflect situations that have already occurred. These indicators do not identify or establish the root cause of a deficiency, and how its recurrence will be prevented. In addition, the effects of corrective actions already taken may not be apparent until the next reported results. Conversely, reported performance may not portray current performance, because underlying factors may have already changed. Table 2.2 summarises the main aspects of both types of indicators.

2.6 QPM Links with Existing Quality Management Awards

The European Foundation for Quality Management (EFQM) Excellence Model provides a framework of criteria that can be applied to a diverse range of organisations, or to any part of an individual organisation intent on the demonstration of outstanding practice in managing the organisation and achieving results (Fig. 2.1). The EFQM Model addresses environmental issues within the nine criteria. For example, within 'Policy and strategy', how an organisation uses information relating to social, environmental and legal issues is addressed. How the organisation promotes awareness and involvement in health and safety and environmental issues is addressed within 'People'. 'Partnerships and resources' considers many areas related to how suppliers and materials are managed. Within 'Processes' there is a focus on how the organisation applies environmental system standards in process management. Finally, within 'Customer results' 'People results' and 'Society results' areas relating to the environmental profile of products and services, perceptions and policies are analysed.

The cause and effect linkages establish the relationships between the nine criteria. However until the introduction of the results, approaches, deploy, assess and review "RADAR" methodology (EFQM, 2000) for evaluation, the former 'blue card' system of appraisal (Armitage, 2002) relied on individual verification team members agreeing a consensus, and an aggregated score being derived for each of the criteria.

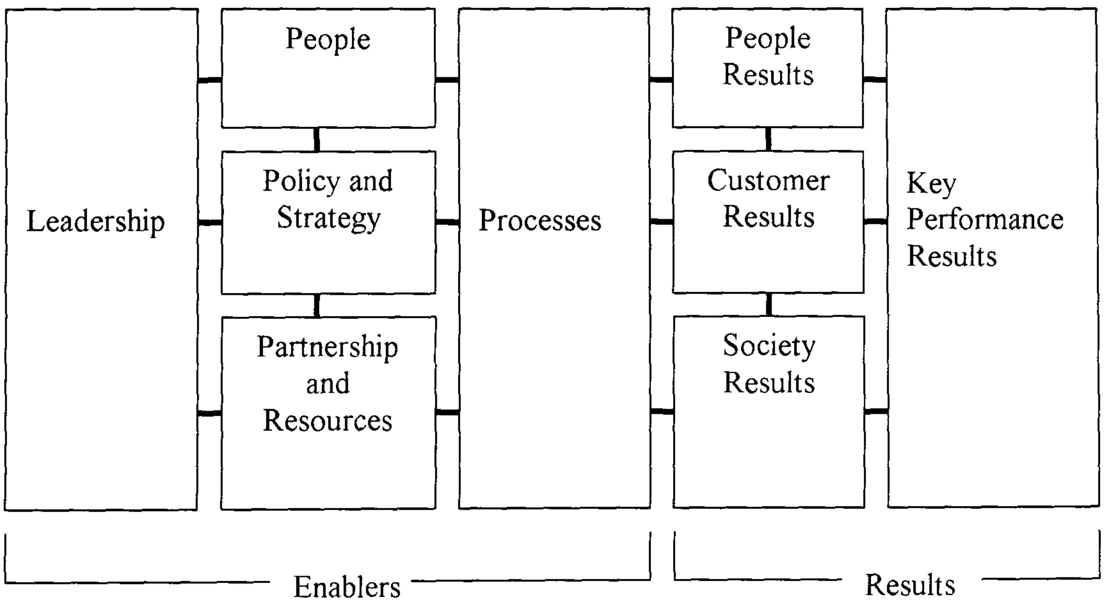

Fig.2.1 The EFQM Business Excellence Model (EFQM, 2003)

The study of the EFQM quality management award for the purpose of the development of a management system for QPM as developed in this thesis has shown that the following elements are issues that are important in this research study:

a. The concept of linking the management elements of the organisation (enablers) to the achievements (results). This establishes the cause and effect relationships between the leadership and management, and the results categories that combine to produce the key performance results. Policy decisions reflect both internally within an organisation and externally to customers, stakeholders and society.

b. The consideration of total involvement by the organisation. In the same way that quality is regarded as the 'totality of characteristics of a product or service that bears on its ability to satisfy stated or implied needs' (Hoyle, 1997), the reporting structure of QPM must consider the totality of the organisation and its actual, and potential for, pollution.

c. The EFQM model reflects a focus on a holistic approach to managing business excellence. By dividing the award criteria into enablers and results, equal weighting is given to cause and effect. To obtain a high rating for a determinant, the organisation must be successful as well as an excellently managed enterprise. The model clearly identifies success in both financial and non-financial terms, recognising the impact on society of managerial actions. The transposition of this methodology to the management system for QPM will add a level of robustness to the process that will encourage greater sector acceptance of QPM in that it can be seen that the achievement of success is as the result of management practices and not in-spite of them.

d. When evaluating the achieved results for the organisation, consideration must be given to performance in absolute terms, and performance against the organisation's own targets.

The Malcolm Baldrige National Quality Award (MBNQA) is very much concerned with the implementation of a company-wide system of total quality management (TQM). The Award is supported by detailed assessment, check lists and documentation. Award applicants and those using the system for self-assessment purposes have a clear understanding of what is expected of them. This has the adjunct of extending a level of transparency to the business process, and establishes a clear benchmark entry level for all entrants in an unambiguous manner. The seven criteria for the MBNQA each contain defined items that are each allocated point values. e.g.

Category 6.0	Business results	Points value		Total value
				250
6.1	Product and service quality results	points value	75	
6.2	Company operational and financial results	points value	130	
6.3	Supplier performance results	points value	45	
		Total	250	250

The MBNQA criteria are continually refined. While the basic structure of seven categories has remained unchanged, there have been alterations of emphasis in meaning and relative scoring weights. For example, category 3.0 was called 'Planning for quality' in 1989, and accounted for a maximum of 80 points out of 1000. In 1990 it became ' Strategic quality planning' with maximum points value raised to 90, and revised in 1995, it became 'Strategic planning' with a subsequent points reduction to 55. Two other categories that have been subtly moved from a definite quality bias to a wider definition of business excellence are category 5.0 'Process management' and category 6.0 'Business results'. Business results have additionally been re-weighted to contain a potential score of 250 points out of a maximum of 1000. This may sign a gradual change in emphasis for the MBNQA from a TQM system to a business excellence model.

The study of the Malcolm Baldrige National Quality Award as a recognised, successful, quality award, has shown that within its structure it has several aspects that are worthwhile for consideration in the development of the QPM management system and reporting process for the current study toward QPM. A consideration for the robustness of the concept of QPM is that it will contain appropriate best practice from other successful awards within its distinctive structure. The MBNQA introduces the following:

a. The introduction of the concept of a structured assessment process which is based on a published and unambiguous set of criteria, with set point values ascribed to each section, enabling participating organisations to conduct a self evaluation prior to assessment, and by the process of self determination, developing a 'learning organisation' for improvement.

b. The direct relation of the organisational score to the published maximum possible score. The MBNQA does not normalise, or in any other way alter, category scores, enabling direct comparisons to be made against the 'best in class' for each category.

c. The transparency of the defined criteria used in the MBNQA indicates that QPM would benefit from having a prescribed category membership function.

d. The ability of the MBNQA to undertake changes to category weightings as a direct response to industry considerations, and technological advances ensure that the award maintains its relevance, and robustness.

2.7 QPM Design Overview

The framework for the criteria that comprise the QPM metrics is based upon the simple process model (see Fig. 1.1). The four criteria enable the consideration of the entire organisation's activities. QPM is intended to provide both recognition of the internal mechanisms within an organisation in achievement of the QPM indicator, and an incentive for other organisations to attain a standard of performance appropriate to their particular organisation's activities. The Bellagio Principles (iisd, 2002) considered that assessment of progress toward sustainable development should be based upon an explicit set of categories or an organisational framework that links vision and goals to indicators and assessment criteria, and should review the whole system as well as its parts. The behaviour of an organisation's management and leadership should create a clarity and unity of purpose within the organisation, and attempt to ensure that all organisational activities are aligned and deployed in a structured and systematic manner. Organisations perform more effectively when all inter-related activities are understood and systematically managed, and decisions concerning current operations and planned changes are made using reliable information (Kaplan *et al.*, 1996). The author's study toward QPM will expand the four criteria of the simple process model to five criteria by the inclusion of metrics based upon organisational management and leadership.

QPM Framework Summary

The QPM framework is produced from the summary of the literature review discussed in Chapter 1, which highlighted the following areas as being important to the QPM model.

The framework for the QPM model should utilise an explicit set of categories that link vision and goals to indicators and assessment criteria. It is important that QPM should take a holistic approach to reviewing the organisation. As it is the behaviour of an organisation's management and leadership that drive and direct the organisation, QPM will require to ensure that all organisational activities are aligned and deployed in a structured and systematic manner. This requires the additional factor of management and leadership to be evaluated in addition to the inputs to the organisation, the controls and activities undertaken by the organisation and the resulting outputs. Any weighting of the model's categories should be reviewed periodically, to consider the possibility of adjustment to category importance weightings, subject to industry, stakeholder, or technological change.

2.7.1 Management / Leadership Function

The CERES reporting requirements, GRI Guidelines and the Public Environmental Reporting Initiative (PERI) Guidelines (IBM, 2002) consider the organisation's environmental policies, its organisation and its management, also taking into account the inherent culture of the organisation. The International Survey of Environmental Reporting (KPMG, 1999) considered that an organisation's management is not only expected to operate in an environmentally responsible manner, but is increasingly asked to demonstrate this publicly. Public awareness and concern have fuelled the environmental movement, creating pressures to report on environmental performance in addition to the mandatory reporting of prescribed substances. Environmental reporting enables reflection on the whole of the organisation. The culture of the organisation in regard of the environment is therefore an important aspect for consideration (James, 1994). Therefore by considering management and leadership in the study of QPM, company mission, vision and culture are embedded into the model.

The evaluation of environmental performance considered in BS 14031:1999 is regarded as an internal management process. The guidelines consider two types of environmental performance indicator:

i. Management Performance Indicators - providing information about management efforts to influence the environmental performance of the organisation's operations.

ii. Operational Performance Indicators - providing information about the environmental performance of the organisation's operations.

In this context of management performance indicators (MPI's), the management of the organisation includes the policies, people, planning activities, practices and procedures at all levels of the organisation. Efforts and decisions undertaken by the management of the organisation may affect the performance of the organisation's operations, and therefore may contribute to overall environmental performance. MPI's should provide information on the organisation's capability and efforts in managing matters such as training, legal requirements, resource allocation and efficient utilisation, purchasing, corrective and preventive actions. Further considerations of MPI's are the environmental management capabilities of the organisation, including flexibility to cope with changing conditions, accomplishment of specific objectives, effective co-ordination, or problem-solving capacity. MPI's may additionally be used in the assessment of compliance with legal and regulatory requirements, and conformance with other requirements to which the organisation subscribes. Utilising the principles proposed by BS 14031:1999, the study of QPM will benefit by conducting analysis of management's involvement in supporting and leading the organisation through its policy and strategy.

Management / Leadership Function Summary

In evaluation of the management / leadership function of the organisation, it is important that the study of QPM should consider the culture of pollution management inherent in the organisation, undertaking analysis of the management's involvement in supporting and leading QPM through its policy and strategy.

2.7.2 Inputs

The activities involved in the sourcing of raw materials / production parts and equipment are critical in this area, and account should be taken of opportunities for resource conservation, or through implementation of better process control. Input performance indicators should provide relevant information on the environmental performance of inputs that are introduced to the organisational process. The inputs considered by BS 14031:1999 view three categories, materials, energy and services.

i. Materials

Endorsers of the CERES reporting requirements consider how to incorporate environmental guidelines into the selection of specific goods and services (as distinct from the selection of suppliers). Design for the Environment (DfE) considers the purchase by the organisation of the most environmentally sound option from the range of products that a supplier offers. Both DfE and Life Cycle Analysis (LCA) techniques can be applied to the product creation process (Lennox *et al.*, 1995). With the integration of DfE concepts into the product development process, products can be designed and built using the most effective corporate resources, maximising environmentally beneficial product features, and minimising environmental impacts (Conway-Schempf, 1996). The value of any strategic environmental programme must be shown to balance the cost of market production, and the need to be competitively priced. Sheldon (1994) considers that organisations encounter a 'green wall', which is the point where the overall organisation refuses to move forward with its strategic environmental management programme, and requires that environmental management functions integrate sufficiently with the business units for both these functions to become effective.

The Sustainability Reporting Guidelines (GRI, 2000) require the reporting of total materials use, and organisationally specific data to include the use and conservation of natural resources, recycled materials, the use of packaging materials and the use of hazardous chemicals / materials. The Guidelines consider water separately, requiring organisations to report total water use, and the supply of information on water sources. In Annex VI of the EMAS Regulation, consideration of environmental aspects for the use of natural resources and raw materials (including energy) is expanded to review the product related issues of design, development, packaging, transportation, use and waste recovery / disposal.

ii. Energy

The production and use of energy are major sources of pollution worldwide (Hill, 1997), making this an area that should be included in the study of QPM. The Environmental Reporting General Guidelines (ERGG) (DEFRA, 2001) show total tonnes of greenhouse gas emissions in terms of tonnes of carbon dioxide equivalents. The indicator considers emissions from energy used on premises by taking information on energy use from electricity or gas bills and converting them into CO_2 equivalents using the ERGG greenhouse gas guidelines. This shows the contribution to global warming. If the organisation includes transport operations, the QPM indicator should also cover emissions from fossil fuels used for transport. The ERGG Guidelines detail the factors to convert fuel use or mileage into CO_2 equivalent emissions. BS 14031:1999 considers the type and quantity of energy used, generated or saved by the organisation.

Exploration of the ways in which energy needs can be met in a way that does not cause serious and /or irreversible environmental degradation (Vellinga, 2000) considers three perspectives, those of consumer, producer and government. Economic prosperity has generated an awareness and concern about the environment. The general public consider sustainability as an overarching condition for production (Steg, 1999), expecting producers and governments to assure that products and services introduced into the market do not cause serious / irreversible damage to the planet. The study by Vellinga (2000) shows that people are prepared to pay more where there is an assurance that the products or forms of energy purchased are environmentally friendly. Energy-consuming companies with high energy costs consider more readily the systematic exploration and exploitation of energy efficiency.

iii. Services

BS 14031:1999 considers 'services' which support organisational operations, and includes environmental issues that directly relate to contracted service providers. Services must be considered to enable QPM to achieve a robust indicator of pollution performance. Environmental effects related to supplier / service management are interpreted by both BS EN ISO 14001:1996 and EMAS as effects over which the organisation has control or over which the organisation may be expected to exert an influence. The CERES reporting requirements expand the concept of 'suppliers' beyond that of BS 14031:1999 to include both producers of the raw materials the organisation uses, and providers of intermediate products or services. The need to consider the environmental performance record of suppliers is particularly relevant in organisations involving a large percentage of outsourced products. Similar to the requirements in BS EN ISO 9001:1994, supplier evaluation prior to commencement of contractual arrangements should take into account the supplier's ability to meet environmental subcontract requirements, and should define the type and extent of control exercised by the organisation over subcontractors. Organisational policy for supplier assessment / evaluation should describe any methodology used for the incorporation of environmental criteria in the selection process. The description of methodologies used in the incorporation of environmental guidelines into the selection of specific goods and services (as distinct from the selection of suppliers) should comment on whether or not they are considered explicitly.

Input Function Summary

The evaluation of inputs considered by QPM should review the materials sourcing and supplier evaluation undertaken by the organisation, and any consideration that the organisation gives to the application of design for environment (DfE). The review of organisational use, and conservation of natural resources should include the product-related issues of design, development, packaging, transportation, use and waste recovery / disposal relevant to the organisation. As the production and use of energy are major sources of pollution worldwide it is important that organisational energy use is included in the QPM evaluation process.

2.7.3 Controls

Control is the act of preventing or regulating change in parameters, situations or conditions (Hoyle, 1997). Controlled conditions are arrangements that provide control over all factors that influence the result. Managerial activities may be classified under three categories, strategic planning, management control and operational control (Anthony, 1965). Using this classification, a framework was developed (Gorry *et al.*, 1989) which differentiated between the information requirements of management planning and those of control activities. Quality Management Systems (QMS) such as BS EN ISO 9001:2000 may be considered in the study of QPM as an indicator of an organisation's ability to produce an output good or service to a particular specification on a repeatable basis. A key performance target of a QMS is the reduction of variability; this will include the procedures involved in controlling the process. The level of control may be reflected by the rate of defective products produced, making certification to a QMS an important factor for QPM. BS EN ISO 14031:1999 considers the rate of defective products produced. Information requirements may be from sources that are internal to, or external from, the organisation, dependent upon the activity that is being controlled.

One of the duties of the UK Environment Agency (EA) is to protect the environment by enforcing regulations to minimise pollution (EA, 1997). Information on the risks of pollution to the environment is needed in order to make informed regulatory decisions at the local and strategic level. The EC White Paper on environmental liability (2000) sets out a structure for a future EC environmental liability regime, which intends to implement a 'polluter pays' principle where damage has resulted to the environment from human acts.

The White Paper considers that acceptance of liability for damage to nature is a prerequisite for making economic participants feel responsible for the possible negative effects of their operations on the environment. The CERES environmental report format requires endorsers to distinguish between the number of consent approvals and the number of penalties cited throughout the organisation. Compliance with environmental legislation is therefore an important consideration for this study of QPM.

The EFQM model considers organisational relations with authorities and bodies that affect and regulate its business (Westlund, 2001). OPRA takes into account the frequency of environmental incidents, justified complaints and non-compliance events.

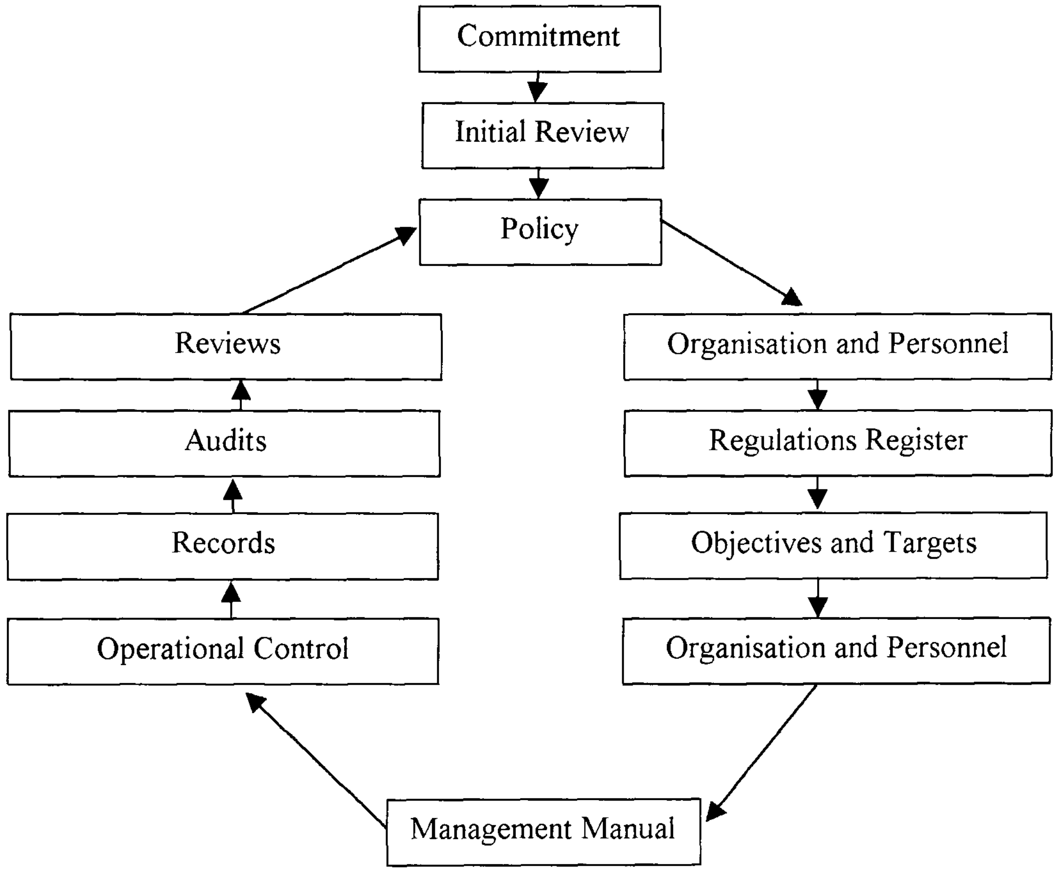

Fig. 2.2 Schematic Diagram of the Stages in the Implementation of an Environmental Management System (Source: British Standard 7750:1992, Page 3).

Organisations demonstrate a commitment to the environment by achieving compliance with BS EN ISO 14001:1996 or EMAS. Third party verification of achievement adds robustness to the compliance process. The implementation stages for an environmental management system (Fig. 2.2) demonstrate the control required for achievement of the requirements of either standard. This study toward QPM intends to expand the basic management and operational functions to develop a quantitative indicator of pollution performance by the organisation.

BS 7850-1:1992 defines total quality management (TQM) as "*management philosophy and company practices that aim to harness the human and material resources of an organisation in the most effective way to achieve the objectives of the organisation.*" TQM ultimately aims for zero defects, preventing defects occurring in the first place, not only in the product or service, but also at every stage of the production process, both internally and externally. The responsibility for this is shared throughout the organisation. Significant parallels can be drawn between attempting to achieve total quality, and the concept of QPM, which is the aim of this study. The environmental equivalent of zero defects in TQM is the ultimate goal of zero net pollution.

Some organisations now believe that the only completely safe and therefore acceptable environmental option is to remove pollution completely (Beaumont *et al.*, 1994). QPM will enable organisations to compare year on year results, and to demonstrate achievements (or lack of them), it is a tool for the strategic benchmarking of an organisation's operations against those of its competitors within its industry sector. Participation by all members of the organisation utilising QPM as the basis for individual activities requires the commitment of senior management, and is fundamental to the successful use of the QPM indicator. The commitment to environmental performance by senior management should be supported by the relevant policies, objectives, management plans, manuals and associated auditing.

Planned and systematic auditing of the complete management cycle requires assessment of the robustness of written procedures and operating instructions, and whether they are actually followed in practice, this is an aspect which QPM will require to investigate and evaluate. The balanced scorecard is based upon four organisational perspectives (Kaplan *et al.*, 1992). The scorecard links the organisation's internal business perspective to the learning and growth perspective in an assessment of what the organisation is required to learn (either individuals or strategic business units) to achieve the required operating conditions. Appropriate knowledge and training are areas which are considered in both BS EN ISO 14001:1996 and EMAS for all employees within an organisation. The assessment of OPRA views not only the management commitment and underpinning management systems, but the competence and training of staff, access to information, and staff understanding at all levels throughout the organisation which may affect environmental performance. In addition OPRA considers the extent of manning, and the reporting relationships, evaluated in relation to different conditions (routine, emergency, abnormal, staff unavailability).

Control Function Summary

The evaluation for the purpose of QPM, of the organisation's ability to establish controlled conditions through planned arrangements that provide control over all factors that influence the result, will be undertaken through the consideration of the management system(s) to which the organisation subscribes, and the maintenance and robustness of the management system(s) through systematic audit and evaluation. Legislation and compliance will be considered as contributing to the QPM process, although not required for maintained certification to either BS EN ISO 14001:1996 or EMAS. Legislation provides information on possible polluting events, by demonstrating non-compliance against prescribed legislation designed for pollution prevention, for example Integrated Pollution Control (IPC).

2.7.4 Activities

The increased efficiency with which resources are used results in lower pollutant emissions produced as outputs. BS EN ISO 14031:2000 considers that the identification of organisational environmental aspects is an important input to environmental performance evaluation, and may typically be developed in the context of an EMS such as BS EN ISO 14001:1996 or EMAS. The identification of aspects is capable of providing management with information on operational environmental performance related to the delivery of outputs resulting from the organisation's operations.

The machinery utilised by the organisation is an important factor in this study of QPM, as actions and controls are required to maintain, within prescribed limits, the accuracy and condition of all measuring and test equipment used during the provision of the service or product, including equipment privately owned by an operator when used in the organisation's activities. OPRA considers an evaluation of environmental performance based upon the scrutiny of the effectiveness of a clearly defined maintenance programme, in terms of environmental performance, using appropriate industry standards of maintenance. BS EN ISO 9001:2000 requires implementing organisations to detail methods for stock control, storing and handling material and parts to ensure the necessary identification, preservation and segregation of material, and the provision of handling methods to prevent misuse, damage or deterioration. BS EN ISO 9001:2000 also considers the recording and disposal of surpluses on completion of service. The storage philosophy utilised by an organisation is therefore an aspect that will need to be evaluated in this study of QPM.

The essence of Integrated Pollution and Prevention Control (IPPC) is that operators should choose the best option available to achieve a high level of protection of the environment taken as a whole (DEFRA, 2002). IPPC achieves this by requiring suitably trained / educated operators to use the most effective and advanced stage in the development of activities and their methods of operation, which indicate the practical suitability of particular techniques. Personnel are an important consideration in this study of QPM. The definitions contained in the IPPC Directive of best available techniques (BAT) additionally consider the availability of techniques, and the cost of the technique balanced against its environmental benefit. The consideration of BAT by an organisation may prevent or reduce emissions that are not covered by specific permit conditions, and may cover the most detailed level of plant design where the organisation may be in the best position to understand what pollution control means in practice for an installation. The basic considerations in determining BAT involve identifying options, assessing environmental effects, and considering economics.

The Environmental Protection Act 1990, Section 7, requires operators to use the best available techniques not entailing excessive cost (BATNEEC) to render harmless both prescribed and other substances which may be released into the environment. Where prevention is not possible, operators should minimise the release into any medium. In determining the unique QPM indicator, evaluation should consider whether abatement plant is appropriate for the process, and is operating as intended. OPRA considers the evaluation of the process plant to be not directly proportional to factors such as plant age and complexity, but on the ability of plant to eliminate or minimise hazards at source, and compare how the plant is functioning against design requirements. BS EN ISO 14031:1999 considers that evaluation of physical facilities and equipment should include the design, installation, operation, maintenance and land use of the facility.

Activities Function Summary

The machinery operated by the organisation must be considered for the study of QPM. The appropriateness, condition and complexity of the machinery are capable of exerting influence on the QPM outcome through consideration of BAT. Personnel employed by the organisation are an important factor for consideration, as staff competence and actual performance have a determining effect on optimum organisational performance.

The storage philosophy of the organisation should be reviewed to establish if detailed methods for stock control, storing and handling material and parts, have been developed to ensure the necessary identification, thereby mitigating the possibility of contamination and incident.

2.7.5 Outputs

In most production processes, there are two outputs, the product and the waste. They must both be disposed of in the safest and most environmentally acceptable way possible. Waste is a measure of organisational inefficiency. BS EN ISO 14031:1999 considers operational performance indicators to consist of three main output classifications; products, wastes and emissions.

i. Products

Products are considered in three sections by BS EN ISO 14031:1999, main products, by-products, and recycled and re-used materials. The CERES reporting format includes sectional reference to product stewardship, and considers organisational procedures for determining the main environmental impacts associated with the use and disposal of products. This requirement is extended to consider organisational programmes to address / prevent product misuse. This study of QPM should expand the CERES view on product stewardship to include by-products of the production process. BS EN ISO 14031:1999 takes into account the environmental performance of the product to evaluate product re-use and recycling potential, both in terms of the number of products which may be recycled, and the percentage of parts within the product which may be recycled. BS EN ISO 14031:1999 views the number of products with instructions regarding environmentally safe use and disposal. The Global Environmental Management Initiative (GEMI) (GEMI, 2002) environmental self-assessment programme (ESAP) requires participating organisations to consider procedures to develop and provide products and services that have no undue environmental impact. The ESAP environmental impact considerations include product energy efficiency, use of natural resources, recycling / re-use, and disposal.

ii. Wastes

Waste is considered by BS EN ISO 14031:1999 as solid / liquid, hazardous / non-hazardous, and re-cycleable / re-usable. The operational performance indicator of total waste generated by the organisation's operations considers not only the quantity of waste per year or per unit of product, but also the division of such waste into the quantities of hazardous, re-cycleable or re-useable waste produced. BS EN ISO 14031:1999 considers the quantity and storage of on-site waste, and waste controlled by authorisation. The quantity of waste converted into re-useable material, and the quantity of hazardous waste eliminated due to material substitution are taken into account. The CERES reporting format expands the requirements of BS EN ISO 14031:1999 to the investigation of the disposal options used by the organisation and the performance of selected waste disposal contractors. The Sustainable Development Draft Strategy (DETR, 2000) considers breaking the link between economic growth and waste generation, and capitalising on the value of materials in waste streams through re-use, recycling and recovery. The ESAP evaluation goes beyond compliance with waste management and disposal legislation, to consider whether the organisation integrates waste management considerations within the product and planning process, and has in place a system to identify and implement improvement.

iii. Emissions

Emissions are considered in BS EN ISO 14031:1999 as emissions to air, effluent to water or land, and noise, heat, vibration, light and radiation, and are based on quantity, either of specific emissions / discharges or specific emissions per unit of product, each measured over the period of one year. The quantity of waste energy released to air or water is taken into account, as are the amounts of heat, light or vibration emitted, the quantity of radiation released, and the noise measurements at specified locations. The CERES reporting format uses generally applicable indicators such as greenhouse gas emissions (per Kyoto protocol definition) in tonnes of CO_2 equivalent (global warming potential), and ozone-depleting substance emissions (per Montreal protocol definition) in tonnes of CFC-11 equivalent (ozone depleting potential). The organisation-specific indicators used indicate emissions to air by type and nature, and effluents discharged by type and nature. OPRA considers a different view of the intrinsic hazardous properties of the representative substance to include acute ecotoxicity, chronic ecotoxic effects, carcinogenic / mutagenic properties, pH, surface water or benthic blanketing properties, chemical / biological oxygen demand (COD / BOD), temperature, health risk to humans, persistence in the environment, and bioaccumulation properties. Annex VI of the Integrated Pollution Prevention and Control guidance (DEFRA, 2002) specifies an indicative list of the main polluting substances for emission limit values based on BAT. For the purpose of deriving the QPM indicator, greenhouse gas emissions should be absolute figures, and not normalised returns such as those to an Emissions Trading Authority used in the course of greenhouse gas emissions trading (DEFRA, 2001).

Output Function Summary

Product stewardship activities undertaken by the organisation provide the QPM study with information obtained from a structured evaluation of current and possible future environmental impacts of organisational outputs. Although heavily influenced by the inputs to the process, product stewardship clearly demonstrates the organisation's intent to identify and manage the effects of pollution over diverse timescales.

The study of QPM will consider both the production of waste, the options considered by the organisation for the disposal of waste, and the disposal method used. Emissions released by the organisation to air, effluent to water or land, and noise, heat, vibration, light and radiation will be considered as important primary sources of possible pollution.

2.8 Chapter Summary

This chapter considers what needs to be included to quantify the pollution performance of an organisation for QPM to deliver a quantifiable social - economic statement based on the pollutant aspects / effects of an organisation.

Using the US EPA definition of pollution as the focus for an environmental management system (EMS) intended to deliver a statement of environmental performance requires a comprehensive understanding of the evaluation of environmental performance. This may be achieved via assessing internal management processes to provide reliable and verifiable information on an ongoing basis. The measurement metrics used must extend beyond the traditional focus on failure rates and end-of-pipe controls which fail to measure adequately the efficiency or effectiveness of the underlying process and do not consider the extent of the deployment.

The EFQM award depends upon:

- The concept of linking the management elements of the organisation (enablers) to the achievements (results).
- The consideration of total involvement by the organisation.
- Focus on a holistic approach to managing business excellence.
- Organisation actual performance, and performance against the organisation's own targets being considered.

The Malcolm Baldrige National Quality Award has several aspects worth considering in the development of the QPM. It introduces the following:

- The concept of a structured assessment process based on a published and unambiguous set of criteria, with set point values ascribed to each section.
- The direct relationship of the organisational score to the published maximum possible score.
- Transparency criteria indicating that QPM would benefit from having a prescribed category membership function.

- The ability to review and amend criteria weightings according to industry demand or technological advance.

The organisation's management and leadership should display a clarity and unity of purpose, attempting to align and deploy all organisational activities in a structured and systematic manner. Effective organisational performance requires all inter-related activities to be understood and systematically managed, and decisions concerning current operations and planned changes to be made using reliable information (Kaplan *et al.*, 1996). In this context, management performance indicators (MPI's) include the policies, people, planning activities, practices and procedures at all levels of the organisation. Efforts and decisions undertaken by management affect the performance of an organisation's operations, and therefore overall environmental performance. MPI's should provide information on the organisation's capability and efforts in managing training, legal requirements, resource allocation and efficient utilisation, purchasing, corrective and preventive actions, flexibility to cope with changing conditions, accomplishment of specific objectives, effective co-ordination, and problem-solving capacity. MPI's may additionally be used in the assessment of compliance with legal and regulatory requirements, and conformance with other requirements to which the organisation subscribes.

Optimal sourcing of raw materials / production parts and equipment is critical, and account should be taken of opportunities for resource conservation through better process control. Design for the Environment (DfE) advocates the purchase of the most environmentally sound option that can be supplied.

Energy production and use are major sources of pollution worldwide. If the organisation includes transport operations, the QPM indicator should also cover emissions during transport. Services that support organisational operations must be considered to enable QPM to achieve a robust indicator of pollution performance. The environmental performance record of suppliers is particularly relevant in organisations involving a large percentage of outsourced products. Organisational policy for supplier assessment / evaluation should transparently incorporate environmental criteria in the selection process. The description of methodologies used to incorporate environmental guidelines into the selection of specific goods and services (as distinct from the selection of suppliers) should comment on whether or not they are considered explicitly.

Senior management commitment to environmental performance should be supported by relevant policies, objectives, management plans, manuals and associated auditing. Planned and systematic auditing of the complete management cycle requires assessment of the robustness of written procedures and operating instructions, and whether they are followed in practice. QPM should consider the competence and training of staff, access to information and staff understanding that may affect environmental performance under different conditions.

Improving resource use efficiency lowers pollutant emissions produced as outputs. Actions and controls are required to maintain, within prescribed limits, the accuracy and condition of all measuring and test equipment used during the provision of the service or product, including equipment privately owned by an operator when used in the organisation's activities.

The consideration of BAT may prevent, or reduce, emissions not covered by specific permit conditions. In determining the unique QPM indicator, evaluation should consider whether abatement plant is appropriate for the process, and is operating as intended. This study of QPM should expand the CERES view on product stewardship to include by-products of the production process. This requirement may be extended to consider organisational programmes to address / prevent product misuse.

The study toward QPM will take into account the environmental performance of the product to evaluate product re-use and recycling potential, considering the number of products with instructions regarding environmentally safe use and disposal.

QPM will consider the quantity and storage of on-site waste, and waste disposal controlled by authorisation. Investigation of disposal options and of the performance of selected waste disposal contractors should be considered, going beyond compliance with waste management and disposal legislation, to consider whether the organisation integrates waste management considerations within the product and planning process, and has in place a system to identify and implement improvement.

Summary of Factors Considered for Inclusion in QPM Study

The review of each of the five categories considered for the author's study of QPM has produced the following factors that will be used in the evaluation process. These are shown in Table 2.3 Factors for Evaluation of Categories used in QPM, which are discussed in Chapter 4.

Category	Factor
Management and Leadership	Culture of pollution management. Visible involvement in leading QPM. Support for QPM. Policy and Strategy.
Inputs	Materials sourcing. Design for Environment (DfE). Use and Conservation of Natural Resources. Energy.
Controls	Management Systems. Audit. Legislation and Compliance.
Activities	Machinery. Personnel. Storage.
Outputs	Product stewardship. Waste. Emissions.

Table 2.3 Factors for Evaluation of Categories used in QPM

Having considered the requirements of QPM in general terms, Chapter 3 considers the methodology used in the design and prototyping of QPM. Chapter 4 investigates the initial model for QPM, and the weightings of the individual, and combined categories. The Chapter also considers the audit guidelines for QPM, and produces an audit protocol based upon Table 2.3, Factors for Evaluation of Categories used in QPM.

Chapter 3

Methodology

Chapter Summary

This chapter considers the author's methodology in deriving the initial model for QPM. It provides a brief overview of the prototyping, application and evaluation of QPM

3.1 Introduction

This chapter explains the methodology used in the design and application of the author's model for quantitative pollution management (QPM). The use of a robust design process and structured methodology enabled the author to evaluate and utilise the information necessary for the derivation and application of the QPM model. As the possibility to apply the model for QPM was limited to one organisation, the author considered that the initial design process should take on increasing importance, and should be as robust as possible. A poor design may not meet stakeholder needs; the design process must also be managed effectively (Russell *et al.*, 2000).

Quality management and environmental management standards that are produced for the International Standardisation Organisation (ISO) are developed according to the following principles (ISO. 2001):

- **Consensus**

  The views of all interests should be taken into account: manufacturers, vendors and users, consumer groups, testing laboratories, governments, engineering professions and research organizations.

- **Industry-wide**

  Global solutions are required to satisfy industries and customers worldwide.

- **Voluntary**

  International standardization is market-driven and therefore based on voluntary involvement of all interests in the market place.

The author's study of QPM reflects these principles in the following manner:

Consensus

The holistic concept of QPM outlined in this study applies to the organisation as a whole. It is the intent of the author that QPM will reflect data that has impact both internal and external to an organisation, requiring a framework that differentiates between the information requirements of management planning and control activities. The consideration of organisational management performance is reflected through conventions such as those developed by both the European Foundation for Quality Management (EFQM) model (EFQM, 2000) and the Malcolm Baldrige National Quality Award (MBNQA) (NIST, 2002) as internationally accepted strategies for determination of management performance. It is important that the author's study of QPM reflects actual performance and the influences of management and employees on that performance. Environmental consideration is included by use of selected criteria for environmental comment, taken from internationally recognised environmental reporting mechanisms such as the Coalition for Environmentally Responsible Economies (CERES) (CERES. 2000), the Global Reporting Initiative (GRI) (GRI, 2000), national studies such as the United Kingdom Operator and Pollution Risk Appraisal (OPRA) system (EA, 1997).

As was shown in the literature survey in Chapter 1, no single method taken in isolation adequately defines the objective of QPM for the purposes of this study. QPM will form a fully specified design that requires characteristics to be identified from stated areas or activities of the organisation. In order to assist the design of QPM the selection of determinants for inclusion in each of the categories is progressively reduced by the screening of options using the design funnel methodology proposed by Slack *et al.* (2001).

Industry Wide

The aim of the author's study is to develop and apply a model for environmental management from which quantifiable indication of overall environmental performance for an organisation may be derived. As the basis of QPM is constructed on the 'simple process model' (Fig. 1.1) given in BS 7850:1992 it is possible to apply QPM to both service and manufacturing sectors of industry. BS EN ISO 14031:2000 defines the characteristics of data for indicators used in environmental performance evaluation as discussed previously in Table 2.1. QPM is to be constructed from generally applicable environmental indicators, and is not limited to a particular sector or process. Environmental indicators can be broadly classed into two types of measures: end of process measures, otherwise known as 'lagging' indicators and in-process measures, otherwise known as 'lead' indicators (GRI, 2000). As QPM considers a holistic view of the organisation, and is not limited to a particular process or function, or product, it will contain both types of measures. A. comparison of characteristics of leading and lagging indicators (GRI. 2000) was discussed in Chapter 2, Table. 2.2.

Voluntary

Both BS EN ISO 14001:1996 and the Eco Management and Audit Scheme (EMAS), Regulation (EC) No. 761/2001 are voluntary environmental standards. Other than for mandatory legislative compliance, environmental reporting by organisations is voluntary. The author's study of QPM seeks to encourage organisations to enable customers / consumers to make a purchase decision that takes into account environmental concerns. Organisational environmental performance therefore becomes a strategic factor in business planning, providing direct business benefits to organisations that manage their business and protect the environment.

3.2 The Principles of Design Applied to QPM

The principles of design which were applied to the author's study of QPM required consideration of the following using principles established by Slack *et al.* (2001).

- Definition of the overall concept of QPM
- The component aspects of QPM required to provide and support the concept
- The process by which QPM will fulfil its concept
- Preliminary evaluation / prototyping
- Application and evaluation

3.2.1 Definition of the overall concept of QPM

The aims and objectives of the author's programme of research have been stated in Chapter 1 as the development and application of a model for environmental management from which quantifiable indication of overall environmental performance for an organisation may be derived. The benefits to both the organisation and the environment are discussed. The clarity of the problem statement gives a clear indication of the requirements of QPM, and the literature survey underpins the concept of the basic model from which QPM is derived.

3.2.2 The component aspects of QPM required to provide and support the concept.

The basic model of QPM is derived using the 'simple process model' shown in BS 7850:1992 (Fig. 1.1). This enabled the focus of the research to concentrate on the individual elements contained in the categories of the model, and to consider the inclusion of a further category on management and leadership. The compilation of determinants for inclusion in each of the categories made use of the principles involved in the production of international standards by ISO, and was achieved through the screening of possible options using the design funnel methodology proposed by Slack *et al.* (2001). As the inputs to the design funnel were considered robust due to their qualification, (i.e. inputs are sourced from recognised methodologies), the certainty in, and confidence regarding, the final design became more apparent as the screening process progressed.

The model for QPM is derived in Chapter 4, and utilises five category weightings for the derivation of the final QPM indicator. The weightings are obtained as the result of the appraisal and evaluation of existing management models that give a quantitative output such as EFQM, MBNQA, and OPRA. The use of the principles of the 'balanced scorecard' (Kaplan and Norton,

1992) form the basis for both the quantitative indicator and the qualitative interpretation of that indicator.

3.2.3 The process by which QPM will fulfil its concept

The achievement of the QPM concept requires the audit and evaluation of the organisation through a structured consistent process. Using established practice QPM supplies the audit protocol to the organisation prior to the site visit. This serves three purposes, as it:

a. Enables the organisation to use self-assessment as a self-diagnostic process.

b. Outlines areas for concern that may be considered during the QPM audit, providing the critical understanding of how activities are actually done within the company, and how they may need to be carried out differently.

c. Provides the basis for the scoring mechanism for QPM.

QPM pursues the assessment of the organisation by establishing the collection of audit evidence against a defined 5-point Likert scale for three specified criteria. QPM ensures a robust audit by utilising the established conventions and guidelines from the three International Standards giving guidance on environmental audit, and the principles involved in quality management system audit.

3.2.4 Preliminary evaluation / Prototyping

The author used his 12 years experience as a quality systems lead assessor, and 6 years experience as an environmental management system lead auditor in compiling and reviewing the audit protocol. The prototyping of the audit protocol was achieved through discussion with both industry (James, 2002) and a subject specialist academic (Armitage, 2002).

The audit protocol was supplied to the technical manager of a high profile environmental management company, who commented from the perspective of industry (James. 2002). The comments were positive, and provided the author with constructive inputs regarding best available techniques (BAT) and best available techniques not entailing excessive cost (BATNEEC).

Subject specialist academic input was provided by a personal contact of the author (Armitage. 2002), who as a registered assessor for EFQM evaluated the initial model, which required no amendment. This resulted in the author proceeding to trial application.

3.2.5 Application and Evaluation

The application of QPM was conducted through an initial audit of Tubex Ltd. and is described in Chapter 5. The audit protocol and the assessment criteria were supplied to Tubex Ltd. three weeks prior to the agreed date for the assessment, and an informative summary of the aims of the author's study were conveyed to senior management as an aid. Having been completed, the self-assessed audit protocol was returned to the author a week prior to the assessment date, and provided a valuable insight into the organisation.

The author conducted the QPM audit over a two-day period, with a shadow audit being conducted by the organisation's quality manager. The results obtained were discussed, and the QPM indicator was calculated. The qualitative interpretation of the quantitative indicator provided an accurate assessment of Tubex Ltd. and was well received by the organisation's management.

Evaluation of the audit is shown, and reflection has taken place on the robustness of the audit process, difficulties encountered during the audit, and the possibilities for improvement.

3.3 Conclusion

The derivation of the QPM model has followed a structured methodology, and has reflected principles used by ISO for the production of both quality management and environmental management standards. The design methodology used in the establishment of the QPM model used the following five stages:

- Definition of the overall concept of QPM
- The component aspects of QPM required to provide and support the concept
- The process by which QPM will fulfil its concept
- Preliminary evaluation / prototyping

- Application and evaluation

The author's study of QPM has benefited by the use of a structured design methodology and the use of a systematic process of evaluation.

Chapter 4

Derivation of the Initial Model for QPM

Chapter Summary

This chapter considers the derivation of a model for QPM, and the weightings of the individual and combined categories. It also considers the audit guidelines for QPM.

4.1 Introduction

This chapter considers the weighting of the individual components of QPM in determining the final indicator of pollution performance, and the structure of the QPM audit.

The chapter identifies the criteria that will form the basis for the QPM audit, and establishes audit conventions that enable QPM to be viewed as the strategic reconciliation of environmental and management requirements with operational resources. It is important to make a distinction within the environmental performance evaluation, between classes of managerial activities (Anthony, 1965). The chapter derives an initial model for QPM using selected audit criteria. The intention of the initial model is to establish that a management system may be derived for the purpose of QPM. The chapter concludes with an appraisal of the initial model for QPM.

4.2 The Structure of the Quantitative Pollution Management (QPM) Process

The concept of QPM outlined in this study applies to the organisation as a whole. A framework that differentiates between the information requirements of management planning and control activities enables decisions to be made for the requirement of quantitative or qualitative information (Gorry and Scott-Morton, 1989). Sources of environmental data are both internal and external to an organisation (Charter, 1992). QPM requires a comprehensive, systematic and regular review of the organisation's activities modelled against the criterion included in the audit protocol. A weakness of the BS EN ISO 14001:1996 certification process is that it is based upon traditional quality management system techniques (Tuberfield, 2002). The environmental management system (EMS) effort can become cyclical with short periods of intense activity immediately preceding an assessment, as the organisation updates and validates documentation not visited since the previous assessment. The assessment activity, focussing mainly on documentation, may fail to provide the critical evaluation of how activities are actually done, and how they may need to be carried out differently. The study by Tuberfield (2002) considers that an assessment should aim to identify existing management mechanisms that are able to deliver enhanced environmental outcomes, and should provide a detailed record of changes in operational practices, modifications to (or new) environmental risks and compliance issues that have occurred and how these are addressed by the organisation's management.

Environmental auditing has established itself as a valuable instrument to verify and help improve environmental performance (ISO, 1996). General principles common to the conduct of environmental audits are shown in BS EN ISO 14010:1996 *Guidelines for Environmental Auditing — General principles* (ISO, 1996). Providing internationally accepted definitions of environmental audit and related terms, BS EN ISO 14010:1996 outlines the general principles of environmental auditing, the conventions of which will be applied to the audit process for the study of QPM. Although these environmental audit guidelines were harmonized in BS EN ISO 19011:2002 it is the author's belief that the robustness of the independent environmental auditing standard has been diluted by the amalgamation of the two audit disciplines of quality and environmental management. The environmental auditing protocol for QPM should provide a level of confidence in the reliability of the audit findings and any audit conclusions. The audit evidence collected during an environmental audit will inevitably be only a sample of the information available, partly due to the fact that an environmental audit is conducted during a limited period of time and with limited resources. There is therefore an element of uncertainty inherent in all environmental audits, even if the audit protocol is well assigned; performance is only viewed as a snapshot (BSI, 1996). In defining the environmental audit process for QPM, consideration should be given to the limitations associated with the audit evidence samples collected, and the recognition of uncertainty in audit findings and any audit conclusions.

In addition to the conventions associated with BS EN ISO 14011:1996, the proposed QPM will integrate an element of the audit methodology used in the European Foundation for Quality Management (EFQM) Model in its assessment process by evaluating the approach toward QPM taken by the organization, and the deployment of that approach. The EFQM model uses a scoring matrix for the assessment process, the application of which has been reviewed in line with the concept of this study toward QPM. The revised matrices are shown in Fig. 4.1, and Fig. 4.2.

The EFQM model and the Malcolm Baldrige National Quality Award (MBNQA) use a self-assessment process against specified criteria for initial applications; these applications are subjected to rigorous appraisal by trained assessors prior to the final selection of a short list of external organizations for evaluative site visits and final scoring. An advantage of this approach is that organizations undertaking the self-assessment process are able to consider their own organisational performance against clear and unambiguous criteria, and accrue benefit from conducting an internal evaluation of the results from the self-assessment process. The disadvantage is that organisations not receiving the evaluative site visit do not have the benefit of the robustness of third party accreditation in verifying performance levels.

Score	**Approach** Approach has a clear rationale with well-defined and developed processes that support policy and strategy.	Total
1 0%	Anecdotal or non-value adding	0 5 10
2 25%	Some evidence of soundly based approaches and prevention based systems. Subject to occasional review. Some areas of integration into normal operations	15 20 25 30 35
3 50%	Evidence of soundly based systematic approaches and prevention based systems. Subject to regular review with respect to environmental effectiveness. Integration into normal operations and planning well established.	40 45 50 55 60
4 75%	Clear evidence of soundly based systematic approaches and prevention based systems. Clear evidence of refinement and improved environmental effectiveness through review cycles. Good integration of approach into normal operations and planning	65 70 75 80 85
5 100%	Clear evidence of soundly based systematic approaches and prevention based systems. Clear evidence of refinement, improved environmental effectiveness through review cycles. Approach has become totally integrated into normal working patterns.	90 95 100

Fig. 4.1 Revision of EFQM scoring matrix for use in QPM audit methodology - Approach.

Score	Deployment Approach is implemented and deployed in a systematic and structured manner	Total
1 0%	Little effective usage	0 5 10
2 25%	Applied to about one quarter of the potential when considering all relevant areas and activities	15 20 25 30 35
3 50%	Applied to about half the potential when considering all relevant areas and activities	40 45 50 55 60
4 75%	Applied to about three quarters of the potential when considering all relevant areas and activities	65 70 75 80 85
5 100%	Applied to full potential in all relevant areas and activities	90 95 100

Fig. 4.2 Revision of EFQM scoring matrix for use in QPM audit methodology – Deployment.

The Eco-Management and Audit Scheme (EMAS) (Council Regulation 761/2001 EEC) advocates the release of detailed information based on a publicly available, third party-validated environmental policy statement. This strategy for verifying the environmental policy of the organisation is made more robust by the introduction of independent third party environmental verifiers. The disadvantage with the EMAS regulation as a reporting mechanism for this study toward QPM is that it lacks the defined structure and clarity of either the EFQM model or the MBNQA.

The Global Environmental Management Initiative (GEMI) environmental self-assessment program (ESAP)(GEMI, 2002) although not an award, is developed upon sixteen categories that each contains four successive performance level descriptors. The self-assessment program allows organizations to make a self-determination of performance that enables the prioritization of improvement efforts.

4.3 QPM Category Weightings

The proposed model for QPM (Fig. 4.3) considers the organization under five areas, leadership, inputs, controls, activities and outputs. A key issue in this unique study of QPM is the weighting determination of significance for each of the areas. The MBNQA uses seven non-linearly ranked categories each of which contributes toward a final numerical indicator derived from a possible score of one thousand. The EFQM Model uses nine individually ranked criteria, each marked out of one hundred and then multiplied by a weighting factor assigned to the criteria concerned. Organizations attempt to achieve an optimal score on a scale between zero and one thousand points. The percentage criterion weightings were established by EFQM, and are a mixture of leading and lagging indicators that are confirmed by the Presidents of the fourteen founding members of EFQM. In consideration of the valuation for the EFQM award, equal weighting is assigned to how things are done (enablers) and to what is achieved (results).

The Operator Pollution Risk appraisal (OPRA) uses a rating of linear values ranging from one to five (as used in the Likert Scale) (Kolarik, 1995) for both operator performance appraisal (OPA) and pollution hazard appraisal (PHA). The equal division by OPRA of the inherent level of risk of pollution from the process and the environmental performance of the operator in managing that pollution risk is an application of leading and lagging indicators. The linear value approach is also applied by the Environment Agency in its 3E's pollution prevention scheme (HMIP, 1996).

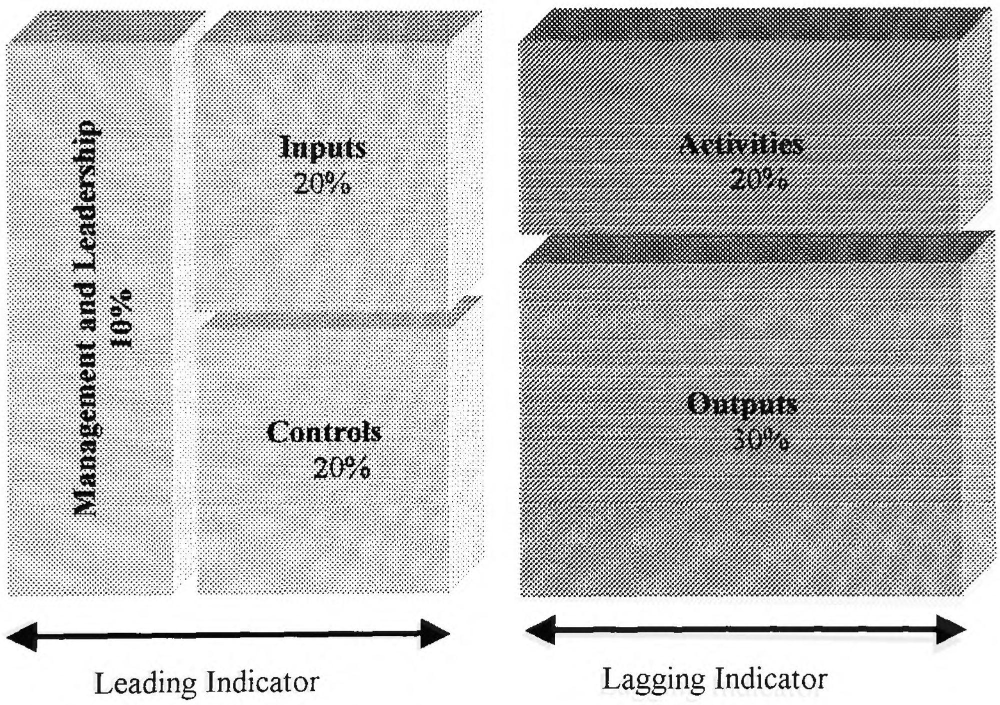

Fig. 4.3 The author's proposed QPM model indicating the category weightings, and lead and lag indicators.

The author's proposed model for QPM is outlined in Fig. 4.3, the basic structure derived in Chapter 2, reflects the consideration that how things are done (leading indicators) are equally as important as what is achieved (lagging indicators).

Both the initial EFQM and the MBNQA models determined criteria weightings through processes of research, and discussion of best practice (EFQM. 2003). The evaluative process for QPM has considered not only quality and environmental awards, but in addition, the corporate reporting mechanisms of GRI, and CERES, both of which provided a valuable insight into what factors are considered to actually influence environmental performance by an organisation. The inclusion of management and leadership to the 'simple process model' (Fig. 1.1) is in direct response to the consideration of the Bellagio principles (iisd.org. 2002), and the underlying concept of the balanced scorecard (Kaplan *et al.*, 1996). The QPM model therefore requires individual evaluation of the five audited criteria, with the final QPM determinant being constructed from an overall consideration of leading and lagging indicators. OPRA reflects the fact that each of the selected attributes belongs to a chain of interactive issues, which lead to the risk of harm to the environment (EA, 1997). Each attribute is considered important. The current OPRA weighting factors are therefore effectively equal. The basic QPM model will reflect the equal importance attributed to each factor by OPRA.

BS 7850: 1992 extends no importance values to any part of the simple process model (Fig. 1.1). QPM does not propose to follow this methodology as the author considers that category weightings are important in obtaining a holistic interpretation of the organisation, this has been demonstrated by reviewing both the EFQM and MBNQA models. The initial model weightings for both EFQM and the MBNQA were not prescribed from absolute values, but were derived following consultation with industry (WQC, 2003). The consultation process produced an initial set of individual weightings capable of being amended to reflect changing circumstances. The ability to change category weightings is an important consideration for this study of QPM.

The weighting of 10% for the category of management and leadership (which is consistent with that used in the EFQM model) is based upon the concept that although management are responsible for leading and directing the organisation, the effectiveness of that management will be reflected throughout the whole of the organisation, influencing scores in other categories, as such, to weight each category with a linear weighting value, would distort the scoring of the remaining categories.

The weighting of 30% for the outputs category can be viewed as a direct reflection of the effectiveness of management on the process of the organisation. The influences of management to prevent or reduce pollution may be quantified in respect of the entire operation (in tones of waste to landfill, volume of effluent to sewer, discharge to atmosphere etc.), as being the success (or failure) having been achieved by the organisation's performance. The initial weighting of the QPM model's categories should consider the possibility to adjust subject to industry, stakeholder, or technological change, and should be reviewed on an annual basis subject to issues identified during the preceding year in the same manner as both EFQM and MBNQA.

The balanced scorecard methodology (Kaplan *et al.*, 1992) considers the 'cause and effect' relationship equally between each of the four perspectives of the balanced scorecard, reinforcing the concept of their inter-relationships. QPM reflects this with each of the five criteria evaluated against a constant set value, and the overall determinant being constructed from the sum of the weighted results of the leading and lagging indicators.

4.4 Environmental Claims and Declarations

BS ISO 14024:1999 Environmental labels and declarations — Type I environmental labeling — principles and procedures (ISO, 1999) considers environmental labeling programs that award their environmental label to products which meet a set of predetermined requirements. The label identifies products that are determined to be environmentally preferable within a particular product category based on life-cycle considerations. Type I environmental labeling programs are voluntary, and can be operated by public or private agencies that may be national, regional or international in nature. Product environmental criteria are established to differentiate between environmentally preferable products and others in the product category, based on a measurable difference in environmental impact. Product environmental criteria are considered for differentiation between products only when environmental impact differences are significant. Testing and verification methodologies used to evaluate products have different levels of precision and accuracy that are considered in determining the significance of the difference.

BS ISO 14021:1999 Environmental labels and declarations — self-declared environmental claims (Type II environmental labeling) (ISO, 1999) specifies requirements for self-declared environmental claims, including statements, symbols and graphics, regarding products. It describes selected terms commonly used in environmental claims and gives qualifications for their use. The International Standard also describes a general evaluation and verification methodology for self-declared environmental claims and specific evaluation and verification methods for the selected environmental claims specified in the standard. Although introducing requirements for self-declared environmental claims, the standard does not specify significance ratings for environmental aspects associated with QPM, the purpose of this study. The study by Trauer *et al.*, (2001) shows that instruments that obtain both satisfaction and importance ratings are usually scored by multiplying the satisfaction and importance ratings e.g. using a five point scale, a satisfaction at performance level rating of 3 and an importance rating of 4 for an environmental aspect of an organisation would lead to a composite score of 12.

4.5 The QPM Categories

This section considers the categories previously discussed in Chapter 2, the five proposed QPM categories are shown in Fig. 4.3 The author's proposed QPM model indicating the category weightings. The categories are shown as:

- Management and Leadership
- Inputs
- Controls
- Activities
- Outputs

It is recognised that for QPM to be effective it will be necessary to obtain documentary evidence to support the audit findings. In Chapter 2, each of the categories has been investigated, and factors that will be used in the evaluation process are given in Table 2.3, Factors for Evaluation of Categories used in QPM.

In addition, the application of the QPM methodology must consider:

a. The degree of excellence of the approach

b. The degree of deployment of the approach.

4.5.1 Management and Leadership

It is important to consider the behaviour of the management of the organisation in leading the organisation toward QPM. This section considers how the executive team and all other managers inspire, drive and reflect QPM. The section also considers if employees embrace the concept of QPM as a basis for their own activities within the organisation, and in the further development of the organisation, and how the policy and strategy of the organisation reflect the concept of QPM in the formulation, deployment, review and improvement of that policy and strategy.

4.5.2 Inputs

This section deals with the activities involved in the sourcing of raw materials, production parts and equipment. It takes into account opportunities for resource conservation, and the implementation of better process control. The input performance indicators are intended to provide relevant information on the environmental performance of inputs that are introduced to the organisational process. The inputs selected are the three categories considered by BS 14031:1999, namely materials, energy and services.

This section of the QPM audit process also considers 'services' which support organisational operations, and includes environmental issues that directly relate to contracted service providers. Environmental effects of supplier / service management have been shown in Chapter 2 to be *effects over which the organisation has control or over which the organisation may be expected to exert an influence*. Consideration of the CERES reporting requirements expands the concept of 'suppliers' to include both producers of the raw materials that the organisation uses, and providers of intermediate products or services. This section also considers the environmental performance record of suppliers as particularly relevant to organisations involving a large percentage of outsourced products. Quality system requirements for supplier evaluation prior to commencement of contractual arrangements are questioned to take into account the supplier's ability to meet environmental subcontract requirements, as these define the type and extent of control exercised by the organisation over subcontractors. Organisational policy for supplier assessment / evaluation should describe any methodology used for the incorporation of environmental criteria in the selection process. The description of methodologies used in the incorporation of environmental guidelines into the selection of specific goods and services (as distinct from the selection of suppliers) should comment on whether or not they are considered explicitly.

4.5.3 Controls

The Control section of the audit considers the act of preventing or regulating change in parameters, situations or conditions. Controlled conditions are arrangements that provide control over all factors that influence the result. This section classifies managerial activities under three categories, strategic planning, management control and operational control, through which differentiation between the information requirements of management planning and control activities are viewed. It acknowledges the fact that information requirements may be from sources that are internal to, or external from, the organisation, dependent upon the activity that is being controlled.

Information on the risks of pollution to the environment is needed in order to make informed regulatory decisions at the local and strategic level. The QPM audit looks for documentary evidence to support the number of consent approvals and the number of penalties cited throughout the organisation. The study of QPM considers organisational relations with authorities and bodies that affect and regulate its business, and takes into account the frequency of environmental incidents, justified complaints and non-compliance events.

QPM views that organisations demonstrate a commitment to the environment by achieving compliance with recognised environmental management systems BS EN ISO 14001:1996 or EMAS. Third party verification of achievement adds robustness to the compliance process. The section also considers the organisation's registration to any Quality Management Systems (QMS) such as BS EN ISO 9001:2000 as QPM considers it an indicator of an organisation's ability to produce an output good or service to a particular specification on a repeatable basis. One of the key elements involved in a QMS is the reduction of variability and the procedures involved in controlling the process. The level of control may be reflected by the rate of defective products produced.

4.5.4 Activities

The activities of the organisation are viewed by QPM against the increased efficiency with which resources are used, as this results in lower pollutant emissions produced as outputs. The identification of organisational environmental aspects is an important input to environmental performance evaluation, and may typically be developed in the context of an EMS such as BS EN ISO 14001:1996 or EMAS. This section seeks to confirm that the identification of aspects is capable of providing management with information on operational environmental performance related to the delivery of outputs resulting from the organisation's operations.

The QPM audit needs to evaluate the actions and controls that are required to maintain, within prescribed limits, the accuracy and condition of all measuring and test equipment used during the provision of the service or product, including equipment privately owned by an operator when used in the organisation's activities using appropriate industry standards of maintenance. The robust nature of the process for determining the QPM indicator also requires participatory organisations to detail methods for stock control, for storing and handling material and parts to ensure the necessary identification, for preservation and segregation of material, and for handling methods that prevent misuse, damage or deterioration, and additionally for the disposal and recording of surpluses on completion of service.

QPM will evaluate the processes employed in the selection by the organisation of the best option available to achieve a high level of protection of the environment taken as a whole. QPM will require organisations to use the most effective and advanced stage in the development of activities and their methods of operation, which indicates the practical suitability of particular techniques. In order to achieve this, QPM will use the definitions contained in the IPPC Directive of best available techniques (BAT) while additionally considering the availability of techniques, and the cost of the technique balanced against its environmental benefit. The consideration of BAT by an organisation may prevent or reduce emissions that are not covered by specific permit conditions, and may cover the most detailed level of plant design where the organisation may be in the best position to understand what pollution control means for an installation in practice. The basic considerations in determining BAT involve identifying options, assessing environmental effects, and considering economics.

QPM will use where applicable the Environmental Protection Act 1990, Section 7, which requires operators to use the best available techniques not entailing excessive cost (BATNEEC) to render harmless both prescribed and other substances which may be released into the environment. Where prevention is not possible, operators should minimise the release into any medium. In determining the unique QPM indicator, evaluation will consider whether abatement plant is appropriate for the process, and is operating as intended. This involves a consideration and evaluation of the process plant to be not directly proportional to factors such as plant age and complexity, but on the ability of plant to eliminate or minimise hazards at source, and compare how the plant is functioning against design requirements. The QPM study additionally considers that evaluation of physical facilities and equipment should include the design, installation, operation, maintenance and land use of the facility.

4.5.5 Outputs

The outputs section of the QPM study considers that in most production processes, there are two outputs, the product and the waste. QPM requires establishing that they are both disposed of in the safest and most environmentally acceptable way possible. As waste may be considered as a measure of organisational inefficiency, QPM considers that operational performance indicators consist of three main output classifications; products, wastes and emissions.

The study toward QPM considers products under three sections, namely; main products, by-products, and recycled and re-used materials. QPM will additionally consider the organisational activities toward product stewardship, and will appraise organisational procedures for determining the main environmental impacts associated with the use and disposal of products. This requirement is extended to consider organisational programmes to address /

prevent product misuse, and will include by-products of the production process. QPM will take into account the environmental performance of the product to evaluate product re-use and recycling potential, both in terms of the number of products that may be recycled, and the percentage of parts within the product that may be recycled. It is the intention of QPM to view the number of products with instructions regarding environmentally safe use and disposal. QPM will seek to establish whether participating organisations have considered procedures to develop and provide products and services that have a reduced, or no undue, environmental impact. These considerations may include product energy efficiency, use of natural resources, recycling / re-use, and disposal.

i. Wastes

Waste is considered by BS EN ISO 14031:1999 as solid / liquid, hazardous / non-hazardous, and re-cycleable / re-usable, and the proposed QPM will use the same criteria. Total waste generated by the organisation's operations will consider not only the quantity of waste per year or per unit of product, but also the division of such waste into the three stated categories. QPM will seek to establish the quantity and storage of on-site waste, and waste controlled by authorisation, additionally viewing the quantity of waste converted into re-useable material and the quantity of hazardous waste eliminated due to material substitution. QPM will investigate the disposal options used by the organisation and the performance of waste disposal contractors used by the organisation. QPM will question the value of materials in waste streams through re-use, recycling and recovery, and whether the organisation integrates waste management considerations within the product and planning process, and has in place a system to identify and implement improvement.

ii. Emissions

In line with BS EN ISO 14031:1999, QPM considers emissions as emissions to air, effluent to water or land, noise, heat, vibration, light and radiation. QPM will seek to establish the quantity, either of specific emissions / discharges or specific emissions measured over the period of one year.

In order to satisfactorily accomplish this, QPM will follow the CERES reporting protocol which uses generally applicable indicators, such as greenhouse gas emissions (per Kyoto protocol definition), in tonnes of CO_2 equivalent (global warming potential), and ozone-depleting substance emissions (per Montreal protocol definition), in tonnes of CFC-11 equivalent (ozone depleting potential). This may prove a complex undertaking for the simple QPM model, but any rule based logic system, which will be constructed for a more complex QPM model, would require valid interpretation of the CERES indicators. In Chapter 5 the possibility of further work is discussed using fuzzy logic as a method for interpretation of results.

The QPM audit will seek to establish emissions to air by type and nature, and effluents discharged by type and nature. QPM will consider the intrinsic hazardous properties of the representative substance, and will use Annex VI of the Integrated Pollution Prevention and Control guidance list of the main polluting substances for emission limit values based on BAT. This also would be an issue that would be able to be established more efficiently by the complex model. For the purpose of deriving the simple QPM indicator, greenhouse gas emissions should be absolute figures, and not normalised returns to an Emissions Trading Authority used in the course of greenhouse gas emissions trading.

4.6 The Assessment Process for QPM

The assessment process for the proposed QPM will use a self-assessment checklist prior to site visits. Both the EFQM award and the Malcolm Baldrige Quality award use a self-assessment checklist prior to any site visit to an organisation. Third party verification of an organisation's QMS requires a desktop study of the system being assessed (Phillips, 2000). The self-assessment process will benefit the QPM assessor by highlighting the strengths of the organisation, and any possible areas for improvement. The self-assessment process has the benefit to the organisation of using a rigorous and structured approach to QPM, allowing it to view for itself any possible strengths or weaknesses, based upon factual data and not individual perception, thereby becoming a powerful diagnostic tool in its own right. The scope of the study enables organisations carrying out periodic self-assessment to measure progress over time, using established benchmark figures. This also has the benefit of enabling the organisation to achieve consistency of direction and consensus on what needs to be done through everyone in the organisation sharing the same conceptual base. Internally, the organisation is provided with the opportunity for the promotion of good practice and approaches, and the opportunity to progress with quantification of actual levels of achievement. Benchmarking opportunities may be internal or external.

In Chapter 2 a review of each of the five categories considered for the author's study of QPM is shown. The review produced factors to be used in the evaluation process. These are shown in Table 2.3 Factors for Evaluation of Categories used in QPM. These factors have been considered in the derivation of the QPM model, and have formed the basic structure for the audit protocol (Appendix A), which is intended to be used for audit and assessment of an organisation for QPM. The audit protocol identifies each category in an individual section, and each section investigates the individual factors associated with a category through a series of evaluative questions to which the organisation is required to produce a response. In addition to using the previously described research in producing the initial audit protocol, the author also used his experience as a quality systems lead assessor, and environmental management system lead auditor in determining an audit checklist that would enable a holistic view of each category through evaluation of the factors determined as applicable. The prototyping of the audit protocol was achieved through discussion with both industry and a subject specialist academic.

The audit protocol was supplied to the technical manager of a high profile environmental management company, who commented from an industrial perspective (James, 2002). The comments were positive, and provided the author with constructive input regarding best available techniques (BAT) and best available techniques not entailing excessive cost (BATNEEC).

In addition to the technical appraisal, subject specialist academic input was provided by a personal contact of the author, who as a registered assessor for EFQM proved positive comment (Armitage, 2002), reflection on which confirmed the author's belief in the robustness of the initial model, and encouraged the author in continuing the process to trial application.

The revision of EFQM scoring matrix for use in the proposed QPM audit methodology (Fig 4.1) evaluates the approach taken by the organisation and the deployment of the approach (Fig 4.2). It does not assess the results of the combined effect of these elements to the operational effectiveness of the organisation. The study of QPM will require a third element to be evaluated, the results of the approach and deployment. This has the benefit of using both 'leading' (approach and deployment) and 'lag' (results) indicators (GRI, 2000). Lagging indicators are usually readily quantifiable and understandable; the required data is often collected for other business purposes as it reflects situations that have already occurred. For example, effluent discharge returns, operational incidents, etc. The results element of the QPM assessment will evaluate what the organisation has achieved, and is achieving, in terms of actual performance, and performance against its own targets. By the sharing of results QPM will enable participating organisations to assess their performance against that of 'world class' organisations or competitors.

The results category audit criteria for the proposed study of QPM are shown in Fig. 4.4 and are intended to be considered in relation to the approach and deployment metrics shown in Figures 4.1 and 4.2.

Score	Results Results support policy and strategy	Total
1 0%	Ineffective Systems. Major breaches of authorizations	0 5 10
2 25%	Evidence of some in-effective systems. Minor breaches of authorisations, no major incidents	15 20 25 30 35
3 50%	Evidence of moderately effective systems. No breaches of authorisations. No reportable incidents	40 45 50 55 60
4 75%	Clear evidence of environmental effectiveness in normal operations and planning	65 70 75 80 85
5 100%	Clear evidence of complete environmental effectiveness in all aspects of operations	90 95 100

Fig. 4.4 The Results Category Audit Criteria for QPM

BS EN ISO 14010:1996 *Guidelines for environmental auditing — General principles* establishes conventions that are intended to guide organizations, auditors and their clients on the general principles common to the conduct of environmental audits. It is one in a series of International Standards in the field of environmental auditing which also includes BS EN ISO 14011:1996, *Guidelines for environment auditing — Audit procedures — Auditing of environmental management systems,* and BS EN ISO 14012:1996, *Guidelines for environmental auditing — Qualification criteria for environmental* *auditors.* The study by Tuberfield (2002) considers that the BS EN ISO 14000:1996 series audit process fails to provide the critical understanding of how activities are actually done, and how they may need to be carried out differently, proposing that the standards simply advocate a quality management systems approach of auditing by attribute. The move toward QPM will pursue the assessment of the organisation by establishing the collection of audit evidence against the defined 5-point Likert scale for each of the three criteria, while ensuring a robust audit by utilising the established conventions and guidelines from the three International Standards giving guidance on environmental audit.

4.7 Deriving an outcome indicator for QPM

The QPM categories are divided into five weighted areas (Fig 4.3). The elements that are considered in each category are evaluated against three criteria, those of approach, deployment and results. The three criteria (Fig 4.1, Fig. 4.2 and Fig 4.4) each use a 5-point Likert scale of evaluation. As each of the individual categories (i) has been evaluated in terms of importance weighting (n). This may be expressed as:

$$Q = \sum_{5}^{i=1} c_n \text{ (k)} \qquad (4.1)$$

Where Q = the QPM outcome, c_n = the weighted element categories, and k represents the category constant. If t represents the three audit criteria,

The QPM indicator is derived using:

$$Cn = \sum_{\leq 30}^{n=1} a \qquad (4.2)$$

where

$$a = \sum_{1}^{3} t \qquad (4.3)$$

This enables the QPM indicator to be established as a model for environmental management from which quantifiable indication of overall environmental performance may be derived. The management system allows organisations to consider a broader perspective on environmental performance, and encourage the application of preventive technologies to reduce pollutant and waste loads, while also promoting environmentally friendly products and services through openly available quantitative indicators. The audit protocol (Appendix 1) has been derived to establish organisational performance against the criteria that influence an organisation's environmental performance, linking leading and lagging indicators. The robustness of the process of auditing the management system is maintained through the use of internationally recognised guides and conventions, while the evaluation of the individual categories utilises a linear rating scale for assessment of the approach, deployment and results obtained by the organisation. The outcome QPM measure is established by summation of the weighted categories.

4.8 Audit Practicalities of Implementation in a Real World Context

In order for the proposed QPM measure to be robustly established, it is necessary for the auditor and the participating organisation's personnel to work closely to gather and analyse the necessary information required in the Audit Protocol (Appendix 1). A focus on documentation would produce a non-compliance list that would focus on documents that do not comply to a particular standard (such as BS EN ISO 14001:1996) with much of the effort being directed at the bureaucracy of environmental management, and not at the management of environmental issues (Tuberfield, 2002). The audit protocol of the proposed QPM study utilises a performance-based approach where by means of an evaluative site visit, observation or finding is made. Sensitive interviewing of personnel and detailed investigation of documentation relating to the management of the environment enable evaluation of the existing management mechanisms of the organisation that are employed in environmental management. By a study of the root cause analysis of an observation or finding made during the site visit, participatory organisations may be able to establish the causes of any weakness in their environmental management, rectification of which would enable an enhanced environmental outcome. Tuberfield (2002) considers that for environmental management systems, documented procedures are usually well written and are rarely the root cause for the issues identified. This performance-based approach uses the environmental assessment and audit techniques given in BS EN ISO 14011:1996, assisted by the quality audit concepts in BS EN ISO 10011:1993.

4.9 Conclusion

This chapter considers the structure of the quantitative pollution management (QPM) process. The chapter establishes the structure of the QPM audit, and specifies the weighting of the individual components of QPM in determining the final indicator of pollution performance. The outlined concept of QPM applies to the organisation as a whole, and requires a comprehensive, systematic and regular review of the organisation's activities modelled against the criterion included in the audit protocol (Appendix 1). Environmental auditing has established itself as a valuable instrument to verify and help improve environmental performance (ISO, 1996). The proposed QPM indicator has taken into account the study by Tuberfield (2002) which considers that an assessment should aim to identify existing management mechanisms that are able to deliver enhanced environmental outcomes, and should provide a detailed record of changes, environmental risks and compliance issues that have occurred and how these are addressed by the organisation's management. The defining of the environmental audit process for QPM has required consideration to be given to the limitations associated with the audit evidence samples collected, and the recognition of uncertainty in audit findings and any audit conclusions. This has required the introduction of a reflective aspect to the audit process. Using the internationally established audit and management conventions associated with BS EN ISO 14010:1996, BS EN ISO 14011:1996, and BS EN ISO 10011:1993, the study toward QPM additionally utilises an element of the audit methodology derived from the European Foundation for Quality Management (EFQM) Model in its assessment process, by evaluating the approach toward QPM taken by the organization, and the deployment of that approach.

The study toward the proposed QPM indicator requires a robust methodology for the derivation of the quantitative indicator. The review of the EFQM model establishes a scoring matrix for use in the assessment process that has been utilized in line with the concept of the study toward QPM. The revised matrices are shown in Fig. 4.1 and Fig. 4.2. These evaluate the approach taken by the organisation and the deployment of the approach. It does not assess the results of the combined effect of these elements to the operational effectiveness of the organisation. The study of QPM requires a third element to be evaluated, the results of the approach and deployment. This has the benefit of using both 'leading' (approach and deployment) and 'lag' (results) indicators (GRI, 2000). The results category criteria for the study of QPM are shown in Fig.4.4 and are intended to be considered in relation to the approach and deployment metrics shown in Fig. 4.1 and Fig. 4.2.

The audit protocol for QPM considers the organization under five areas, those of leadership, inputs, controls, activities and outputs. A key issue in this unique study of QPM is the weighting determination of significance for each of the areas. Initially based upon the linear category weighting used in OPRA, the resulting weighting of categories is shown in Fig. 4.3, and was determined by study of the MBNQA which uses seven non-linear ranked categories each of which contribute toward a final numerical indicator derived from a possible score of one thousand, and the EFQM Model which uses nine individually ranked criterion, each marked out of one hundred and then multiplied by a weighting factor assigned to each criterion. The criterion are evaluated on an annual basis, which is an important consideration for the development of the

QPM process. The percentage criterion weightings established by EFQM are a mixture of leading and lagging indicators, the values of which are confirmed by the Presidents of the fourteen founding members of EFQM. In consideration of the valuation for the EFQM award equal weighting is given to how things are done (enablers) and what is achieved (results). This methodology has been incorporated into the QPM model. The Operator Pollution Risk appraisal (OPRA) uses a rating of linear values ranging from one (lowest) to five (highest) for both operator performance appraisal (OPA) and pollution hazard appraisal (PHA). The equal division by OPRA of the inherent level of risk of pollution from the process and the environmental performance of the operator in managing that pollution risk is an application of leading and lagging indicators. The linear value approach is also applied by the Environment Agency in its 3E's pollution prevention scheme (HMIP, 1996). This has also been reflected in the proposed QPM management system.

The QPM model requires individual evaluation of five audited criteria, with the final QPM determinant being constructed from an overall consideration of both leading and lagging indicators. QPM reflects the 'cause and effect' relationship of the balanced scorecard methodology (Kaplan *et al.*, 1992) with each of the five criteria evaluated against a constant set value, and the overall determinant being constructed from the sum of the weighted results of the leading and lagging indicators, reinforcing the concept of their inter-relationships. It is recognised that for QPM to be effective it will be necessary to obtain documentary evidence to support the audit findings. In addition, the application of the QPM methodology must consider:

a. The degree of excellence of the approach

b. The degree of deployment of the approach

The assessment process for QPM will make use of a self-assessment checklist prior to site visits. Both the EFQM award and the Malcolm Baldrige Quality award use a self-assessment checklist prior to any site visit to an organisation. Third party verification of an organisation's QMS requires a desktop study of the system being assessed (Phillips, 2000). The self-assessment process will have the benefit to the organisation of highlighting any strengths, and any possible areas for improvement, prior to the audit for QPM, using a rigorous and structured approach by allowing organisations to view any possible strengths or weaknesses, based upon factual data and not individual perception, thereby becoming a powerful diagnostic tool in its own right. The scope of the study will enable organisations carrying out periodic self-assessment to measure progress over time, using established benchmark figures for comparison analysis. This also has the benefit of enabling the organisation to achieve consistency of direction and consensus on what needs to be done through everyone in the organisation sharing the same conceptual base. Internally, the organisation is provided with the opportunity for the promotion of good practice and approaches, and the opportunity to progress with quantification of actual levels of achievement. Benchmarking opportunities may be internal or external.

The study toward QPM will pursue the assessment of the organisation by establishing the collection of audit evidence against the defined 5-point Likert scale for each of the three criteria, while ensuring a robust audit by utilising the established conventions and guidelines from the three International Standards giving guidance on environmental audit. This is achieved through independent evaluation against the three criteria of approach, deployment and results in each of the five categories using a 5-point Likert scale of evaluation.

It is the view of the author that the initial aim of this programme of research outlined in Chapter 1 as the contribution of the establishment of a model for environmental management from which quantifiable indication of overall environmental performance may be derived has been achieved. In Chapter 5, the model for QPM is applied to a manufacturing organisation, and evaluation of the outcome measure for QPM is discussed.

Chapter 5

Audit and Evaluation of QPM

Chapter Summary

This chapter considers the initial audit of Tubex Ltd. for QPM, and the derivation of the initial QPM indicator. It also discusses a qualitative interpretation of the quantitative QPM indicator.

5.1 Introduction

This chapter reviews the first application of the author's QPM management system in an audit of Tubex Ltd. Tubex Ltd. are based in the industrial valley area of Rhondda Cynon Taff, and operate from a purpose built industrial unit originally sponsored as part of the South Wales regeneration initiative by the Welsh Development Agency. The company's primary process is the manufacture and supply of tree / vine / shrub protection and support systems, for use in forestry, landscaping, amenity sites, agriculture and habitat preservation. A BS EN ISO 9002:1994 registered company, Tubex produces approximately 18 million items of product per annum by plastic extrusion. The company employs 120 people, and with net annual sales in 2001 of £5 million, and has total assets of £7 million. Tubex has one employee assigned to environmental management as part of his employment. The organisation does not undertake any voluntary environmental reporting. The audit used the conventions and guidelines established in Chapter 4 to derive a QPM indicator for Tubex Ltd.

The environmental performance of an organization is of increasing importance to internal and external interested parties (ISO, 1996). Achieving sound environmental performance requires organizational commitment and a systematic approach to environmental management. QPM provides order and consistency for an organization to evaluate its approach to environmental concerns through consideration of the deployment of resources, assignment of responsibilities, and the ongoing evaluation of the results of these practices, procedures and processes. In order to allow interested parties to reflect on this, QPM is further developed in this chapter by the production of a qualitative interpretation of the quantitative indicator.

5.2 Initial Audit for QPM at Tubex Ltd.

The initial audit for QPM was carried out by a planned audit and site evaluation in June 2002. The audit was carried out by the author, accompanied by a member of management of Tubex Ltd. The audit protocol (Appendix A) was used to determine verifiable information, records or statements of both qualitative and quantitative fact and the audit was based on interviews, examination of documents, and observation of activities and conditions. The conventions used to perform the audit were based upon the established guidelines considered in BS EN ISO 14010, 14011, 14012: 1996, and BS EN ISO 10011:1993.

5.2.1 The Audit Process

The audit process for the initial application of QPM involved five stages, which are adapted from recognised audit practice used by the British Standards Institute (BSI) (Phillips. 2000) and are detailed below.

1. Supply of audit protocol to Tubex Ltd.
2. Desktop study of completed audit protocol
3. Plan site audit timetable
4. Conduct site audit
5. Conclusions and report

Supply of audit protocol to Tubex Ltd.

Using the established framework utilized by both EFQM and MBNQA, the audit protocol (Appendix A) was supplied to Tubex Ltd. 3 weeks prior to the site audit, in order to allow Tubex Ltd. to conduct the self-assessment process. An explanatory outline of QPM (Appendix B) was sent to the management of Tubex Ltd. to assist understanding and interpretation of the model, and to reinforce the initial discussions that had been held between the author and Tubex management in gaining approval for the pilot application of QPM. The Quality Manager of Tubex Ltd., a qualified lead assessor of quality management systems, completed the audit protocol (comprising of 35 pages of objective evidence) and returned it to the author. The results of the self-assessment provided the initial input for the QPM process. The feedback from the Quality Manager regarding the audit protocol was positive, and reflected the view that the holistic interpretation of the organisation with regard to pollution achieved by QPM would be a useful commercial mechanism to enable comparative analysis and target organisational improvement.

Desktop study of completed audit protocol

The completed audit protocol was reviewed by the author, and highlighted several practical implementation issues that needed to be addressed prior to the planning of the site audit; these were:

- Access to staff, as Tubex operated a three shift, 24-hour work pattern.
- Auditor site safety during audit.
- Access to restricted areas.

The issue of access to staff was addressed by reaching agreement with Tubex Ltd. that the audit would be conducted during two 12-h visits to the site, which would allow observation of activities and conditions and interview of staff during the three shifts. Auditor site safety, and access to restricted areas were secured by allowing the Quality Manager of Tubex Ltd. to conduct a shadow audit alongside the author. This had the additional benefit of highlighting the differing approaches taken to auditing by environmental auditors (guidelines for environmental audit are established in the BS EN ISO 14000 series of standards) and quality management auditors (guidelines for quality audit are established in the BS EN ISO 10000 series of standards). The approach of the environmental auditor was shown to be more applicable to the auditing requirements of QPM in determining approach, deployment and results, as it was not based upon the premise of audit by attribute, i.e. yes / no, right / wrong, present / missing, but allowed explanation and interpretation of actions taken by the company. The difference was highlighted during the assessment of audit question 3.2 Design for Environment (DfE). Table 5.7 gives an illustrative example of personnel interviewed, documents examined, and observation of activities and conditions, undertaken during the audit of Tubex Ltd., for audit question 3.2 Design for Environment (DfE). The objective evidence supporting the scoring by the Tubex quality auditor lacked the rigour of sufficient detail and evaluation in ensuring a robust evaluation.

Plan site audit timetable

The plan of the audit of Tubex Ltd could not solely concentrate assessment activities on documentation, as that would produce an evidence list focussed on the bureaucracy of environmental management, and not at the management of environmental issues. The study by Tuberfield (2002) highlights the difficulties involved in conducting an environmental audit. The intent of the QPM process is achieved by sensitive interviewing of personnel, and the detailed investigation of documentation relating to the management of the environment, to enable a holistic evaluation of the organisation regarding environmental impact.

The practicalities of the situation demanded that the audit was carried out with as little disruption to the everyday activities of Tubex Ltd. as possible, requiring the scheduling of meetings, and area observations, with notification being sent to personnel in advance. This had an effect on the structure of the audit, as it did not lend itself to the traditional horizontal or vertical audit structure (Hoyle. 1997). However, as the audit protocol was prescriptive in its requirements, and by making use of the completed audit protocol from Tubex Ltd., which detailed records and locations, a structure was defined which included:

Observation of activities

Interviews with personnel

Observation of management meetings

Documentation review

Conducting the site audit

Prior to commencement of the site audit, an opening meeting was held with the Quality Manager each day, for the purpose of confirming the activities of that day, and the discussion of the scope of the audit and the audit protocol. The initial audit evaluated each question of the audit protocol (Appendix A) using the assessment of three attributes: approach, deployment and results. The assessment criteria used a Likert scale of 1-5 utilising the membership functions of the general categories developed in the three assessment criteria shown in Fig. 4.1, Fig. 4.2 and Fig. 4.4.

The study by Tuberfield (2002) considers that '*for environmental management systems, documented procedures are usually well written and are rarely the root cause for the issues identified*'. Tuberfield's (2002) study proved correct for the audit of Tubex Ltd. Although not currently implementing an environmental management system, the documentation examined during the audit of Tubex Ltd. was consistently well presented and maintained. However, it lacked the detail from which to determine the methodology used in determining policy and strategy, for example question 4.2 (iv) Environmental Audit – Reporting audit findings to senior management.

The interviews with personnel were conducted in an open manner, and employees did not appear to be intimidated by the presence of the Quality Manager during the interview process. Employees at all levels in the organisation engaged in the process, and gave full accounts of their activities. Determination of organisational strategy proved problematic during the time available. Scoring against the set criteria of the audit protocol was completed using notes made at the time. The resulting score for each attribute evaluated is shown in Tables 5.1– 5.5.

Audit Question	Approach	Deployment	Results	Total	Mean
2.1 Culture of pollution management					
i	3	2	4	9	3
ii	2	2	4	8	2.7
iii	1	1	2	4	1.3
2.2 Visible involvement in leading QPM					
i	4	4	4	12	4
ii	4	4	4	12	4
iii	1	1	3	5	1.7
2.2 *Support for QPM*					
i	4	3	4	11	3.7
ii	4	4	4	12	4
iii	5	5	4	14	4.7
iv	2	1	4	7	2.3
2.4 *Policy and Strategy*					
i	5	4	4	13	4.3
ii	3	4	3	10	3.3
iii	5	5	4	14	4.7
iv	2	3	3	8	2.7
v	2	3	3	8	2.7
vi	2	4	3	9	3
vii	3	3	3	9	3
viii	3	5	4	12	4
ix	4	4	3	11	3.7
x	4	5	4	13	4.3
xi	5	3	3	11	3.7
xii	4	3	3	10	3.3

Table 5.1 The Initial Audit Score Summary, Tubex Ltd. - Organisation, Management and Leadership

Audit Question	Approach	Deployment	Results	Total	Mean
3.1 *Materials sourcing*					
i	2	1	2	5	1.7
ii	4	4	4	12	4
iii	3	2	2	7	2.3
iva	2	1	2	5	1.7
ivb	2	2	2	6	2
ivc	4	3	3	10	3.3
ivd	1	1	1	3	1
v	2	2	2	6	2
vi	2	2	1	5	1.7
3.2 *Design for Environment (DfE)*					
i	4	3	3	10	3.3
ii	4	3	2	9	3
iii	4	5	4	13	4.3
iv	2	2	2	6	2
v	4	3	3	10	3.3
vi	5	5	5	15	5
3.3 *Use and Conservation of Natural Resources*					
i.	2	1	2	5	1.7
ii.	4	3	2	9	3
iii.	2	1	1	4	1.3
3.4 *Energy*					
i	1	1	1	3	1
ii	3	5	5	13	4.3
iii	3	4	3	10	3.3
iv	1	1	1	3	1
v	1	1	1	3	1
vi	1	1	1	3	1
vii	4	3	4	11	3.7

Table 5.2 The Initial Audit Score Summary, Tubex Ltd. - Inputs

Audit Question	Approach	Deployment	Results	Total	Mean
4.1 *Management Systems*					
i	1	1	1	3	1
ii	1	1	1	3	1
iii	1	1	1	3	1
iv	2	1	1	4	1.3
v	2	1	2	5	1.7
vi	5	5	3	13	4.3
vii	5	5	3	13	4.3
viii	2	1	1	4	1.3
4.2 *Audit*					
i	1	1	1	3	1
ii	1	1	1	3	1
iii	3	1	1	5	1.7
iv	1	1	1	3	1
v	2	1	1	4	1.3
vi	1	1	1	3	1
vii	3	1	1	5	1.7
4.3 *Legislation and Compliance*					
i	3	5	4	12	4
ii	3	1	2	6	2
iii	5	5	5	15	5

Table 5.3 The Initial Audit Score Summary, Tubex Ltd. - Controls

5.1 Machinery					
i	4	4	4	12	4
ii	3	1	3	7	2.3
iii	3	2	3	8	2.7
iv	2	1	1	4	1.3
v	5	5	5	15	5
5.2 Personnel					
i	3	2	3	8	2.7
ii	4	3	3	10	3.3
iii	4	2	2	8	2.7
iv	4	3	3	10	3.3
5.3 Storage					
i	4	4	3	11	3.7
ii	2	2	2	6	2
iii	1	1	1	3	1
iv	4	5	3	12	4
v	5	5	4	14	4.7
vi	3	4	4	11	3.7

Table 5.4 The Initial Audit Score Summary, Tubex Ltd. - Activities

Audit Question	Approach	Deployment	Results	Total	Mean
6.1 Product Stewardship					
i	4	1	1	6	2
ii	3	4	3	10	3.3
iii	1	1	1	3	1
iv	2	1	1	4	1.3
v	5	5	5	15	5
vi	5	4	4	13	4.3
vii	5	5	5	15	5
6.2 Waste					
i	5	5	5	15	5
ii	3	1	1	5	1.7
iii	4	4	4	12	4
iv	4	5	4	13	4.3
v	4	4	4	12	4
vi	5	4	4	13	4.3
6.3 Emissions					
i.	1	1	1	3	1
ii.	1	1	1	3	1
iii.	1	1	1	3	1
iv.	1	1	1	3	1
v.	3	3	3	9	3
vi.	2	1	1	3	1.3
vii	1	1	1	3	1

Table 5.5 The Initial Audit Score Summary, Tubex Ltd. – Outputs

Audit Conclusion and report

The conclusion of the audit resulted in the collection of detailed objective evidence to support the assessment for QPM (An illustrative example of the audit is included in Appendix C - *Illustrative example of the typed up notes taken by the Auditor to facilitate recall of basis on which scores were allocated for Question 2.3 Support for QPM*). A closing meeting was held before leaving the site, in which opportunity was given to Tubex Ltd. to comment on the conduct of the audit by the author. There were no issues of concern raised by Tubex Ltd.; however, positive comment was made regarding the thoroughness of the audit, and the ease of use of the audit protocol. The author thanked Tubex Ltd. for their co-operation and involvement.

The completion of the evaluative process required a review of the objective evidence gathered during the audit. The evaluation produced the scores shown in Tables 5.1 – 5.5 for each of the assessed categories.

The data shown in Table 5.6 gives the combined result of the 300 data points assessed during the audit process, using the audit protocol (Appendix A). The three audit attributes are shown as totals of the combined category scores achieved during the audit. The mean figure for the combined scores of each attribute is displayed, along with the percentage weighting of each category toward the QPM indicator figure.

Category C	Attribute Audit Total t				Mean Attribute	% QPM	Weighted Contribution
	n	Approach	Deployment	Result			
Management	22	72	73	77	3.4	10	0.34
Inputs	25	67	60	59	2.5	20	0.50
Controls	18	42	34	31	2.0	20	0.40
Activities	15	51	44	44	3.1	20	0.62
Outputs	20	60	53	51	2.7	30	0.81
					Σ 13.5		
Total	100	292	264	262	2.7	100	2.67

Table 5.6 The QPM Audit Score for Tubex Ltd.

The weighted contribution shows the normalised figure, which has been totalled. The displayed total of 2.67 gives a figure based upon the totals for the 5 categories, which if displayed as a percentage figure shows that the initial QPM indicator for Tubex Ltd. (QPM) = 53.4.

5.3 Interpretation of the QPM Indicator

The QPM indicator established in Chapter 4 is derived through the sum of the mean figures for the combined total weighted scores of each attribute at the micro level. The QPM indicator is therefore a composite of the combined attributes of the audit process. This composite reflects the organisational performance against the three audit criteria at the macro level. The qualitative interpretation of the QPM indicator (Fig. 5.1) utilises the principles established in the application of the 'Balanced Scorecard' (Kaplan *et al.*, 1992), in which a 'top level' scorecard card is established in line with the mission statement and strategy of the organisation, from which subsequent scorecards evolve, ensuring that focus and application are consistent throughout the organisation.

Score	Qualitative Interpretation of QPM	Total
1 0%	Ineffective Systems. Major breaches of authorizations. Anecdotal or non-value adding approach. Little effective usage	0 **5** 10
2 25%	Evidence of some in- effective systems. Minor breaches of authorisations, no major incidents. Some evidence of soundly based approaches and prevention based systems. Subject to occasional review. Some areas of integration into normal operations. Applied to about one quarter of the potential when considering all relevant areas and activities	15 20 **25** 30 35
3 50%	Evidence of moderately effective systems. No breaches of authorisations. No reportable incidents. Evidence of soundly based systematic approaches and prevention based systems. Subject to regular review with respect to environmental effectiveness. Integration into normal operations and planning becoming established. Applied to about half the potential when considering all relevant areas and activities.	40 45 **50** 55 60
4 75%	Clear evidence of environmental effectiveness in normal operations and planning. Clear evidence of soundly based systematic approaches and prevention based systems. Clear evidence of refinement and improved environmental effectiveness through review cycles. Good integration of approach into normal operations and planning. Applied to about three quarters of the potential when considering all relevant areas and activities	65 70 **75** 80 85
5 100%	Clear evidence of complete environmental effectiveness in all aspects of operations. Clear evidence of soundly based systematic approaches and prevention based systems. Clear evidence of refinement and improved environmental effectiveness through review cycles. Approach has become totally integrated into normal working patterns. Applied to full potential in all relevant areas and activities.	90 95 **100**

Fig. 5.1 Qualitative Interpretation of QPM Indicator

In order not to alter the intent or vision of the QPM indicator, the qualitative interpretation of the indicator will combine the descriptors used for the evaluation of individual audit criteria at each (micro) audit score level. Slack and Lewis (2001) consider that this is a strategy intended for the longer term, being considered at a higher level in the organisation, and more aggregated, giving a holistic view of performance. The study by Senge (1994) considered that a system is *"perceived whole whose elements 'hang together' because they continually affect each other over time and operate toward a common purpose… The structure of a system includes the quality of perception with which you, the observer, cause it to stand together"*.

5.4 Reflections on the QPM Audit of Tubex Ltd.

The audit protocol (Appendix A) determined verifiable information used in constructing the indicator of pollution performance of Tubex Ltd. The audit was based on interviews, examination of documents, and observation of activities and conditions. An illustrative list of documentation used by Tubex Ltd. is given in Appendix D. In order to be considered robust, the audit process established an assessment based on fact and structured analysis and not on individual perception. An illustrative example of the rigor of the audit process is shown in Table 5.7. *Illustrative Example of personnel interviewed, documents examined, and observation of activities and conditions undertaken during QPM audit of Tubex Ltd. for audit question 3.2 Design for Environment (DfE).*

3.2 Design for Environment (DfE) How does the organisation focus on pollution prevention and cleaner process technologies as a principal means of achieving continual product and process improvements?		
Documents viewed during audit	Personnel interviewed during audit	Observations made during audit
QAP 02 Purchasing control QAP 02/2 Supplier appraisal and approval QAP 02/3 Consignment stock purchasing and control QAP 05/1 Plant care inspection and test procedure QAP 6/1 Storage QAP 8/1 Control of non-conformance and customer complaints QAP 8/2 Control of customer complaints QAP 11 Internal quality audits and review QAP 15 Plant care production and scheduling QAP 15/1 Plant care production and planning control QAP 20 Development project identification and review QAP 21 Control of product modifications	Production Manager Operations Manager Quality Manager Production Engineer Shift Foremen (2)	Observed management review meeting Viewed associated documentation included in Production Control Register Observed production control meeting.

Table 5.7 Illustrative Example of personnel interviewed, documents examined, and observation of activities and conditions undertaken during

QPM audit of Tubex Ltd. for audit question *3.2 Design for Environment* (DfE).

The QPM indicator that resulted from the audit of Tubex Ltd. shows a mid-table result consistent with an organisation which has moderately effective systems that have avoided breaches of authorisations. Throughout the audit, Tubex Ltd appeared to be an organisation that utilised systematic approaches and prevention-based systems that were subject to regular review, with an overall deployment to approximately 50% of the organisation. This has reflected well in the impression given to the writer of Tubex Ltd. and which has been confirmed by evaluation of not only the overall QPM indicator, but by review of the individual mean attribute scores.

The execution of the audit of Tubex Ltd. gave the author an impression of an organisation that was well managed; this has been reflected in the mean attribute audit score of 3.4 (from an optimum score of 5) assessed against 66 individual data points. The inputs to the organisation provide relevant information on the environmental performance of inputs that are introduced to the organisational process, and reflect the non-hazardous nature of the Tubex Ltd. operation. The mean attribute audit score of 2.5, based upon 75 individual data points, has confirmed this. The controls exerted by Tubex Ltd. appeared to exhibit evidence of soundly based approaches and prevention-based systems, but the deployment of these systems was poor, with many awaiting implementation. The QPM audit has reflected this in providing a mean attribute audit score of 2.0, based upon 54 individual data points. The activities of Tubex Ltd. produce the highest mean attribute audit score of 3.1

over some 45 individual data points, reflecting a lack of control over certain activities over which they are able to exert an influence, for example the lack of monitoring for discharges to air from the process. The outputs from Tubex Ltd. are benign with no anthropogenic effects that are causes for concern. There have been no breaches of their local authority authorisation to discharge to sewer, and their final product is non-hazardous.

The QPM indicator has shown that it has been able to translate the operational activities of the organisation into a quantitative representation of pollution activities. The individual categories of the QPM indicator are able to be used in the overall appraisal of organisational activities, allowing the targeting of improvement activities, and are able to be used for both internal and external benchmarking.

Possible Modifications to QPM

The possibility for modification to the process of evaluation of QPM is based upon three issues:

1. Practices prior to audit
2. Auditor competencies
3. Engagement by the organisation

Practices prior to audit

Although having met with the management of Tubex Ltd. to establish their approval and co-operation in undertaking this study, it is the opinion of the author that information regarding QPM was not adequately distributed to employees of Tubex Ltd. A possible response to this would be to hold awareness seminars with the staff prior to the audit. This would assist the auditor by reducing the instances of having to explain the purpose and intent of the QPM audit.

Auditor Competencies

The audit protocol uses an assessment regime based upon approach, deployment and results. Traditional auditing for either quality management or environmental management focuses on determining compliance, while QPM seeks to allocate a score. As was shown during the audit of Tubex Ltd., quality system auditors require to undertake the audit in a manner that may be unfamiliar to them. In order to make the QPM audit process more robust, auditors involved in organisational audit for QPM should receive training that enhances current auditing skills. Having conducted the audit of Tubex Ltd., and having previously dismissed the use of the combined quality and environmental auditing standard (BS EN ISO 19011:2002) it is the revised opinion of the author that BS EN ISO 19011:2000 provides generally applicable guidelines for audit, which are suited to the application of QPM as they combine elements of both quality management audit, and environmental audit. Both quality management auditors and environmental management auditors are now trained using the same methodology, concepts, and practices contained in the standard, and this provides an equitable basis for the movement to auditing for QPM, with both disciplines using the same baseline standard.

Engagement by the organisation

The participation in QPM by an organisation requires a level of organisational maturity in order for that participation to be meaningful and worthwhile. Neither EFQM nor the MBNQA have any baseline entry requirements. However these awards, use the self-assessment process to filter the applications, as entry at this level is generally received from those organisations that consider they may be successful. Further participation requires payment of an entry fee, and the selection by judges of those applications to receive an evaluative visit (Haavind. 1992).

It is not the intent of the author to restrict participation in QPM. Organisations may consider their own reasons for participation. It is however, the belief of the author that organisations would benefit by the use of the audit protocol as a self-assessment framework, and that the determination of the maturity of the organisation should be considered prior to participation in the QPM process. Assessment of organisations may be conducted against the performance maturity levels shown in Annex 2 of BS EN ISO 9004:2000; however no entry limits are currently applied for QPM, and all organisations are invited to participate.

5.5 Conclusions

The initial audit for QPM shown in this chapter was carried out by a planned audit and site evaluation of Tubex Ltd. in June 2002. The company's primary process is the manufacture and supply of plastic devices for protection and support of plants in forestry, landscape and amenity creation and agriculture and for habitat preservation. The end result shown in Table 5.6 gives the combined result of the 300 data points assessed during the audit process. The three audit attributes are quantified as totals of the combined category scores achieved. The mean figure for the combined scores of each attribute is displayed, along with the percentage weighting of each category toward the QPM result. The value of 2.67 found gives a figure based upon 5 categories that, if displayed as a percentage figure, show an initial QPM indicator for Tubex Ltd. of = 53.4.

The QPM indicator is a composite of the combined attributes of the audit process, and thus reflects the organisational performance against the three audit criteria at the macro level. Utilising the principles established in the application of the 'Balanced Scorecard' (Kaplan *et al.*, 1992), whereby a 'top level' scorecard card is established in line with the mission statement and strategy of the organisation, and from which subsequent scorecards evolve, ensures that strategic focus and application are consistent throughout the organisation. In order not to alter the holistic nature or strategic vision of the QPM indicator, the qualitative interpretation of the indicator will combine the descriptors used for the evaluation of individual audit criteria at each (micro) score level.

Evaluation of the resultant QPM indicator derived from the audit of Tubex Ltd. shows a mid-table result consistent with an organisation that has moderately effective systems that have suffered no breaches of authorisations. This reflects well the impression given to the author of Tubex Ltd. and which has been confirmed by evaluation of not only the overall QPM indicator, but by review of the individual mean attribute scores.

In detailing the process of the audit of Tubex Ltd., it is the author's belief that the hypothesis that is central to this work, that it is possible to develop an environmental management system that is capable of delivering a quantitative social / economic statement based on the pollutant aspects / effects of the organisation, has been established as correct.

Chapter 6

Conclusions and Contributions

Chapter Summary

This chapter reviews the author's study of QPM, and summarises the contributions afforded by the study.

6.1 Introduction

The aims and objectives of the programme of research, as outlined in Chapter 1 were to:

- Develop and apply a model for environmental management from which a quantifiable indication of overall environmental performance for an organisation may be derived. This will assist in allowing environmental performance to become a strategic factor in business planning.
- To provide a mechanism by which direct comparisons may be made between the operational characteristics of organisations, and how those organisations impact on the environment via pollution, providing direct business benefits to organisations that manage their business and concurrently protect the environment.

In Chapter 1, several research methods are described which consider pollution performance. The links between environmental performance and financial performance are also considered, as are several research methods that consider pollution performance. It is clearly shown that no single method wholly reflects quantitative pollution management (QPM), the main aim of this study. Although neither BS EN ISO 14001:1996 nor EMAS actually consider any form of quantitative output, the basis for a management system to enable QPM can be derived from either of the certified EMS. The derivation of a management reporting system capable of allowing the development of QPM is given. The QPM management system is a synthesis evolving from factors emerging from BS EN ISO 14001: 1996, EMAS, BS 14031:2000, GRI, OPRA, EFQM and the Malcolm Baldrige Award.

Chapter 2 identifies the necessary metrics in the design of the QPM system, and discusses their inclusion. The chapter shows that QPM requires a comprehensive understanding of the evaluation of environmental performance, which may be achieved *via* the assessment of the internal management processes to provide reliable and verifiable information on an ongoing basis. To ensure the robustness of the QPM process, the measurement metrics used must extend beyond the traditional focus on failure rates and end-of-pipe controls to enable evaluation of methods used by the organisation and the management processes that underpin the selection of those methods. Traditional metrics fail to measure adequately the efficiency or effectiveness of the underlying process, and do not consider the extent of the deployment.

The author's design of the QPM system in Chapter 2 requires that the organisation's management and leadership should display a clarity and unity of purpose in attempting to align and deploy all organisational activities in a structured and systematic manner. Effective organisational performance requires all inter-related activities to be understood and systematically managed, and decisions concerning current operations and planned changes to be made using reliable information (Kaplan *et al.*, 1996). Efforts and decisions undertaken by management affect the performance of an organisation's operations, and therefore overall environmental performance. By improving the efficiency of resource use, organisations are able to reduce pollutant emissions produced as outputs. Five categories are shown to contribute toward the author's study of QPM, the review of each of the five categories produced the definitive factors to be used in the category evaluation process. These are shown in Table 2.3 Factors for Evaluation of Categories used in QPM.

Chapter 3 establishes the author's methodology in deriving the initial model for QPM. It provides a brief overview of the prototyping, application and evaluation of QPM. The derivation of the QPM model has followed a structured methodology, and has reflected principles used by ISO for the production of both quality management and environmental management standards. The design methodology used in the establishment of the QPM model used the following five stages:

i. Definition of the overall concept of QPM
ii. The component aspects of QPM required to provide and support the concept
iii. The process by which QPM will fulfil its concept
iv. Preliminary evaluation / Prototyping
v. Application and Evaluation

In Chapter 4, the initial model for QPM is derived, and the weightings of the individual, and combined categories are established. The concept of QPM outlined in Chapter 4 applies to the organisation as a whole. QPM requires a comprehensive, systematic and regular review of the organisation's activities modelled against the criteria included in the audit protocol (Appendix 1). This use of the audit protocol enables organisations to utilise a self-assessment process, which may be used as a means to undertake a rigorous and structured assessment of organisational approach to pollution management, by utilising an assessment based upon factual data and not individual perception. The self-assessment process may be applied at all levels within the organisation, and used to target improvement initiatives or areas for concern.

The defining of the environmental audit process for QPM has required consideration to be given to the limitations associated with the audit evidence samples collected, and the recognition of uncertainty in audit findings and any audit conclusions. QPM makes this more robust by evaluating the approach toward QPM taken by the organization, the deployment of that approach and the results obtained by its use. This has the benefit of using both 'leading' (approach and deployment) and 'lag' (results) indicators (GRI, 1998).

The audit protocol for QPM considers the organization under five areas, those of leadership, inputs, controls, activities and outputs. A key issue in the development of the QPM model is the appropriate determination of weighting for each of the areas. This weighting of categories is shown in Chapter 4, Fig. 4.3 where the final QPM determinant is constructed from an overall consideration of both leading and lagging indicators. The final indicator clearly defines organisational performance in respect of QPM, and may be utilised by an organisation as a strategic tool for environmental strategy. The derivation of the overall indicator through consideration of the weighted categories in the QPM model allows temporal, competitive and functional analysis of categories to be undertaken. The study of QPM provides a link between what the organisation needs to achieve, and organisational approach and deployment of strategies and processes to deliver optimum performance levels.

Chapter 5 considers the initial application of QPM, carried out by a planned audit and site evaluation of Tubex Ltd. in June 2002. The end result shown in Table 5.6 gives the combined result of the 300 data points assessed during the audit process. The QPM indicator is derived as a composite of the combined attributes of the audit process, and thus reflects the organisational performance against the three audit criteria at the organisational macro level. In order not to alter the holistic nature or strategic vision of the QPM indicator, the qualitative interpretation of the indicator combines the descriptors used for the evaluation of the three individual audit criteria at each (micro) score level. A unique aspect of the author's study of QPM is that in addition to the quantification of organisational performance, a performance level descriptor is given which equates the numeric total with a clear interpretation of holistic performance by the organisation.

Evaluation of the resultant QPM indicator derived from the audit of Tubex Ltd. reflected well the impression of the organisation obtained by the author during the initial audit shown in Chapter 5. Tubex Ltd appeared to be an organisation that utilised systematic approaches and prevention-based systems that were subject to regular review, with an overall deployment to approximately 50% of the organisation. The impression was confirmed by evaluation of not only the overall QPM indicator, but by review of the individual mean attribute scores.

6.2 Possible Future Work

The author's QPM indicator provides a numeric variable, by using numerical values that have been obtained from a set of linguistic values evaluated against determinations of prescribed events. The robust nature of the developed QPM indicator is provided by means of a prescribed methodology where the outcome indicator is constructed from the results of the audit and the inter-relationship of the individual components. This inter-relationship of numeric and linguistic variables encourages the use of modified set theory in which an individual could have a degree of membership ranged over a continuum of values, as proposed by Zadeh (1965). The ideas involved in Zadeh's (1965) study have become popular under the name 'fuzzy logic' as they allow the combination in a 'logical' way of weighting factors associated with propositions from different sources (Johnson and Picton, 1995). Fuzzy logic is based on natural language, and refers to a logical system for reasoning under uncertainty (Wang, 2001). The seminal work by Zadeh (1965) interprets a fuzzy set as a class of objects with a continuum of grades of membership function, which assigns to each object a grade of membership ranging between zero and one. Fuzzy sets and their associated fuzzy logic are used in a wide range of problem domains that have included process control, classification, management and decision making (Yan *et al.*, 1994). The study by Wang (2001) considers that fuzzy logic can be viewed as a convenient way to map an input space into an output space using the experiences of experts and natural language, citing Gulley and Jang (1995) to establish that fuzzy logic may be used to create a fuzzy system to match imprecise data.

The potential for using fuzzy logic in progressing the author's study of QPM is in its applicability for the three assessment areas of Approach, Deployment and Results. Fuzzy sets can be used to describe vague concepts or linguistic variables. Each of the three assessed areas uses crisp interval boundaries between absolute membership of one set, to partial membership of the adjacent sets, during the assessment process.

6.3 Contributions

The contributions developed in this study enable organisations to consider a broader perspective on environmental performance, and encourage application of preventative technologies to reduce pollutant and waste loads by considering organisations applications of design for environment (DfE). QPM also promotes environmentally friendly products and services through openly available quantitative indicators that consider a holistic view of organisational activities. The contributions are considered in the following section:

1. ***The contribution of the research and development of a management system that derives a quantifiable indication of overall environmental performance.***

The research that underpins the study is developed in Chapter 2, while the methodology used in deriving the management system is shown in Chapter 3.

The management system is developed by utilising methodologies and systems, and awards from both quality management and environmental management, which have been considered and adapted for use in the author's study. The management system is derived in Chapter 4. The audit of Tubex Ltd. in Chapter 5 is used to test the developed management system, and shows that QPM clearly identifies areas of strength and weakness in the organisation, as the direct result of deriving a quantifiable indication of overall environmental performance

2. ***The contribution of the development of a measure for quantitative pollution management (QPM).***

The scoring mechanism developed in Chapter 4 enables the derivation of a quantitative indicator of overall environmental performance to be established. The additional benefit afforded by the QPM indicator is that it will assist in promoting a sustainable management strategy with preventative approaches to pollution. A QPM indicator enables industrial and regulatory strategies to be implemented beyond the traditional boundaries of pollution control and waste management by the evaluation of the approach taken by the organisation, the deployment of that approach and the results obtained. The derived indicator will be based upon the state of a particular process at a given point in time, and as such will need recalculation over given time intervals. Following the development of a quantifiable pollution indicator, customers / consumers would be able to make a purchase decision that takes into account environmental concerns.

3. ***A contribution by the development of an audit regime for use within QPM.***

The audit evidence collected during an environmental audit will inevitably be only a sample of the information available, partly due to the fact that an environmental audit is conducted during a limited period of time and with limited resources. The environmental auditing protocol for QPM shown in Chapter 4 provides a level of confidence in the reliability of the audit findings and any audit conclusions as it is derived from guidelines established from published international standards on both quality and environmental auditing. The additional contribution afforded by the audit regime is that it has been developed to establish the identification of existing management mechanisms, that are able to deliver enhanced environmental outcomes, and which are capable of providing a detailed record of changes, environmental risks and compliance issues that have occurred, and how these are addressed by the organisation's management. This new methodology enables the organisation to demonstrate improvement, if applicable. Monitoring tools should in any case be an aid to strategy formulation, not a determinant of it [Escoubes, 1999].

4. ***The contribution of a unique method of qualitative interpretation of a quantitative result for QPM***

This contribution is shown in Chapter 5, and has been developed by utilising the principles established in the organisational application of the 'Balanced

Scorecard' (Kaplan *et al.*, 1992). Balanced scorecard adds value by providing both relevant and balanced information in a concise way. This 'balance' enables organisations to clarify their vision and strategy by translating them *via* a tool that effectively communicates strategic intent, and motivates and tracks performance against strategic goals. The balanced scorecard structures an organisation's focus on the cause and effect relationships, which interact between the four 'perspectives' considered by Kaplan and Norton (1992). The quantitative QPM indicator is evaluated against a combination of the three audit attributes, in line with an assessment against the five individual audit categories. The assessment level descriptors for the organisation's approach, deployment and results are combined to provide a robust qualitative indication of the organisational profile.

5. ***The contribution of a method for conducting comparative analysis for process and organisational improvement.***

Unsolicited analysis may be rigorous and swift, coming from independent reviewers as well as interested stakeholders. This study enables the measurement of year on year progress according to specified indices, and for communicating those indices in a meaningful way. This has the advantage for the organisation of providing a single index, which may be easily understood by both corporate management and external stakeholders, and which is able to identify areas in need of improvement or corrective action, and provide a means for comparative analysis by enabling organisations to focus on how to improve any given business process by exploiting world-class approaches rather than merely measuring the best performance. Finding, studying and implementing best practices provide opportunity for gaining a strategic, operational and financial advantage.

6.4 Conclusion of Thesis

This study has considered whether it is possible to develop an environmental management system that is capable of delivering a quantitative social / economic statement based on the pollutant aspects / effects of the organisation. The aims and objectives of the study are contained in Chapter 1, and in the view of the author have been met.

The study has produced five clearly defined contributions, each of which has been shown to be effective and efficient in an industrial environment by the application of the QPM process in an audit of Tubex Ltd. The possibility of using fuzzy logic for future work is made by the author for an interesting area that may be expanded by further research.

The Audit Protocol

1. Introduction

The purpose of this audit protocol is to enable a detailed interpretation of this study toward quantitative pollution management (QPM). The audit process needs to establish a rigorous and structured approach toward pollution management, achieving an assessment based on fact and structured analysis and not on individual perception.

In Chapter 2 the criteria that inform QPM were discussed for inclusion. The model to be established using the 'simple process model' (Fig. 1.1), and the audit structures from the EFQM, MBNQA, and OPRA. The QPM audit protocol is divided into five areas, based around the organisation's profile.

These areas are:

1. Management and Leadership
2. Inputs
3. Controls
4. Activities
5. Outputs.

The audit approach uses the enablers / results and approach / deployment methodology used in the EFQM model.

The auditor must obtain documentary evidence to support the audit findings. In addition, the auditor must consider:

a. The degree of excellence of the approach

b. The degree of deployment of the approach.

Table A.1 indicates criteria that enable the auditor to establish membership set boundaries.

Approach	Deployment	Results
Anecdotal or non-value adding	Little effective usage	Ineffective Systems. Major breaches of authorizations
Some evidence of soundly based approaches and prevention based systems. Subject to occasional review. Some areas of integration into normal operations	Applied to about one quarter of the potential when considering all relevant areas and activities	Evidence of some in-effective systems. Minor breaches of authorisations, no major incidents
Evidence of soundly based systematic approaches and prevention based systems. Subject to regular review with respect to environmental effectiveness. Integration into normal operations and planning well established.	Applied to about half the potential when considering all relevant areas and activities	Evidence of moderately effective systems. No breaches of authorisations. No reportable incidents
Clear evidence of soundly based systematic approaches and prevention based systems. Clear evidence of refinement and improved environmental effectiveness through review cycles. Good integration of approach into normal operations and planning	Applied to about three quarters of the potential when considering all relevant areas and activities	Clear evidence of environmental effectiveness in normal operations and planning
Clear evidence of soundly based systematic approaches and prevention based systems. Clear evidence of refinement and improved environmental effectiveness through review cycles. Approach has become totally integrated into normal working patterns.	Applied to full potential in all relevant areas and activities	Clear evidence of complete environmental effectiveness in all aspects of operations

Table A.1. Membership categories for QPM approach, deployment and results. Revision to EFQM assessment criteria.

1. Organisational Profile

Name of organisation **Contact address** **Telephone** **Fax** **E-mail** **Corporate website**
Major products / services
Nature of market served (e.g. retail, wholesale, government)
Contact person with executive environmental responsibility **Relevant information on scale of activity** i. number of employees ii. net sales iii. product produced mass, amount, quantity iv. total assets v. activity level (e.g. gross margin, net profit) vi. Annual turnover vii. No. of employees assigned to environmental management Time period for which information is provided
Public accessibility to information on environmental activity

2. Organisation, Management and Leadership

This section deals with the behaviour of the management of the organisation in leading the organisation toward QPM. It considers how the executive team and all other managers inspire, drive and reflect QPM. The section also considers if employees embrace the concept of QPM as a basis for their own activities and further development of the organisation, and how the policy and strategy of the organisation reflect the concept of QPM in the formulation, deployment, review and improvement of policy and strategy.

2.1 Culture of pollution management

How do managers:

i. Assess awareness of pollution?

ii. Become involved in reviewing progress in QPM?

iii. Include commitment to, and achievement in QPM in appraisal and promotion of staff at all levels?

2.2 Visible involvement in leading QPM

How do managers:

i. Communicate with staff?

ii. Lead by example?

iii. Demonstrate commitment to QPM?

2.3 Support for QPM

How do managers:

i. Define priorities in improvement activities?

ii. Fund learning and improvement activities?

iii. Actively support employees' pollution reduction initiatives?

iv. Release staff to participate in QPM activities?

2.4 Policy and Strategy

How:

i. Is QPM reflected in the organisation's mission, values, vision, and strategy statements?

ii. Is the organisation's policy and strategy formulated?

iii. Is use made of data on social, environmental, regulatory and legislative issues?

iv. Does the organisation use internal environmental cost information to support internal decision-making?

v. Is use made of employee feedback?

vi. Is organisational policy and strategy communicated both internally and externally?

vii. Is QPM policy and strategy a basis for planning of activities and setting objectives throughout the organisation?

viii. Are business plans tested, evaluated, improved, aligned and prioritised within the organisation's policy and strategy?

ix. Does the organisation evaluate the relevance and effectiveness of its pollution management policy and strategy?

x. Does the organisation review and improve its policy and strategy?

xi. Is use made of performance data on competitors and 'best in class organisations'?

xii. Are organisational policies reviewed to ensure continuing relevance in light of changing standards, technology and emerging concerns?

3.0 Inputs

3.1 Materials sourcing

Does the organisation:

i. Have a policy to incorporate environmental criteria in the selection of suppliers for the goods and services it purchases?

ii. Consider if the supplier has necessary environmental permits / authorisations for the transaction?

iii. Conduct a physical evaluation of the supplier's facility?

iv. Review the supplier's
  a. product packaging?

  b. use of chemicals in manufacture?

  c. generation and management of waste?

  d. compliance record?

v. Work co-operatively with suppliers / contractors to develop environmentally preferable materials, products and processes?

vi. Give preference to local suppliers and /or goods produced locally to minimise adverse transport impacts?

3.2 Design for Environment (DfE)

How does the organisation:

i. Evaluate processes and chemical use to achieve cleaner production?

ii. Focus on pollution prevention and cleaner process technologies as a principal means of achieving continual product and process improvements?

iii. Incorporate environmental considerations into business decisions?

iv. Identify critical processes that have a significant impact on the environment?

v. Discover and utilise new principles of design, new technology and new operating philosophies?

vi. Implement process changes and evaluate the benefits?

3.3 Use and Conservation of Natural Resources

Does the organisation:

i. Incorporate environmental guidelines into its selection of goods and services (as distinct from its supplier assessment)?

ii. Have a formal materials / resource conservation policy, and what specific programs are in place to ensure that policies are implemented?

iii. Track chemical use through the operation, under any circumstance?

3.4 Energy

Does the organisation:

i. Have an energy conservation programme as part of a formal written energy conservation policy?

ii. Provide figures for total energy use by source

a. Electricity?

b. Fuel oil?

c. Natural gas?

d. Other (please specify)?

iii. Document vehicle fuel use?

Please supply figures for:

Petrol (litres purchased)
Total km travelled
Litres per 100 km travelled

Diesel (litres purchased)
Total km travelled
Litres per 100 km travelled

Other (specify fuel units)
Total km travelled
Litres per 100 km travelled

How does the organisation;

iv. Maximise proportional use of environmentally safer and more sustainable energy sources?

v. Minimise the environmental burdens associated with employee transportation for work-related or other purposes?

vi. Minimise energy requirements of its products?

vii. Conserve global non-renewable resources, and minimise waste?

4.0 Controls

4.1 Management Systems

Does the organisation:

i. Have an EMS?

State which EMS.

ii. Have 3rd party accreditation of the EMS?

iii. Have a procedure to deal with audit non-conformities?

iv. Have a procedure to prevent recurrence of non-conformities?

v. Have recognised training procedures for qualification of environmental auditors?

vi. Have a QMS?

State which QMS

vii. Have 3rd party verified registration of its QMS?

viii. Integrate any management systems?

4.2 Audit

Does the organisation:

i. Have a documented programme for environmental auditing?

Describe:
Audit frequency

Scope of audits

Structure of audits

ii. Have environmental audits carried out by trained personnel?

Describe:
Nature of training

Auditor qualification

iii. Have an energy audit programme for identifying conservation opportunities and progress?

iv. Report audit findings to senior management and / or board of directors?

v. Have its audit programmes reviewed by a 3rd party organisation?

vi. Ensure that employees have access to relevant information on the environmental impact of the task that they perform?

vii. Consider operations in abnormal and emergency conditions, including shutdown and start-up?

4.3 Legislation and Compliance
Does the organisation:

i. Operate under any permits, authorisations or consents in respect of environmental performance?

Please list.

ii. Have a documented procedure for maintaining records on current and impending environmental legislation?

iii. Maintain compliance to applicable environmental legislation?

If not: state reasons why, and detail breaches and any enforcement actions / fines.

5.0 Activities

5.1 Machinery

Does the organisation:

i. Follow a planned preventative maintenance procedure?

ii. Assess the actual process performance of machinery against potential capability in terms of environmental performance?

iii. Have a documented procedure for assessing and reporting whether on-site machinery represents BAT?

iv. Implement total quality environmental management for defect prevention / reduction, e.g. sub optimal pollution performance?

v. Have documented procedures for identification of the calibration status, safe storage and handling all measuring and test equipment used in the provision?

5.2 Personnel

How does the organisation:

i. Ensure only appropriately trained personnel are selected for a particular job / task?

ii. Review training requirements for staff in line with organisational policy?

iii. Communicate and implement policy and strategy statements internally and externally?

iv. Deal with the unavailability of staff in the short and long term?

5.3 Storage

Does the organisation:

i. Have a documented site storage philosophy, which is regularly reviewed and communicated to all staff?

ii. Ensure that tanks or storage vessels containing potential pollutants are stored within a bunded area that has an impermeable base and walls and is capable of containing at least 110% of the contents of the tanks or storage vessels in event of failure?

iii. Have documented procedures to prevent polluting substances from entering the land?

iv. Provide spill kits and/or absorbent granules / sawdust in locations where spills or leaks of pollutants could occur and find their way into or onto the land?

v. Ensure that all relevant employees and contractors are aware of the necessary procedures which must be followed to prevent spills or leaks of substances from causing contamination?

vi. Ensure the security and integrity of storage areas?

6.0 Outputs

6.1 Product stewardship

Does the organisation:

i. Have a formal, documented procedure for undertaking an environmental evaluation of its products?

ii. Have a formal, documented procedure for undertaking an environmental evaluation of its process to include by-products?

iii. Have a procedure for determining if a product misuse problem exists?

iv. Have a programme to minimise product misuse over a given period of time?

v. Give consideration to disposal of by-products in the planning and development process?

vi. Communicate the number of products that may be recycled and the percentage of parts within the product that may be recycled?

vii. Supply its products with instructions regarding environmentally safe use and disposal?

6.2 Waste

Does the organisation:

i. Have a specific programme in place to encourage minimisation of hazardous waste?

ii. Monitor hazardous waste generated to discover what percentage was:

Recovered for sale?

Recycled?

Incinerated?

Treated?

Land filled?

Other (please specify)?

iii. Audit the environmental performance of its waste disposal contractors?

iv. Identify non-hazardous waste streams associated with its products or processes?

If Yes: Please list.

v. Monitor non-hazardous waste generated to discover what percentage was::

Recycled / re-used?

Incinerated?

Treated?

Land filled?

Used for energy recovery?

Other (please specify)?

vi. Integrate waste management considerations within the product and planning process, and has it in place a system to identify and implement improvement?

6.3 Emissions

Does the organisation:

i. Have a formally adopted climate change policy?

ii. Monitor and quantify greenhouse gas emissions (per Kyoto protocol definition)?

Please state substance and amount

iii. Monitor and quantify ozone-depleting substance emissions (per Montreal protocol definition)?

Please state substance and amount

iv. Measure the quantity of energy released to air?

Please state amount.

v. Measure the amounts of heat, light or vibration emitted, the quantity of radiation released, and the noise measurements at specified locations?

vi. Have a procedure for the evaluation of BAT for the abatement technology used by the organisation?

vii. Monitor the quantity of emissions to air by type and nature, and the quantity of effluents discharged by type and nature?

The Study of Quantitative Pollution Management – Tubex Ltd. Briefing Document

Introduction

This work has been carried out as part of a PhD. study undertaken through the University of Wales College, Newport. The aim of this research is to develop and apply a model for environmental management from which quantifiable indication of overall environmental performance for an organisation may be derived.

Stakeholders increasingly have a heightened expectation of organisational commitment to good environmental and societal practice. Proponents of the link between environmental and financial performance have argued that pollution reduction provides future cost savings by increasing efficiency, reducing compliance costs, and minimising future liabilities.

Environmental management systems such as BS EN ISO 14001:1996 or the Eco-Management and Audit Scheme (EMAS) do not require organisations to comment on overall environmental performance. BS EN ISO 14001: 1996 simply advocates that the organisation should have viewed each particular function of the business process and applied a self- formulated quantitative / qualitative analysis to the function in question, providing no incentive to add a level of independently verifiable transparency to the analysis process.

Quantitative Pollution Management (QPM) investigates whether it is possible to develop an environmental management system that is capable of delivering a quantitative social / economic statement based on the pollutant aspects / effects of the organisation.

The QPM Process

A model for quantitative pollution management (QPM) has been developed, and a scoring mechanism has been defined which enables an indicator of pollution performance to be derived. This indicator reviews the organisation as a whole system, as well as commenting on its constituent parts. The indicator is based upon evaluation of five areas, those of:

1. Management /leadership,
2. Inputs,
3. Controls,
4. Activities,
5. Outputs.

The prototyping test of QPM in an industrial environment is to be carried out through the proposed audit of Tubex Ltd., a numeric QPM indicator will be derived from the audit results. The numeric QPM indicator will be subsequently considered by means of a qualitative interpretation of the quantitative indicator score. The qualitative interpretation will then be considered against the impression of the organisation gained by the auditor during the conduct of the audit.

The Audit Process

A copy of the audit protocol (enclosed) will be supplied to the Tubex Quality Manager prior to the site audit. The completion of this document serves two main purposes, as it allows Tubex to conduct a self-assessment of activities, and provides guidance for the QPM auditor in scheduling the audit to ensure minimal disruption to Tubex Ltd. It is envisaged that the QPM audit will take approximately 2 days.

As QPM considers a holistic view of the organisation, objective evidence will need to be established regarding the approach taken by Tubex Ltd., the deployment of that approach, and the results obtained from that deployment in respect of each of the areas of the audit. This is in excess of the scope of the typical quality audit that is undertaken at Tubex Ltd., but is necessary for the achievement of QPM.

Conclusion

The prototyping study of QPM will involve an approximate 2-day audit of Tubex Ltd., and the completion of the supplied audit protocol prior to on site attendance.

The QPM audit process is more rigorous than a typical quality audit, as it is intended to produce a holistic view of the organisation, this will require co-operation and engagement from Tubex Ltd. staff and employees.

The QPM audit will produce a quantitative and qualitative evaluation of the Tubex Ltd., process.

Illustrative example of the typed up notes taken by the Auditor to facilitate recall of basis on which scores were allocated for Question 2.3 Support for QPM.

Where identified, documentation refers to that given in Appendix C.

i. How do managers define priorities in improvement activities?

Objective Evidence obtained during audit:

Approach.

Systematic approach based upon legislative compliance and / or cost savings, showing review cycle. Good evidence of reviews for improvement (Viewed audit documentation).

For examples of this systematic approach see documents

QAP 20, Issue 01, Development Project Identification and Review

QAP 21, Issue 02, Control of Product Modifications

Clear evidence of integration of approach into normal operations and planning with suggestion scheme in operation that is open to all staff. Suggestion box situated near employees exit, verbal suggestions accepted during weekly 'team' meetings. E.g. Engineering Daily Production Report, FPC 108, WFU

Appendix C Illustrative example of the typed up notes taken by the Auditor to facilitate recall of basis on which scores were allocated for Question 2.3 Support for QPM.

Evidence of external benchmarking for 'best practice'. Discussion with quality manager and production manager showed evidence of refinement and improved environmental performance, the organisation having considered benchmarking results during management review. No formalised benchmarking partners.

Management reviews have improvement activities as an agenda item. For example as illustrated in document QAP 11, Issue 07, Internal Quality Audits & Review. Regular review as part of QMS.

The above evidence resulted in a score for 'approach' of 4.

Deployment

Process focussed system concentrating on process engineering activities involved in the extrusion process. Tubex Ltd., misses the opportunity for improvement of activities on approximately 50% of site by not implementing the approach fully throughout the ancillary / support staff and administration.

Good visibility for employees giving successful suggestions, with notice board near to suggestion box showing photographs of employees who had made successful suggestions. Staff photographs were all of production staff.

Complaints of management not acting on suggestions considered as operable by staff were noted when interviewing production staff.

The above evidence resulted in a score for 'deployment ' of 3.

Appendix C Illustrative example of the typed up notes taken by the Auditor to facilitate recall of basis on which scores were allocated for Question 2.3 Support for QPM.

<u>Results</u>

Clear evidence of effective environmental effectiveness in normal operations and planning were demonstrated by continued compliance to legislation by Tubex Ltd. For examples see documents

QAP 17, Issue 08, Plant Care Reclaim Material Control

QAP 05/1, Issue 05, Plant Care Inspection & Test Procedure.

QAP 19, Issue 06, Preventive Planned Maintenance.

Good results for selected activities, as demonstrated by savings of. £50K achieved through heat exchanger unit on extrusion process.

Results were not fully exploited due to poor deployment of a good approach, and requirement by Tubex Ltd. for cost savings.

The above evidence resulted in a score for 'results' of 4.

Question	Approach	Deployment	Results
i.	4	3	4

Appendix C Illustrative example of the typed up notes taken by the Auditor to facilitate recall of basis on which scores were allocated for Question 2.3 Support for QPM.

ii. How do managers fund learning and improvement activities?

Evidence:

Approach.

Clear evidence of proactive approach evidenced by dedicated training budget. (see also QAP 12, Issue 03, Training). However training / learning linked to identification of improvement activities which use the stated criteria of legislative compliance / cost savings. Open to all staff.

Use made of valleys initiative moneys (Agenda 1), and local Universities (TCS with University of Glamorgan)

Training request system formalised in QMS -QAP 12, Issue 03, Training. Training identification by Quality Manager. Success of training request initiative assessed through involvement levels and perceptions e.g. environmental awareness.

Management funded to attend forums and conferences in resource conservation and forestry. The Quality Manager is currently studying toward a M.Sc. in Environmental Management; this is supported by Tubex Ltd.

The above evidence resulted in a score for 'approach' of 4.

Deployment

Dedicated budget open to all staff by application.

Appendix C Illustrative example of the typed up notes taken by the Auditor to facilitate recall of basis on which scores were allocated for Question 2.3 Support for QPM.

No clear evidence of structured assessment methodology being used to determine successful applicants. Funding dependent upon cost savings / continued compliance, viewed applications were predominantly received from production / management staff. Ancillary / administration staff (approximately 25%) of staff stated that they did not engage in the process.

Evidence of application being rejected due to position of employee in organisation (i.e. wrong level) e.g. rejection of application for environmental lead auditor course by production operator e.g. Training Record Card, FPC 097, issue 2, Training Matrix, FPC 098, issue 2.

The above evidence resulted in a score for 'deployment ' of 4.

Results

Clear evidence of funding of learning and improvement activities linked to strategic goals of Tubex Ltd. When selected, training is evaluated for effectiveness, and due to the rigidity of the selection process is normally reported as positive. Good links with academia, and local regeneration initiatives.

Clearly effective in terms of environment in normal operations and planning.

The above evidence resulted in a score for 'results' of 4.

Question	Approach	Deployment	Results
ii.	4	4	4

iii. How do managers actively support employees' pollution reduction initiatives?

Approach.

Tubex Ltd., demonstrated soundly based approaches to actively supporting employees' pollution reduction initiatives through systematic approach that results in discussion at board level (e.g. QAP 20, Issue 01, Development Project Identification and Review, QAP 21, Issue 02, Control of Product Modifications, and QAP 11, Issue 07, Internal Quality Audits & Review). Good integration into normal operations and planning (e.g. Engineering Production Schedule, FPC 085, WFU. Engineering Contract Review Form, FPC 086, WFU. Engineering Works Order, FPC 087, WFU.)

The approach was shown to result in initiatives that resulted in improved environmental effectiveness (e.g. sourcing of 'support stakes' from managed forest, and recovery of chemicals from trade effluent), given that a main consideration was shown to be cost, management were pleased to support initiatives, this practice has become totally integrated into normal working practices.

The above evidence resulted in a score for 'approach' of 5.

Deployment

Having accepted the initiative for action, support is given to the employee's pollution reduction initiative by enabling the project to become integrated into

the process by means of a concession to the QMS (see QAP Concession Note, FPC 073, issue 3). Records of instructions issued to operatives were recorded in QAP - Operator Instructions Issued Register, FPC 062, issue 4. Disruption to plant activity was recorded in QAP Downtime Summary (Daily), FPC 005/1, issue 3. Initiatives were able to be applied to all relevant areas and activities. The management control of the initiatives was shown through use of QAP 20, Issue 01, Development Project Identification and Review, and QAP 21, Issue 02, Control of Product Modifications, and verified by audit (QAP 11, Issue 07, Internal Quality Audits & Review).

The above evidence resulted in a score for 'deployment ' of 5.

Results

The active support of employees' pollution reduction initiatives showed clear evidence of environmental effectiveness in normal operations and planning. The results obtained were dependent upon the authorised activities, each of which was constrained by cost (e.g. carbon filtration extraction project 006/02), this resulted in effective but not optimal pollution prevention.

The above evidence resulted in a score for 'results' of 4.

Question	Approach	Deployment	Results
iii.	5	5	4

Appendix C Illustrative example of the typed up notes taken by the Auditor to facilitate recall of basis on which scores were allocated for Question 2.3 Support for QPM.

iv. How do managers release staff to participate in QPM activities?

Approach.

Tubex Ltd. showed evidence of a soundly based systematic approach to the release of staff to participate in QPM activities, by allowing the Quality Manager to participate by completion of the audit protocol (Appendix A). Consideration of activities was evidenced at team level and board level (see document QAP 11, Issue 07, Internal Quality Audits & Review, and QPM 12, issue 03, Training.

The result of the completed audit protocol is proposed to be used to increase employee awareness within normal operations and planning,

The above evidence resulted in a score for 'approach' of 2.

Deployment

There is little effective usage of the approach, with only one employee being released to participate in QPM activities.

The above evidence resulted in a score for 'deployment ' of 1.

Results

Although poor scores have been achieved for both approach and deployment, the results obtained by Tubex Ltd have shown clear evidence of effectiveness in normal operations and planning. The Quality Manager has been the sole official participant, however results have been achieved through voluntary participation by employees at all levels. The audit has benefited from open and clear

discussion, and the willingness of employees to produce documentary evidence when requested.

The above evidence resulted in a score for 'results' of 4.

Question	Approach	Deployment	Results
iv.	2	1	4

tubex

Q.A.P Index

QAP Number	Issue	TITLE
01/1	03	Plant Care Sales Order Review & Processing
01/2	03	Sales Order Invoice Processing.
01/3	05	Customer Returns.
01/4	03	Sales Quotation Procedure
01/5	02	Sales Pricing
01/6	01	Sales Forecasting
02	04	Purchasing Control.
02/2	08	Supplier Appraisal & Approval.
02/3	03	Consignment Stock Purchasing & Control.
3	04	Goods Receiving & Issue.
05/1	05	Plant Care Inspection & Test Procedure.
6	03	Loading.
6/1	04	Storage
6/3	04	Warehouse Transfer Control.
7	07	Delivery.
8	05	Corrective & Preventive Action
8/1	06	Control Of Non-Conformance & Customer Complaints
8/2	06	Control Of Customer Complaints
9	09	Calibration.
10	06	Documents & Records.
11	07	Internal Quality Audits & Review.
12	03	Training.
13	09	Tooling Control.
14	07	Drawing Control.
15	01	Plant Care Production Scheduling.
15/1	01	Plant Care Production & Planning Control
16	01	Data Control.
17	08	Plant Care Reclaim Material Control
19	06	Preventive Planned Maintenance.
19/1	04	Vehicle Planned Maintenance
20	01	Development Project Identification and Review
21	02	Control of Product Modifications

Issued By: A Morse	Date: 5th December 2002

TUBEX Ltd.

Production Control Documentation Register

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Title	Doc' N°.	Issue	Loc/Holder	Date
Product Specification Holders Register	FPC 001	3	QA Manager	11/01
FPC Holders Register	FPC 002	3	QA Manager	06/00
Plant Care Production Schedule	FPC 003	8	PMC	11/02
Daily Production Report	FPC 004	WFU	PJ	03/00
Daily Downtime Report/1st Off	FPC 005	4	Cell Leaders	01/02
Downtime Summary (Daily)	FPC 005/1	3	PJ	02/98
Raw Material Blending Record	FPC 006	4	Mixer	06/00
Material Usage Record	FPC 007	11	Cell Leaders	11/00
Pigment Usage Record	FPC 008	1	Cell Leaders	04/93
Batch Control Chart	FPC 009	8	Cell Leaders	09/02
Data Sheet	FPC 010	3	QA Manager	08/02
Manual Blending Weekly Material Use Record	FPC 011	3	PC PS	06/00
Average Product Weight Record	FPC 012	8	QC	10/01
Purchase Order	FPC 013	2	PC PE	06/00
Daily Product Report	FPC 014	8	Cell Leaders	11/02
Classic Mat'l Blend Spec C/T Unit	FPC 015	1	AE	08/93
Classic Tie Distance Specification	FPC 016	1	AE	08/93
Classic Weight Spec.	FPC 017	1	AE	08/93
Classic Operator Visual Insp.	FPC 018	1	AE	08/93
Weekly Checklist	FPC 019	1	Cell Leaders	04/97
Std Tie Spec.	FPC 020	WFU	QC	10/02
Standard Weight Spec.	FPC 021	WFU	QC	10/02
Standard Visual Inspec.	FPC 022	3	QC	03/01
Purchase Requisition	FPC 023	2	PC PE	03/00
Shrubshelter Weight Spec (4 Dia)	FPC 024	WFU	QC	06/00
Shrubshelter Weight Spec (3 Dia)	FPC 024/1	WFU	QC	06/00
Shrubshelter Visual Spec (4 Dia)	FPC 025	3	QC	07/01
Shrubshelter Visual Spec (3 Dia)	FPC 025/1	WFU	QC	06/00
Shutdown Checklist	FPC 026	1	Cell Leaders	04/97
Shrubshelter Tie Spec.	FPC 027	6	QC	07/01
Start Up Checklist	FPC 028	1	Cell Leaders	04/97
Manual Blending Pigment Use	FPC 029	1	PC PS	05/98
Visual Insp Issued	FPC 030	WFU	QC	05/99
Reclaim I/D Label	FPC 031	4	Cell Leaders	02/00
50mm Quill Weight Chart	FPC 032	7	QC	07/01
50mm Quill length & Angle Chart	FPC 033	6	QC	07/01
Spiral Guard Visual Inspection	FPC 034	5	QC	11/00
50mm Quill Visual Inspection	FPC 035	4	QC	07/01
Nested Quill Visual Inspection	FPC 035A	1	QC	06/97
GI Inspection Sampling Plan	FPC 036	1	QC	06/98
Delivery Note	FPC 037	1	TM	06/98
Operations GI Data Entry Specification	FPC 038	1	Storeman	11/98
Daily Collation of Raw Material	FPC 039	4	PJ	07/97
Reclaim Material Identification Label	FPC 040	8	DW	02/00

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50mm Quill Banding Spec	FPC 043	4	QC	07/01
Shrubshelter Banding Spec (5 Dia)	FPC 044	5	QC	07/01
Shrubshelter Banding Spec (3 Dia)	FPC 044/1	WFU	QC	06/00
Nested Quill Banding Spec	FPC 045	2	QC	06/97
Spiral Guard Banding Spec	FPC 046	6	QC	11/00
Transport Load Summary Record	FPC 047	1	TM	06/98
Drivers Checklist	FPC 048	1	TM	06/98
Non-Conformance Report	FPC 049	1	QM	08/99
Vole Guard Packaging Spec	FPC 050	5	QC	09/97
Daily Stock Movement Record	FPC 051	2	TM	08/00
Formula for Calculating Masterbatch % in Products	FPC 052	1	QC	08/99
Calibration Specification for Colortronics (Bay 3)	FPC 052/1	9	QC	12/02
Calibration Specification for Colortronics (Bay 1)	FPC 052/2	14	QC	12/02
Calibration Specification for Colortronics (Bay 3)	FPC 052/3	15	QC	12/02
Calibration Specification for Colortronics (Bay 2)	FPC 052/4	18	QC	12/02
Mat' Additive Record	FPC 053	4	Cell Leaders	12.02
Colortronic Calibration Record	FPC 054	4	PC PE	08/99
Masterbatch Usage Record	FPC 055	WFU	Foremen	07/00
Finished Goods Stock Record	FPC 056	2	PC PC	10/00
Sleeve Tie & Weight Spec	FPC 057	5	QC	08/98
Sleeve Visual and Banding Spec	FPC 058	7	QC	06/00
Computer Stock Entry Instructions	FPC 059	2	PC PC	05/00
Spiral Vole & Sleeve Insp Record	FPC 060	WFU	QC	04/99
Net/Hybrid Visual and Banding Spec	FPC 061	6	QC	09/00
Operator Instructions Issued Register	FPC 062	4	QC	03/01
Seed Tubes Visual & Packaging Spec	FPC 063	1	QC	10/94
Net Cutting & Packaging Record	FPC 064	WFU	PC Foreman	12/00
Net & Hybrid Tie Usage Record	FPC 065	1	Cell Leaders	10/94
PC Division Inventory Control Record	FPC 066	WFU	Storeman	01/00
Daily Masterbatch Use Record	FPC 067	2	Cell Leaders	08/00
Stock Control Record	FPC 068	1	Transport	11/96
Freezer Test Spec	FPC 069	5	QC	10/00
Tie Usage Spec	FPC 070	9	QC	10/00
Stock Movement Summary	FPC 071	1	Transport	10/96
Nested Quill Length Angle & Weight	FPC 072	3	QC	06/97
Concession Note	FPC 073	3	QC	05/00
Rejection Note	FPC 074	2	QC	06/00
Economy Weight & Tie Spec	FPC 075	WFU	QC	11/98
Standard 'E' Weight & Tie Spec	FPC 075/1	WFU	QC	10/02
Economy Visual Spec	FPC 076	WFU	QC	11/98
Standard 'E' Visual Spec	FPC 076/1	5	QC	10/02
Economy Banding & Packaging Spec	FPC 077	WFU	QC	11/98
Standard 'E' Banding & Packaging Spec	FPC 077/1	4	QC	10/02
Stores Requisition	FPC 078	3	All Dept's	12/00
Originals Weight & Length Chart	FPC 078/2	8	QC	03/01
Originals Visual Inspection Spec	FPC 079	2	QC	03/01

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Vine Trainers Visual Inspection	FPC 081	2	QC	12/02
Vine Trainers Banding	FPC 082	2	QC	12/02
Vine Quills Banding	FPC 083	2	QC	12/02
Order Confirmation	FPC 084	1	GG	11/98
Engineering Production Schedule	FPC 085	WFU	AH	10/99
Engineering Contract Review Form	FPC 086	WFU	A.H	10/99
Engineering Works Order	FPC 087	WFU	A.H	10/99
Order Entry Specification	FPC 088	1	GG	11/98
Process Control Chart	FPC 089	4	PC Super's	04/01
Standard 'V' Tie Spec	FPC 090	6	QC	07/01
Equilibre Weight Spec	FPC 091	WFU	QC	09/00
Standard 'V' Visual Inspection	FPC 092	4	QC	07/01
Equilibre Hole Pattern Visual Inspection	FPC 092A	WFU	QC	09/00
Standard 'V' Banding	FPC 093	6	QC	07/01
Originals Banding Spec	FPC 094	3	QC	12/00
PC Division Contract Review Form	FPC 095	1	Sales	02/99
PC Verbal Order Form	FPC 096	1	Sales	02/99
Training Record Card	FPC 097	2	QA	11/98
Training Matrix	FPC 098	2	QA	11/98
Training Matrix (Plant Care)	FPC 98/1	3	PC Super's	03/99
Square Cut N/Q Weight Spec	FPC 099	4	QC	07/99
Tubexpres Weight Chart	FPC 099A	1	QC	08/97
Square Cut N/Q Visual Spec	FPC 100	2	QC	07/99
Tubexpres Visual Spec	FPC 100A	1	QC	08/97
Square Cut N/Q Banding Spec	FPC 101	4	QC	12/00
Tubexpres Banding Spec	FPC 101A	3	QC	10/97
Stock Control Data Entry Form	FPC 102	1	Storeman	11/98
Forestry Stock Discrepancy Report	FPC 103	1	Transport	11/96
End of Month Stock Movement	FPC 104	1	Transport	11/96
Engineering Reclaim Labels	FPC 105	WFU	AH	10/99
Engineering Operator Inspection Sheet	FPC 106	WFU	A.H	10/99
Engineering Pains Wessex Trimmer Insp Sheet	FPC 106 A	WFU	A.H	10/99
Engineering OEN India Inspection Sheet	FPC 106 B	WFU	AH	10/99
Engineering OEN India Inspection Sheet	FPC 106 C	WFU	A.H	10/99
Engineering OEN India Inspection Sheet	FPC 106 D	WFU	A.H	10/99
Engineering QC Inspection Sheet	FPC 107	WFU	AH	10/99
Engineering Daily Production Report	FPC 108	WFU	A.H	10/99
Engineering Daily Production Sheet	FPC 109	WFU	A.H	10/99
Vine Quills Weight Length & Angle	FPC 110	WFU	QC	12/02
Vine Quills Visual	FPC 111	2	QC	01/97
Engineering Dryer Loading Sheet	FPC 112	WFU	AH	10/99
Plant Care Primary Tooling Label	FPC 113	N/A	Aluminium	Tag
Plant Care Secondary Tooling Label	FPC 114	2	PC Super's	09/99
Plant Care Primary Tooling Register	FPC 115	5	PC Super's	09/02
Plant Care Secondary Tooling Register	FPC 116	5	PC Super's	09/02

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Plant Care QC/Setter Patrol Inspection Sheet	FPC 119	3	QC	09/01
Plant Care QC/Setter Patrol Inspection Sheet	FPC 120	4	QC	02/01
Plant Care QC/Setter Patrol Inspection Sheet	FPC 121	3	QC	03/01
Engineering Reclaim /Scrap Material Control	FPC 122	WFU	AH	10/99
Engineering Tooling Specification Sheet Register	FPC 123	WFU	AH	10/99
Purchase Invoice Entry	FPC 124	1	Accounts	01/99
Calibration Equipment List	FPC 125	5	QC	07/01
Calibration Equipment Issued	FPC 126	1	QC	01/99
Calibration Equipment Record	FPC 127	4	QC	08/02
Calibration Specification List	FPC 128	4	QC	09/01
Plug and Length Gauge Calibration Record	FPC 129	WFU	QC	10/99
Tooling Use Record	FPC 130	1	PC Super's	12/96
Audit Record	FPC 131	2	QC	04/02
Audit Report	FPC 132	2	QC	04/99
Audit Report Summary	FPC 133	2	QC	11/01
Goods Inwards Receipt of Raw Materials Check List	FPC 134	1	Storeman	01/99
Freezer Test Record	FPC 135	1	QC	01/99
Stock Records	FPC 136	1	Storeman	02/99
Stock Records (Raw Materials)	FPC 137	1	Storeman	02/99
Supplier Assessment Questionnaire	FPC 138	1	GAE	05/99
New Supplier Approval	FPC 139	3	GG	06.02
Treessntials Originals Weight & Length	FPC 140	3	QC	03/98
Treessntials Originals Visual	FPC 141	1	QC	02/98
Treessntials Originals Pack & Labelling	FPC 142	1	QC	02/98
Consignment Stock Control Record	FPC 143	1	Storeman	02/99
Goods Inwards General Goods	FPC 144	1	Storeman	02/99
Approved Materials List	FPC 145	16	QC	01/03
Goods Inwards Raw Materials	FPC 146	1	Storeman	02/99
Close Sales Invoice	FPC 147	1	Sales Co-ord	02/99
Tubex Sales Invoice	FPC 148	1	Sales Co-ord	02/99
Pick List	FPC 149	1	Transport	02/99
Order Referal Form	FPC 150	1	Sales	02/99
Fork Lift Daily Inspection Sheet	FPC 151	1	Transport	02/99
Tubex Export Despatch Form	FPC 152	2	Transport	06/00
Product Code Engineering	FPC 153	WFU	AH	10/99
Engineering Quotation Form	FPC 154	WFU	AH	10/99
Engineering Costing Sheet	FPC 155	WFU	AH	10/99
Consignment Stock Register	FPC 156	6	Op's Direct'	09/02
Delivery to Consignment Stock Note	FPC 157	2	Op's Direct'	05/00
Consignment Stock Identification Label	FPC 158	2	Goods In'	04/99
Consignment Stock Booking In Spec	FPC 159	2	Goods In'	10/00
Consignment Stock Declaration Note	FPC 160	2	Op's Direct'	05/00
Goods Returned Note	FPC 161	1	Transport	02/99
Customer - Client Drawing File	FPC 162	WFU	Draw' Office	10/00
Customer - Client Drawing Holders Register	FPC 163	WFU	Draw' Office	10/00

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Drawing Modifications Sheet	FPC 166	1	Draw' Office	03/99
Warehouse Transfer Request Form	FPC 167	3	PMC	06.02
Product Drawing Register	FPC 168	1	Draw' Office	03/99
Product Drawing Holders Register	FPC 169	2	Draw' Office	01/02
Quotation Request Form	FPC 170	3	Draw' Office	10/00
Plant Care Line Setting Chart	FPC 171	WFU	PC Super's	04/99
Engineering Process Control Chart	FPC 172	WFU	Eng Man	04/99
Development Drawing Register	FPC 173	1	Draw' Office	03/99
Development Drawing Holders Register	FPC 174	1	Draw' Office	03/99
Plant Maintenance Drawing Register	FPC 175	1	Draw' Office	03/99
Repro Mat'l Return Checklist	FPC 176	WFU	DW	01/00
Reclaim Material Despatch Checklist	FPC 177	3	DW	03/00
Preliminary Proposal Drawing Register	FPC 178	1	Draw' Office	03/99
Preliminary Proposal Drawing Holders Register	FPC 179	1	Draw' Office	03/99
Warehouse Transfer Instruction	FPC 180	1	PMC	03/99
Drawing Modification Register	FPC 181	1	Draw' Office	03/99
Tooling Manual Holders Register	FPC 182	2	QC	08/99
Maintenance Record	FPC 183	1	Maint Office	11/01
Transport Department Maintenance Record	FPC 183/1	1	Transport	04/00
Back Up Tape Register	FPC 184	2	Draw' Office	07/99
Plant Care Identification Labels Spec'	FPC 185	1	PC Super's	03/99
Dryer Specification Sheet	FPC 186	WFU	Eng Foreman	10/99
Maintenance Wall Chart	FPC 187	5	Maint F'man	01/02
Transport Department Maintenance Wall Chart	FPC 187/1	1	Transport	04/00
Clipper Packaging Specification	FPC 188	5	QC	09/01
Easy-Wrap Operators Visual Inspection + Packing Specification	FPC 189	2	QC	07/01
Clipper Visual Inspection Specification	FPC 190	1	QC	09/99
Product Review Form	FPC 191	1	QC	08/99
Purchasing Specification Review Form	FPC 192	1	PC Prod Eng	08/99
Clipper Weight and Length Specification	FPC 193	1	QC	10/99
Clipper Template	FPC 194	1	QC	09/99
Plant Care QC/Setter Patrol Inspection Sheet	FPC 195	2	QC	06/02
PPE Register	FPC 196	1	Pers' Man	11/99
PPE Working Arrangements	FPC 197	2	Pers' Man	10/00
Induction Check List	FPC 198	3	Pers' Man	09/01
Goods Inwards Inspection Record	FPC 199	2	QC	01/01
Regrind Material Despatch	FPC 200	1	GG	01/00
End of Month Report for Goods Inwards	FPC 201	3	GG	10/01
Current Primary Tooling	FPC 202	10	M Dennis	09/02
Plant Care Tooling Specification Holders Register	FPC 203	2	QC	12/00
Customer Complaints Form	FPC 204	3	QA Manager	10/00
Packaging Details for RabbitPro	FPC 205	1	GG	03/00
Tooling Stores Spanners Issued Register	FPC 206	3	TM	08/00
Reclaim - Goods Inwards Works Entry	FPC 207	1	GG	03/00

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Pick List (General)	FPC 210	1	GG	06/00
Pick List (AVP)	FPC 211	WFU	GG	11/01
Temperature Control Chart (See M Dennis)	FPC 212	1	MD	06/00
Haul Off Belts	FPC 213	4	MD	09/02
Audit Corrective and Preventative Action	FPC 214	2	QA	07/00
Map Tubes Inspection and Packaging Specification	FPC 215	2	QA	09/00
Eco Start Weight and Dimension Specification	FPC 216	4	QA	07/02
Eco Start Operator Visual Inspection Specification	FPC 217	1	QA	10/00
Eco Start Operator Packaging Specification	FPC 218	2	QA	07/01
Drawing Distribution Sheet	FPC 219	1	Draw' Office	10/00
Maintenance Register	FPC 220	1	Maint Man	11/01
Health and Safety Audit Schedule	FPC 221	1	QA Office	04/02
Stillage Bundle Stacking	FPC 222	1	QA	01/01
Development Projects Register	FPC 223	1	QA Office	NYI
Development Time Record	FPC 224	1	QA Office	NYI
Development Purchasing Record	FPC 225	1	QA Office	NYI
Standard V Alignment Record	FPC 226	2	QA Office	10/01
Standard V Drilling Record	FPC 227	2	QA Office	10/01
Hazard Report Form	FPC 228	1	QA Office	03/01
Process Control Variation Record	FPC 229	1	PC Super's	03/01
Bird Net Length Gauge	FPC 230	1	QA	03/01
Tooling Trolley Maintenance Schedule	FPC 231	2	PED	10/01
Maguire Calibration and Setting Specification	FPC 232	3	QA	03/02
Water Test Record	FPC 233	1	QA	04/01
Export Despatch Work Instruction	FPC 234	1	Transport	06/01
Loading Check List	FPC 235	1	Transport	06/01
Maguire Scale Calibration Instruction	FPC 236	1	QA	06/01
Receipt of Induction Documentation	FPC 237	1	QA/PCS	06/01
Spiral Saw Setting Chart	FPC 238	1	PC Super's	07/01
Risk Assessment Schedule	FPC 239	1	QA/H+S	07/01
Eco Start (Spain) Weight and Dimension Specification	FPC 240	1	QA	10/01
Eco Start (Spain) Operators Visual Inspection Specification	FPC 241	1	QA	10/01
Eco Start (Spain) Banding Specification	FPC 242	1	QA	10/01
Pick List Shortage Form	FPC 243	1	Transport	09/01
Gravimetric Tag Key Instruction	FPC 244	1	GG	10/01
Permit to Work	FPC 245	1	SR	10/01
Maguire Blender Instruction.	FPC 246	1	GG	10/01
Hopper filter Cleaning Schedule	FPC 247	1	GG	10/01
Eco Vine Visual Inspection	FPC 248	1	QA	11/01
Eco Vine Banding Specification	FPC 249	1	QA	11/01
Eco Vine Weight and Length Specification	FPC 250	1	QA	01/02
Display Screen Equipment Questionnaire	FPC 251	1	QA	10/01
Asset and Equipment Specification Sheet	FPC 252	1	Maint Man	09/02
Service Request Form	FPC 253	1	All Dept's	09/02
Cell Leader Fault Report Sheet	FPC 254	1	PC Super's	11/01

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Cage Packaging Specification	FPC 257	1	QA	11/01
Breakdown and Job Request Work Sheet	FPC 258	1	Maint man	11/01
Quality Manual Holder Register	FPC 259	1	QA	12/01
Risk Assessment Form	FPC 260	1	QA	12/01
QAP Holders Register	FPC 261	2	QA	06/02
Standard V Cutter Change Over Record	FPC 262	1	QA	02/02
Hand Saw Blade Record	FPC 263	1	PCS	02/02
Colortronic Blade Change Record	FPC 264	1	PCS	02/02
Pressure Transducer Readings Record	FPC 265	1	GG	02/02
Colortronic Blade Schedule	FPC 266	2	GG	02/02
Spiral Saw Operation	FPC 267	1	PCS	03/02
Floataire Saw Setting Record	FPC 268	1	PCS	03/02
Quotation Request Form	FPC 269	1	Sales	03/05
Goods Return Request Form	FPC 270	1	Sales	05/02
Vacuum tank filter Change	FPC 271	1	P C Super	07/02
Employment Application Form	FPC 272	1	PC Super's	11/01
Equipment Change Over List	FPC 273	1	PC Super's	08/02
Raw Material Control & Use Instruction	FPC 274	1	PC Super	09.02
Standard Sales Order Form	FPC 275	1	Sales	09.02
H & S Function Organisation Chart	FPC 276	1	QA	09.02
H & S Contacts	FPC 277	2	QA	12.02
4 Diameter Shrub Shelter Operator Visual	FPC 278	1	QA	09.02
4 Diameter Shrub Shelter Banding Specification	FPC 279	1	QA	10.02
Credit Note Authority	FPC 280	1	Sales	10.02
Raising a Works Order Instruction	FPC 281	1		10.02
Booking Stock Against a Works order	FPC 282	1		10.02
Stock Order Generation / Authority to make	FPC 283	1		10.02
Cycle Count Instruction	FPC 284	2	PMC	11.02
Warehouse Stock Count / Adjustment Record	FPC 285	1	PMC	10.02
Control of Granulator Sweepings	FPC 286	1	PCS	10.02
Control of Raw Materials. (Granule Sweepings)	FPC 287	1	PCS	10.02
Control of Raw Materials. (Lump Scrap)	FPC 288	1	PCS	10.02
Control of Raw Materials. (Regrind/Reclaim)	FPC 289	1	PCS	10.02
W.I.P Transfer Instruction	FPC 290	1	PMC	10.02
Tubex Enquiry Form	FPC 291	1	Sales	11.02
Print on Products Instruction.	FPC 292	1	QA	12.02
Banding Spec, for products that have extruded with the full nest not complete.	FPC 293	1	QA	12.02
Treessentials. USA Loading checklist	FPC 294	1	QA	01.03
Vacuum Tank Water Setting Instruction	FPC 295	1	PE	01.03
	FPC 296			
	FPC 297			
	FPC 298			
	FPC 299			
	FPC 300			

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Title	Doc' N°.	Issue	Loc/Holder	Date
Quill Laser Cut	FPC L001	WFU	QC	05/99
Treeshelters Laser Cut	FPC L002	WFU	QC	05/99
Originals Laser Cut	FPC L003	WFU	QC	05/99
Plant Care Laser Cut Inspection Record	FPC L004	1	QC	05/99
Line Speed Standard	PCPR 01	1	QC	02/99
Line Speed Mini Tube	PCPR 02	1	QC	02/99
	PCPR 03			
Line Speed Ventex/Equilibre	PCPR 04	1	QC	02/99
Line Speed Hybrid	PCPR 05	1	QC	02/99
Line Speed Original	PCPR 06	1	QC	02/99
Line Speed Seed Tube	PCPR 07	1	QC	02/99
Line Speed Shrubs	PCPR 08	1	QC	02/99
Line Speed Standard Quill	PCPR 09	1	QC	02/99
Line Speed Nested Quill	PCPR 10	1	QC	02/99
Line Speed Square Cut Nested Quill	PCPR 11	1	QC	02/99
Line Speed Tubexpres	PCPR 12	1	QC	02/99
Line Speed Sleeve	PCPR 13	1	QC	02/99
Line Speed Spiral	PCPR 14	1	QC	02/99
Line Speed Vine Quill	PCPR 15	1	QC	02/99
Line Speed Vole Guard	PCPR 16	1	QC	02/99
Line Speed Australian Vine Trainer	PCPR 17	1	QC	02/99
Line Speed Net Guard	PCPR 18	1	QC	02/99
Line Speed Easy Wrap	PCPR 19	1	QC	02/99
Line Speed Clipper Grow Tube	PCPR 20	1	QC	02/99
Line Speed	PCPR 21			
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Line Speed	PCPR 24			
Line Speed	PCPR 25			

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Date	Issue	Summary of Changes
9.9.93	01	First Issued
26.3.98	02	Revised to include corrections to FPCs 64, 65, 67 and to include 130
31.3.98	03	Revised to include reference to FPC 71 and authorisation signature on page 1.
21.04.98	04	Revised to detail FPC 01, FPC 002 and up issuing of FPC 052.
27.04.98	05	Revised to include forms FPC 103, 104 & 68, additionally to include reference to the up-issue of FPC 78/2 to issue 04
05.05.98	06	Revised to include reference to FPC 10 Plant Care data sheet
12.05.98	07	Revised to include reference to FPC 011
05.06.98	08	Revised to include reference to FPC 029 and FPC 030
18.06.98	09	Revised to detail up-issuing of FPC 053 to issue 02
22.06.98	10	Revised to include reference to up-issuing of FPC 11 to Issue 02
23.06.98	11	Revised to include reference to FPC 13 and FPC 23 Purchase Requisition and Purchase Order
07.11.98	12	Revised prior to issue. Issued as below.
07.11.98	13	Revised to include all up-dated documents upto 07.11.98
26.11.98	14	Revised to remove Plant Care Division from document title and to continue ongoing update of documentation.
04.12.98	15	Revised to include re-numbered documents upto and including 4.12.98
18.12.98	16	Revised to include all new and renumbered documents upto and including 18.12.98
11.01.99	17	Revised to include all new and renumbered documents upto and including 11.01.99
22.01.99	18	Revised to include all new and renumbered documents upto and including 22.01.99
11.02.99	19	Revised to include all new and renumbered documents upto and including 11.02.99
01.03.99	20	Revised to include all new and renumbered documents upto and including 01.03.99
12.03.99	21	Revised to include all new and renumbered documents upto and including 12.03.99
24.03.99	22	Revised to include all new and renumbered documents upto and including 24.03.99 and minor changes to register format

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Date	Issue	Summary of Changes
22.04.99	23	Revised to include all new and renumbered documents upto and including 22.04.99 and minor changes to register format
13.05.99	24	Revised to include all new and renumbered documents upto and including 13.05.99
17.06.99	25	Revised to include all new and renumbered documents upto and including 17.06.99
14.07.99	26	Revised to include all new and renumbered documents upto and including 14.07.99
20.08.99	27	Revised to include all new and renumbered documents upto and including 20.08.99
31.08.99	28	Revised to include all new and renumbered documents upto and including 31.08.99
25.10.1999	29	Revised to include all new and renumbered documents upto and including 25.10.99 and status of all Engineering Dept paperwork changed to WFU.
21.01.2000	30	Revised to include all new and renumbered documents upto and including 21.01.00, and to mark FPCs 066 and 176 WFU
11.03.2000	31	Revised to include all new and renumbered documents upto and including 11.03.00, and to mark FPC 004 WFU.
06.04.2000	32	Revised to include all new and renumbered documents upto and including 06.04.2000. With all Withdrawn From Use (WFU) documents now being highlighted in RED
28.04.2000	33	Revised and re-issued after audit of documents currently in use.
28.06.2000	34	Re-issued to include all new and revised documents upto and including 28.06.2000
16.08.2000	35	Re-issued to include all new and revised documents upto and including 16.08.2000
22.09.2000	36	Re-issued to include all new and revised documents upto and including 22.09.2000
03.10.2000	37	Re-issued to include all new and revised documents upto and including 03.10.2000. Also the withdrawal from use of FPCs 091, 092A, 162 and 163.
14.12.2000	38	Re-issued to include all new and revised documents upto and including 14.12.2000. Also the withdrawal from use of FPC 064.
03.03.2001	39	Re-issued to include all new and revised documents upto and

		including 03.03.2001

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Date	Issue	Summary of Changes
31.08.2001	41	Re-issued to include all new and revised documents upto and including 31.08.2001
05.10.2001	42	Re-issued after review.
29.11.2001	43	Re-issued to include all new and revised documents upto and including 29.11.2001
14 .03.02	44	Re-issued to include all new and revised documents upto and including 14.03.2002.
24.07.2002	45	Re-issued to include all new and revised documents upto and including 24.07.2002.
10.09.2002	46	Re-issued to include all new and revised documents upto and including 24.07.2002. (Adding page 8)
17.12.2002	47	Re-issued to include all new and revised documents upto and including 17.12.2002. (Up to FPC 293)

The management of hazardous waste by high temperature incineration in the United Kingdom.

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Synopsis

This paper shows the way in which U.K. companies manage hazardous waste from the initial contact by the waste producer to the Disposal Company with reference to relevant standards. The final environmental destiny of any residue associated with the disposal process is also discussed. It will highlight difficulties which are encountered during acceptance, handling, transport and storage of waste. The operating parameters which ensure the robustness of the core disposal process and abatement systems will be considered. The paper will conclude with an assessment of process capability.

Key words : Waste Incineration : Legal Compliance : Disposal Process : Pollution : Special Waste

Introduction

There are currently only three rotary kiln hazardous waste incinerator plants in operation within the United Kingdom, authorised by the Environment Agency (EA), providing a disposal service to the United Kingdom (U.K.) chemical industry which fulfills the 'Duty of Care' regulations in respect of special, difficult and hazardous waste. As the range of synthetic pathways and end products increases, and the use of novel intermediates becomes more prevalent, the final environmental fate can be of critical importance. Gas phase auto-oxidative combustion firmly and predictably defines the nature of the final products and their final environmental fate, affording quantifiable impact assessment. Caution with hazardous waste is important for secure environmental protection, since risks arise as a result of the types and quantities of materials held and the method of storage, in addition to the associated pollution risks within the destruction and residue disposal process.

1.0 The Regulatory Framework

The legislative framework within which the operators of U.K. rotary kiln hazardous waste incinerator plants must operate clearly defines a pathway for the management of the disposal process. The legislation derives from U.K. Statute and EEC Directives administered by the appropriate regulatory bodies in the public interest.[1]

1.1 The Regulation of Waste Incineration

Waste management strategy in the UK was set out in the Environmental Protection Act (EPA) of 1990. Part 1 of the Act deals with prescribed processes, including waste incineration, and Part II deals with disposal of waste on land, including landfill. The Act introduced the system of Integrated Pollution Control (IPC) where the environmental impacts of the process on the air, water and land environment are viewed as a whole. The prescribed processes to be controlled under IPC are set out in the Environmental Protection (Prescribed Processes and Substances) Regulations 1991.

1.1 Process Guidance Notes

Waste treatment prescribed processes are covered by guidance notes issued by the Environment Agency. The sector applicable to hazardous waste incineration is IPR 5/1. Although not having statutory force these guidance notes represent best available techniques, and define the standard against which applications for authorisation are considered. The process guidance notes contain requirements imposed on the Environment Agency in the EPA 1990 to ensure that the best available techniques not entailing excessive cost (BATNEEC) are used to prevent, minimise or render harmless the release of the prescribed substance into the environmental medium of air, water or land. In addition the best practicable environmental option (BPEO) must be achieved where a process is likely to involve releases into more than one medium.

1.2 Duty of Care

The 'duty of care' concept was introduced by the EPA 1990, and seeks to ensure the safe storage, handling and transport of waste by authorised people and to authorised sites for commercial and industrial waste. There is a responsibility imposed on the producer of the waste to ensure that an authorised operator transfers the waste for suitable treatment and disposal. This duty is legally enforceable, and also requires anyone involved in the storage, transport, treatment or disposal of the waste to take reasonable measures to prevent pollution to the environment or harm to human health. There is also a requirement for the making and keeping of records.

1.3 The Special Waste Regulations 1996

The 1996 regulations introduce conformity with European legislation and unify the definition of hazardous waste throughout the European Community (Council Directive 91/689/EEC, 1991). The regulations give a list of over 200 different types of waste, catalogued into different industrial processes. The full list of hazardous wastes is listed in Council Decision 94/904/EC (1994), which, together with the EC Directive on Hazardous Wastes (Council Directive 91/689/EEC, 1991) establishes the list of EC hazardous wastes. The properties which define the waste as special are wide-ranging, and are categorised with hazard codes.

1.3.1 Consignment Notes

A consignment note must accompany every movement of special waste. In order to consign special waste, the consignor or their agent, has to notify the Environment Agency in advance of the movement. The Environment Agency will allocate to each load a unique identification number, ensuring traceability between the Environment Agency, consignor, consignee and carrier. Copies of consignment notes should be retained as part of a register for not less than three years.

1.4 The Hazardous Waste Directive 94/67/EC

Existing plant will need to comply with the Hazardous Waste Incineration Directive 94/67/EC by 1 July 2000, unless a shutdown regime is agreed in accordance with Article 13. The IPC Guidance Note S2 5.01 (Waste Incineration) supercedes IPR 5/1 .

1.5 The Transport of Waste

Waste materials are delivered to plant either as bulk liquids or sludges in road tankers, or as non-bulk materials in drums or a variety of miscellaneous packaging. Deliveries must be compliant with the criteria defined in Council Directive 94/55/EC (the ADR Framework

Directive) and the Carriage of Dangerous Goods (Classification, Packaging and Labeling) and Use of Transportable Pressure Receptacles Regulations 1996 (referred to as CDGCPL2).

2. The Acceptance and Storage of Waste on Site

Waste acceptance is subject to a technical appraisal in terms of both physical, and chemical characteristics, prior to being accepted for delivery to the plant.[2] The decision must be made whether the material can be processed under the guidelines of each individual plant authorisation. Whether any special handling requirements are necessary, or the material should be subjected to a trial, and if the Statutory Authorities should be notified. The potential for emission prior to processing is also reviewed during the risk assessment, in addition to fire precautions, spillage control and first aid procedures. Special waste arrival at each plant is governed by the consignment note procedure, the prenotification copy of which acts as an aid to input planning and scheduling. Each consignment or delivery of waste is allocated a unique identification number which allows for identification and traceability of the material from receipt to incineration.

On arrival at the plant all wastes are validated against the delivery schedule, the previously agreed specification, and the consignment note, prior to being off-loaded into specially designed and maintained storage areas.

3. The Core Disposal Process

The destruction of hazardous wastes by high temperature incineration is achieved by controlled charging.[3] Discrete packages of solid waste are fed directly to the incinerator. The derived criteria listed in S2 5.01, which govern efficient combustion of furnace gasses, are:

Criteria governing efficient combustion of furnace gases	
Adequate oxygen content	At least 6% v/v
High temperature to promote combustion	1100 - 1200^0 C
Sufficient time to complete the combustion reactions	2 - 4 seconds
Turbulence to promote mixing	2nd chamber geometry

3.1 Temperature

Temperatures in excess of 1000^0 C are generally considered to define the area of 'High Temperature Waste Incineration', with 1100^0 C as the typical temperature used as a regulatory standard. However to reach optimum performance, it is necessary to establish the characteristics of the waste e.g. chlorine content - which results in a higher incineration temperature. It is not the case that increased efficiency can be gained from ever increasing temperatures, as the higher the incineration temperature, the higher the NOx emission. In addition, a practical limitation of around 1300-1400^0 C is reached due to restrictions on available oxygen. Temperatures must be maintained for as long as combustible waste is in the combustion chamber.

3.2 Oxygen

Adequate oxygen content is a key factor in the degree of completion of combustion. However the EC Directives do not state whether combustion oxygen levels are measured wet or dry. Insufficient oxygen results in the formation of carbon monoxide. The combustion efficiency may be calculated on-line as:

$$\textbf{Combustion efficiency (CE)} = (1 - (CO/CO_2)) \times 100\%$$

This value represents the percentage efficiency of oxidation of carbon to CO_2. Residual CO in the afterburner chamber has shown to be <10mg/m3 with typical CO_2 values in the range of 5-10%. This methodology has resulted in CE values of >99.99% for each of the UK incinerators

3.3 Residence Time

Rotary kilns operate in the UK at controlled speeds of between 1 and 10 revolutions per hour. The primary refractory lined combustion chamber is inclined downwards from the feed end, ensuring maximum burnout and volatilisation of organic materials during the 30 to 120 minute residence time, and the production of an inert slag which is drained from the kiln into a quenching water bath. Gas residence time in the afterburner chamber must be at least 2 seconds from the point of the last injection of combustion air. Insufficient residence time results in incomplete combustion, the products of which can vary according to the circumstances.

3.4 Turbulence

The effective mixing of the gas stream in the afterburner chamber is essential for complete combustion. The potential for slipstreaming will result in the incinerator gases possessing a wide distribution of residence times, depending on the position of the gas flow along the afterburner. In addition the ineffective mixing of the gas stream results in unacceptable temperature profiles across the afterburner chamber.

4. Gas Cleaning

Gas cleaning plants are designed to remove materials, particularly acid gasses and particulate solids from the combustion gasses carried over from the incineration process. In order to reduce the scope for the formation of dioxins/furans, it is necessary to reduce the gas temperature almost instantaneously to below the primary temperature zone of concern, which lies between 200 and 450°C. Rapid quenching at this stage is considered more important than waste heat recovery. The rapid quench is carried out either by the use of a saturate venturi or by the use of a quench tower. Both of which reduce gas temperature instantaneously to below 80 °C.

4.1 Abatement Configuration

Following the quench system, configurations used are site and process specific.[4] Variations are limited to either:

(i) an absorber system incorporating a conventional cooling tower, where cooled wash liquor will in flowing down the bed, absorb any remaining halogen acids to a level below the discharge limit for the exhaust gas. Delivering the added benefit of removing some of the remaining particulate, while controlling values of pH. The cool and effectively pH neutral gas stream then passes through an electrostatic precipitator for the final removal of any solid particles, and any liquid droplets or mist carried over from the previous stage. Pre-heated ambient air is mixed with the exhaust gas to produce a stack emission having a temperature of between 30-40°C and a relative humidity in the region of 50% delivering a free from water vapour plume.

(ii) cooled saturated gasses passing through a variable throat venturi scrubber, which removes a part of the suspended particulate matter before the saturated gasses enter vertical scrubbing towers, where initial cleaning is carried out via a system of sprays and sieve plates using water, and a packed section bed using caustic soda solution. The second scrubber comprises a three-stage spray tower, designed for the removal of bromine and oxides of sulphur. The gas, at a temperature of 55°C at this stage, requires re-heating to approximately 90°C and the addition of an injection of lime, prior to passing through a two compartment fabric filter, which finally removes any remaining suspended particulate matter. The cleaned exhaust gasses are then re-heated to 150°C to minimise visible steam plume formation on release to atmosphere.

4.2 Effluent Treatment

The aqueous effluents from the gas cleaning plants undergo acid neutralisation prior to the addition of controlled amounts of flocculant, complexing agents and antifoam. The slurry is then pumped to a settling tank, where supernatant liquor can be further filtered, preceding analysis prior to discharge to sewer.

4.3 Solids

The plants operate in slagging mode as recommended in S2 5.01for the purposes of eliminating leachable organics and heavy metals. This production of a vitreous glassy slag of very similar composition to furnace slag is the result of shock freezing in water. The slag demonstrates extremely low leachability potential in respect of both metals and organics due to its vitreous nature, and is considered inert for the purposes of Landfill Tax on disposal to landfill.

5. Conclusion

Combined mean plant capacity approximates to 120,000 tonnes per annum. Capacity values vary according to the elemental component characteristic of the waste. Total and continuous control of the incineration process, waste input and process residues is of fundamental importance.

The acceptance of the high temperature waste incineration sector by the public, the authorities and the waste producers, can be related directly to the level of transparency and traceability of the individual steps of the process, from waste production, acceptance, transport and storage, to incineration and residue disposal.

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Achieving an Integrated Management System Using IDEFO

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Key words : Integrated Management Systems, IDEFO, Quality, Environment, Health and Safety

Summary :

In recent years it has become increasingly apparent that the integration of the growing number of management system standards is of major interest to the process industry at large. The achievement of a total business management system, which efficiently and effectively encompasses the needs of quality, environment and health and safety, and by association the wider interests and concerns of the community and other stakeholder groups can be viewed by individual organisations, as a strategic plan for survival. The development of an integrated management system (IMS), is an organisationally specific under-taking, which will vary according to the differing size and focus of individual companies. The success of the integration depends on a complete understanding of the organisational business process and the management system targets. The key to successful integration is to form permanent connections between processes. Several process mapping methodologies exist, however the application of IDEFO provides a formal method of describing processes or systems, using several techniques to avoid complex diagrams, producing a complete and correct description of the process. This paper considers how

an organisation can achieve a fully integrated management system using IDEFO as a consistent and scalable process description language.

Introduction

An IMS is a total business management system, which manages the business process, the manufacturing process, the management system standards and the support functions, or organisationally selected functions within the business process. It is able to consider all activities that serve the business, which are determined by management standards, resulting in a unified approach to organisational management. Integration requires a comprehensive and clear description of the process where the overall understanding is not lost in the detail of development. IDEFO provides a methodology, which allows a decomposition strategy to be undertaken that directly links resource management to the existing management system targets of quality (the customer), environmental management (stakeholders and regulators) and health & safety (primarily employees).

Integrated Management System Development

Management systems have developed in recent years to form a fundamental aspect of an organisations operational activity. The strategic implication of third party registration has in many cases, become integral to the survival of the organisation. Operational requirements for additional management system accreditations have developed an ever-increasing responsibility for visible conformance to system requirements while still requiring the organisation to retain focus on the core business activity. Typical registrations for Quality Management Systems (QMS) include BS EN ISO 9001: 1994 [1] (with impending revision focussed toward an increasingly systems / process approach to QMS), and the additional elements which are required to achieve the automotive manufacturing standard QS 9000. Environmental Management Standards (EMS) can include both BS EN ISO 14000: 1996 [2] and the Eco-Management and Audit Scheme (Council Regulation No. 1836 / 93 EEC, the EMAS Regulation). While Health and Safety can be identified through BS 8800: 1996.[3]

The impetus toward the development of integrated management systems has increased due to pressures for rationalisation, and the increased emphasis on 'lean and clean technology'. The benefits of having common procedures with less documentation and overlap, producing a reduced system auditing requirement, engendering an improved focus toward objectives. Additionally, by unifying the thinking concerned, an IMS brings increased clarity of purpose to the organisation as a whole, increasing participants' ownership of common problems, and breaking down cultural barriers [4]. Unlike the generic systems for quality management, environmental management and health and safety, each integrated model is individual in character and requires registration bodies to become increasingly conversant with the process profile of individual organisations.

IDEFO

There are numerous diagrammatic techniques capable of process description. The benefit of IDEFO is that it is precise and at the same time, comprehensible at all levels [5]. Using a basic process element descriptor, (figure 1) similar in construction to the 'simple process' detailed in BS 7850 -1: 1992.[6] IDEFO describes processes by the application of ICOM codes.

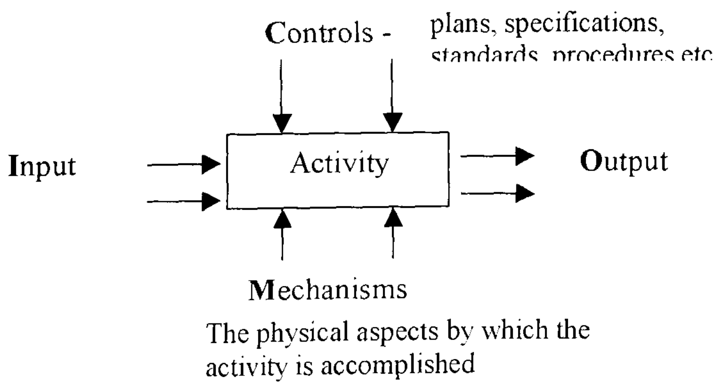

Figure 1 : The Basic IDEFO Element

The ICOM codes represent the inputs to the activity, controls on the activity, outputs from the activity, and the mechanisms by which the activity is accomplished. The basic element is subsequently decomposed into sub-element diagrams (normally of between three and six activity boxes). Hierarchical decomposition is repeated for each activity box in the resultant diagrams, until the process is fully described The decomposition is simplified by the availability of only five types of connector between the boxes, giving visible indication of the robustness of the overall system.

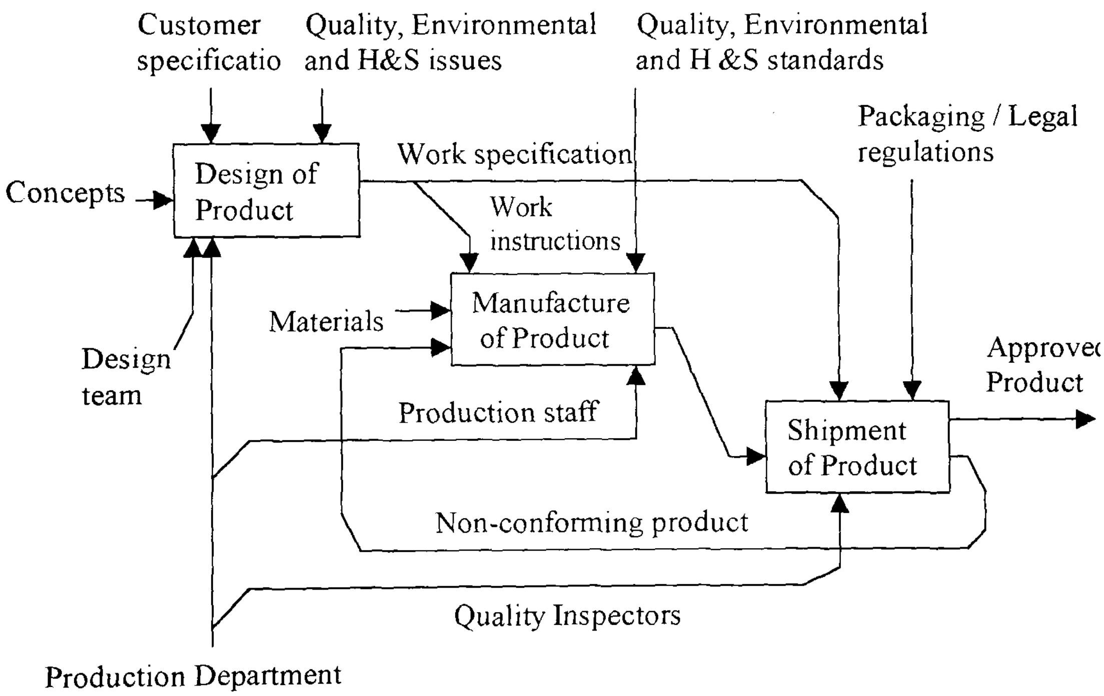

Figure 2 : Decomposition Element

As the decomposition process expands, IDEFO produces comprehensible diagrams, which initially define the overall process, but additionally determine the process structure in terms of the organisation (Figure 2). Thereby clearly, yet concisely illustrating areas that require compliance issues to be met in order to satisfy QMS, EMS and H&S standards. Decomposition of the core business process allows the organisation to chart and identify its operation. While the use of a functional decomposition strategy defines 'what' is done within the manufacturing environment, allowing the 'how' it is done documentation to be developed within the context of satisfaction of criteria for the IMS.

The sub-clause linkages between ISO 9001and ISO 14001 (Annex B ISO 14001 : 1996) and ISO 9001 and BS 8800 (Annex A, BS 8800 : 1996) illustrate the many common elements of the three standards, there-bye questioning the scope of the integration. Oldfield [7] calls for the integrated management system to include suppliers, however, it is the preference of the individual organisation, which should determine the scope of the IMS. UKAS certified accreditation of an IMS is not available, though several accreditation bodies who are themselves certified by UKAS, are currently offering limited compliance confirmation schemes, which are based on the demonstrably compliant elements of the included management systems.

Conclusion

The integration of management systems is an organisationally specific proposal, which necessitates a comprehensive and yet comprehensible understanding of all elements of the key business process. IDEFO provides a process description language that enables an organisation to identify and illustrate in a straightforward, while discernible format all aspects of organisational activity necessary for the successful integration activity.

When considering the process of integration, organisations should contemplate the scope of their proposed integration, what standards they wish to integrate, and how inclusive they wish the integration to be undertaken.

IDEFO provides a methodology for identification of organisational activities at a functional level, while allowing the freedom for documentation of how the activities are conducted.

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Balancing Act

Balance Scorecard - Translating Organisational Vision and Strategy into Operational Terms

Abstract
This paper investigates the Balanced Scorecard, an innovative management measurement system devised by Robert Kaplan and David Norton, It considers the methodology and structure of the Balanced Scorecard, and a generic development model. The paper concludes with two case studies of UK organisations using the Balanced Scorecard.

Introduction
Balanced Scorecard is a methodology for strategic control using a multidimensional framework for describing, implementing and managing strategy through all levels of an organisation. Introduced by Kaplan and Norton [1] in 1992, Balanced Scorecard adds value by providing both relevant and balanced information in a concise way [2]. This 'balance' enables organisations to clarify their vision and strategy by translating them into a tool, which effectively communicates strategic intent, and motivates and tracks performance against strategic goals.

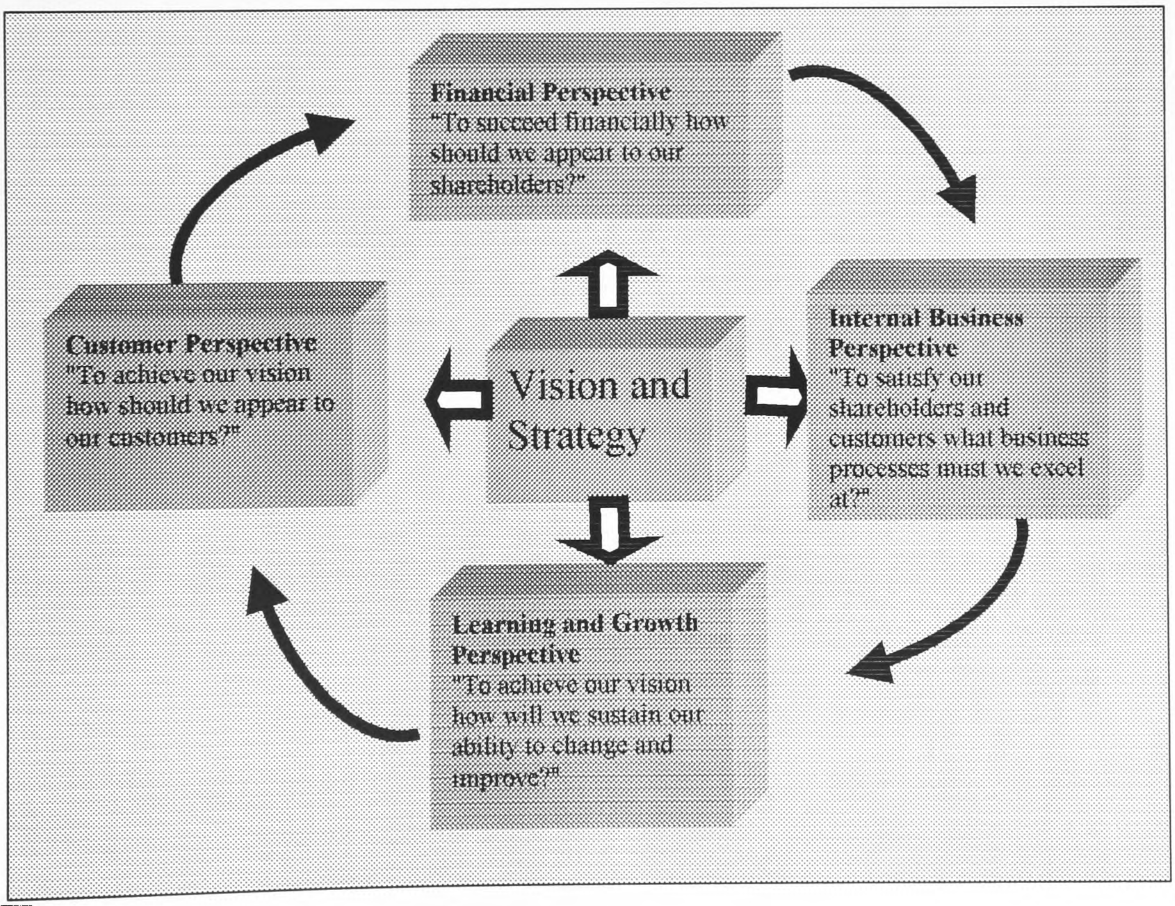

Fig.1 The Balanced Scorecard Perspectives. (Adapted from "The Balanced Scorecard", Kaplan and Norton. Harvard Business School, 1996.

Balanced Scorecard is more than an assorted collection of financial and non-financial measures. Balanced Scorecard structures an organisation's focus on the cause and effect relationships, which interact between the four 'perspectives', considered by Kaplan and Norton.

Balanced Scorecard Structure

The four ' perspectives' derived by Kaplan and Norton which are used to translate a strategy into operational terms are the Customer Perspective, The Financial Perspective, the Internal Business Process Perspective and the Learning and Growth Perspective. The interactions of which are illustrated in Fig. 1..

The Customer Perspective

Customer focus and customer satisfaction is a driving force for management in manufacturing and service organisations. The formulation of the customer perspective requires that targeted customer and business segments should be clearly identified and quantifiable core outcome measures derived. In addition it is important to identify what customers in these targeted sectors value, ensuring organisational focus on delivering a superior value proposition.

The Financial Perspective

The traditional need for financial data is recognised by the Balanced Scorecard, as timely and accurate financial data will always be a fundamental requirement. However the metric by which the long-term success of the organisation is to be evaluated is left to the selection of the management. All objectives and measures in the Balanced Scorecard should eventually be linked to the achievement of one or more of the objectives in the financial perspective. These linkages recognise the importance of the generation of financial returns to investors.

The Internal Business Process Perspective

The internal business process perspective requires the identification of the critical processes at which the organisation must excel in order to meet the objectives of the shareholders and the targeted customer segments. In addition to the traditional performance measurement system Balanced Scorecard enables metrics for internal process performance to be derived from the needs and expectations of external as well as internal agencies.

The Learning and Growth Perspective

The deciding factor on which an organisation may consider it's ability to meet ambitious or stretch targets for the Customer, Financial and Internal Business Process Perspectives is the organisation itself, and its own capability for learning and growth. There are three primary enablers for the Learning and Growth Perspective, these are employees, systems and organisational alignment. Strategies aimed at superior levels of performance will generally require investment in people, systems, and increasing organisational capability

Balanced Scorecard Methodology

The cyclical process of the Balanced Scorecard allows comparison with Dr. W. Edwards Demming's Plan Do Check Act (PDCA) cycle. (Fig. 2) The control is based on performance metrics that are continually tracked over time to look for trends, good and bad practice, and areas for improvement. The Balanced Scorecard makes managers take a wider view of the organisation, and by focussing energies, attention and measures on all four of the perspectives, organisations become driven by their mission, rather than by short-term financial performance. Crucial to achieving this is the application of measures to company strategy. Instead of being beyond measurement, the Balanced Scorecard strengthens the argument that strategy should be central to any process of measurement [3]. A good Balanced Scorecard should be capable of telling the story of the organisation's strategy.

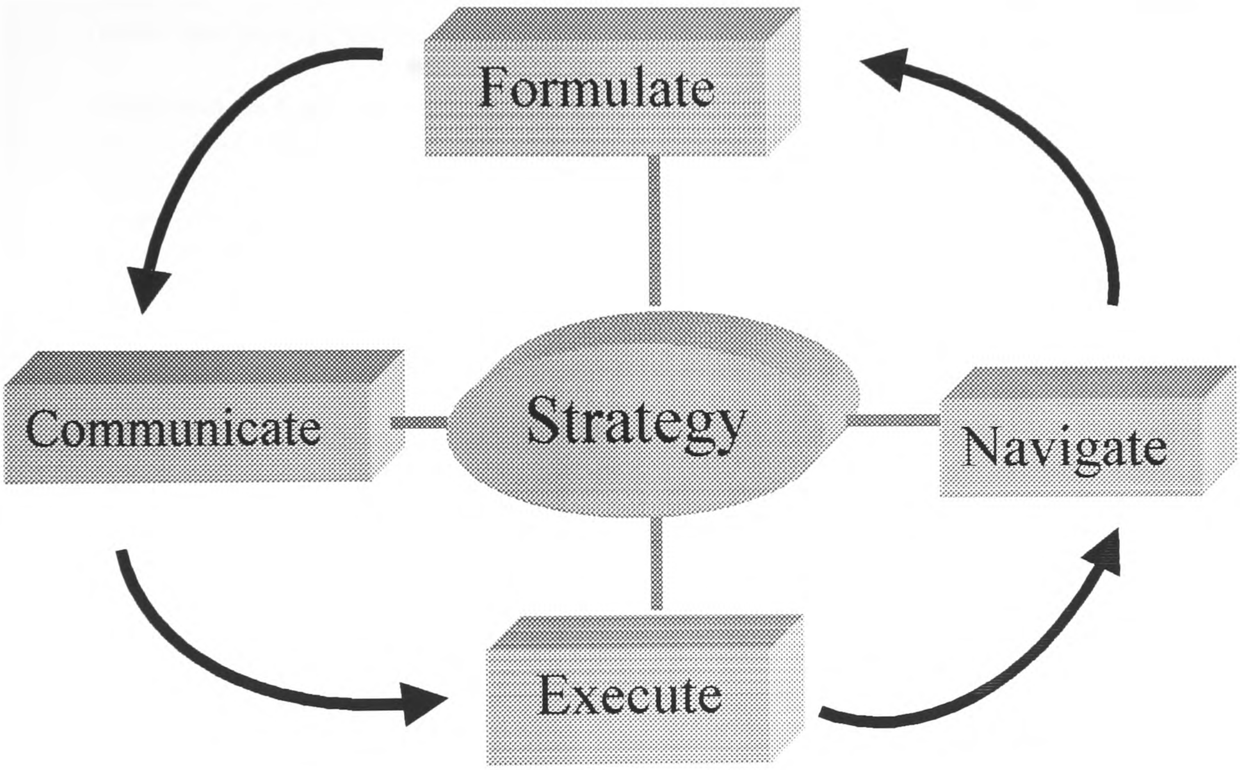

Fig. 2 The Cyclical Process

There are three key elements that contribute to the success of the Balanced Scorecard. These are

- Cause and Effect Relationships
- Performance Drivers
- Linkages to Financial Measures

Cause and Effect Relationships - Rather than being isolated or 'stand alone' each measure selected for a Balanced Scorecard should be part of a chain of cause and effect relationships the resultant network of which reflect the strategy.

Performance Drivers - A Balanced Scorecard should have a combination of "lead" and "lag" indicators. Measures common to organisations within an industry sector are known as "lag indicators". e.g. market share. "Lead indicators" are drivers of performance and tend to be unique as they reflect differing strategies, they are company (and strategy) specific.

Linkages to Financial Measures - The pursuit of single change programmes such as quality, customer satisfaction or re-engineering are frequently strategic. However they should be translated into measures that are ultimately linked to financial indicators rather than pursued indiscriminately.

Developing a Balanced Scorecard

The factors underlying an effective measurement regime and the failings of more traditional measurement systems that rely traditionally on financial indicators [4], illustrate that the construction of a Balanced Scorecard requires consideration of the two main reasons for the failure of measurement systems - poor design and difficulty of implementation [5]. Kaplan and Norton describe a typical and systematic development plan [6]. The methodology is a four-step process, the implementation strategy is intended to encourage commitment to, and the production of a Balanced Scorecard which will assist in the achievement of programme objectives. The philosophical intents and practical applications of Balanced Scorecard stems from similar precepts to the management by objectives (MBO) introduced in the late 1950's by Peter Drucker [7]. Inherent with both management systems, is the fact that partial implementation will prove to be a problematic issue, as alignments and linkages will remain unstructured and unstable.

The Process of Building A Balanced Scorecard

The four step methodology of Kaplan and Norton [6] entails a series of 'tasks'. Which are combined into the four 'milestone' steps.

Step 1 Define the Measurement Architecture

Task 1 The architect of the Balanced Scorecard should define the business unit for which the initial scorecard is to be produced. Corporate level scorecards may be a difficult first task.

Task 2 Having defined the business unit, the architect should investigate the financial objectives of the business unit, it's overriding corporate themes, and any linkages to other business units.

Step2 Build Consensus around Strategic Objectives

Task 3 Conduct First Round of Interviews

Used as an information exchange phase not only to brief managers on the Balanced Scorecard, but to gain input regarding organisational strategy. The implicit objectives include facilitating the management thought process toward translating strategy and objectives into operational terms, and learning of any concerns which may be expressed.

Task 4 Synthesis Session

Following the interviews the architect and team meet to discuss the responses gained, highlight any issues raised and produce a list of ranked objectives in the four perspectives, considering whether the list represents the business unit's strategy, and whether the objectives appear to be linked in cause and effect relationships.

Task 5 Executive Workshop: First Round

The architect meets with the top management team to begin gaining consensus on the Balanced Scorecard. By dividing the team into four groups, each responsible for a perspective, the required output is an identification of three to four strategic objectives for each perspective, to include a detailed descriptive statement and a list of potential measures for each objective.

Step 3 Select and design Measures

Task 6 Subgroup Meetings

Working with individual subgroups, the architect attempts to identify the measure (s) which best capture and communicate the intention of the objective, while identifying the sources of information for the measure. The architect will additionally attempt to identify the linkages between measures within the perspective, and between other Balanced Scorecard perspectives. The final output should be a listing and description of objectives and measures for each perspective, an illustration of how each measure can be quantified and displayed, and a graphical model of internal and external linkages of the measures.

Task 7 Executive Workshop: Second Round

This second workshop considers the organisation's vision, strategy statements, and the tentative objectives and measures for the Balanced Scorecard. A good output from this stage is a brochure, which communicates the Balanced Scorecard intentions and contents to the employees in the business unit.

Step 4 Build the Implementation Plan

Task 8 Develop the Implementation Plan

A team formalises the targets and develops an implementation plan for the Balanced Scorecard. Included in the plan should be proposals for linking to database and information systems, and communicating the Balanced Scorecard through the organisation.

Task 9 Executive Workshop: Third Round

The top management team meets to agree the vision, objectives and measures, and to validate the targets. The implementation programme for communication to employees, and the integration of the Balanced Scorecard into a management philosophy should be agreed at this time along with an information system to support the Balanced Scorecard.

Task 10 Finalise the Implementation Plan

In order to create value, a Balanced Scorecard should be integrated into the organisation's management system as soon as is practicably possible, in order to ensure that current philosophy and best available information is used.

Balanced Scorecard Case Study - West Mercia Constabulary

Balanced Scorecard was introduced to West Mercia Constabulary Organisational Development Unit in 1998. [7] Providing a policing service to 1.1 million people living in Herefordshire, Shropshire, Telford and Wrekin, and Worcestershire, the UK's fourth largest Police Area. It has 2,000 Police Officers and 580 Special Constables, supported by 1,000 civilian staff. The Constabulary has a duty to report to many stakeholders on its Joint Policing Plan with the West Mercia Police Authority. It has to satisfy the HM Inspectors of Constabulary, the Home Secretary, district and local councils, and each of the small policing units. Each stakeholder group has its own priorities, many of which are measured. West Mercia Constabulary uses a PC based Executive Information System to present a Balanced Scorecard that measures its performance and helps it to deliver its diverse services in a fully integrated manner.

Balanced Scorecard Case Study - Boots Opticians Ltd.

Boots Opticians are the Optical Division of Boots PLC. With approximately 300 practices both in-store and free standing, Boots Opticians attribute a passion for commercial success to a totally professional approach to providing eye care and eye wear. A close knit team culture pervades an organisation committed to the highest standards of customer care. Balanced Scorecard was introduced to Boots Opticians in early 2000, following a review. Senior management considered the methodology, and the applicability of using the four perspectives within such a multifaceted organisation, a pilot study was instigated in Northern Ireland and N.W.England, this took Balanced Scorecard to practice level, and involved store team members to Optical Advisor level. The administration of Balanced Scorecard at practice level uses a unique "traffic light" system to identify and prioritise key objectives and measures (Red - "stop, key activity requirement" through to Green- "proceed, satisfactory").

In April 2000, a localised study was instigated in Wales and South West, where four Group Store Managers were asked to consider one perspective each. This study determined measures and objectives, which were in line with the Boots Operating Plan, and as the result of which, management at practice level became involved. The outcome of these exercises has been a strategically focussed Balanced Scorecard from operational level to policy level within the organisational structure of Boots Opticians. This has resulted in an activity based management approach with clearly defined cause and effect linkages. Although initially having to adapt existing management practices and policies to be used within the Balanced Scorecard, it had the effect of introducing the discipline of looking at the operational plan in application terms. The result of the Balanced Scorecard has been the alignment of operations to the vision, allowing a clearer conception of the company vision.

Conclusion

Balanced Scorecard may be considered as a common sense approach to ensuring that organisational focus is maintained on the organisation's vision and strategy. Kaplan

and Norton have shown that the cause and effect relationships between objectives and measures form the strategic alliances of the four perspectives.
As organisations become increasingly aware of the advantages of using the Balanced Scorecard methodology, the levels of Balanced Scorecards will become devolved further down the organisational structure. The consequence of this may be individual Balanced Scorecards, and the possibility of result orientated salaries considered as a 'balanced paycheque'.

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Beyond Environmental Management Systems

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Abstract
This paper evaluates current environmental management systems as indicators of the environmental performance of an organisation. It considers in particular the development of current environmental management systems BS EN ISO 14001:1996 and The Eco-Management and Audit Scheme (EMAS) 761/2001 EEC. It appraises environmental performance evaluation guidelines, and introduces quality awards as a conceptual framework for classification of environmental performance. The paper concludes with an indication of further work currently being undertaken.

Introduction

A quality management system (QMS) does not in itself decide the technical or commercial specification of a product, but establishes disciplines that assist in the consistent attainment of quality requirements. An environmental management system (EMS) requires in the main that an organisation identifies and registers its environmental effects, while promoting continual environmental improvement, but does not need to comment on overall environmental performance.

The subjective assessment of environmental effects that is required by BS EN ISO 14001: 1996 does not focus attention on the overall environmental performance of the organisation. It simply advocates that it should have viewed each particular function of the business process and apply a self-formulated quantitative/qualitative analysis to the function in question. This requirement for 'self formulation' provides no incentive to add a level of independently verifiable transparency to the analysis process (lack of transparency provides no incentive to the manufacturer to consider anything other than end-of-pipe solutions). As has been shown by Rechem International Ltd. over the past decade [Jones, 1995], sector acceptance by the public, the regulatory authorities and other stakeholders can be directly related to the levels of transparency, scientific uncertainty and traceability of the individual steps of the process. As the range of synthetic pathways and end products increases within an organisation, and the use of novel intermediates becomes more prevalent, overall environmental performance is of critical importance [James, 1994].

Proponents of the link between environmental and financial performance have argued that pollution reduction provides future cost savings by increasing efficiency, reducing compliance costs, and minimising future liabilities [Reinhardt 1999]. Opportunities for profitable pollution reduction exist because managers often lack the skills and experience to understand the full cost of pollution [Jaffe *et al.*, 1995]. Hart [1997] proposed that excess returns (i.e. profits above industry average) result from differences in the underlying environmental capabilities of firms. Managers may possess unique resources or capabilities that allow them to employ profitable environmental strategies that are difficult to imitate. The study of empirical "pays to be green" literature [King and Lennox, 2000] has supported the positive relationship between pollution reduction and financial gain by relying on correlative studies of environmental and financial performance.

Event studies are a means of demonstrating that 'greening' can cause changes in stock/share price following an event with environmental consequences. By isolating an environmental event within a narrow time frame, event studies establish causes for important differences between firms that cannot otherwise be reconciled. The limitation with event studies is that they may study the effect of events of an organisation that are only partially environmental in nature, and do not facilitate benchmark comparison. In some cases research has sought to avoid this problem by using published results such as the annual release of toxic emission data through the US EPA's Toxic Release Inventory (TRI) programme as the "event" [Hamilton, 1995; Konar and Cohen, 1997; Khanna *et al.* 1998]. Polluting firms were found to have lost market value in a one-day window following the release of TRI information. Given the complexity of analysing TRI data, it seems possible that same-day stock price movements may reflect contemporaneously reported pollution rankings. However, it remains to be established whether or not there is some critical threshold of perceived environmental "damage" before a stock market response is triggered.

Current Environmental Management System Development

In early 1980's the United Nations Environment Programme (UNEP) saw environmental management as the control of all human activities that could potentially have significant impact on the environment (Toolba, 1982). The two current published environmental management system standards are the BS EN ISO 14000: 1996 family of standards, and the Eco-Management and Audit Scheme (EMAS), Council Regulation 761/2001 EC. Both of these are voluntary standards to which an organisation may choose to become accredited, both being validated by means of third party confirmation audit. There is a marked difference in the reporting philosophy of these two standards, which results in organisations having to internally identify their own organisational reasons for wishing to achieve either standard [Harmer, 1997; Barker, 2000].

Environmental management can be described as a methodology by which organisations acting in a structured manner assess their operations to ensure that they are functioning in an environmentally legitimate way [Whitelaw, 1997]. They define the impacts of their activities on the natural environment, subsequently proposing actions (within defined timescales) to minimise or reduce those impacts that they consider (under criteria defined by themselves) as harmful. An environmental management system is a management system that aims to encourage an organisation to control its environmental impacts and reduce such impacts continuously. It is unfortunate that the opportunity afforded to the technical standards committees responsible for the development of the two recognised environmental management systems operating within the European Union (EU) to introduce management principles and methodologies for positive pollution management was not taken. Overall environmental performance is not commented upon within either standard.

BS EN ISO 14000: 1996

In August 1991 the International Standards Organisation (ISO) established a Strategic Advisory Group on the Environment (SAGE) to assess the need for international environmental management standards and to recommend an overall strategic plan for such standards. The SAGE remit required the investigation of the promotion of a common approach to environmental management, of enhancement of an organisation's ability to attain and measure environmental performance, and of ways to facilitate trade and remove trade barriers. In 1992, based on SAGE findings, ISO formed Technical Committee TC-207 which formulated the standard BS EN ISO 14001. BS EN ISO 14001: 1996 superseded BS 7750: Environmental Management System 1992 in September 1996, although agreement was reached to allow certification against the draft standard DIS / ISO 14001 from December 1995. The speed of development to this stage was remarkable compared to that for the development of quality assurance standards.

It may be judged that it was the speed of development of BS EN ISO 14000: 1996 that denied the evolution of an environmental management system that was able to set out appropriate environmental performance guidelines. No maximum levels of volatile organic compounds (VOCs) emitted to atmosphere, no maximum volumes of effluent, and no maximum tonnage of waste sent to landfill are quoted. The individuals and committees responsible for the drafting of the Standard, having had prior experience of writing BS 7750: 1992 (ISO 14000's predecessor), recognised that every organisation is unique, every business is different; therefore to set or prescribe absolute levels would be an impossible undertaking. It avoids the possibility for comment on the existing environmental situation of the organisation by an emphasis on the recognition and registering of environmental aspects. Accreditation to the standard confirms that the organisation has viewed its environmental aspects, and is demonstrably aware of any applicable environmental legislation. It is the term "accredited" which is key to understanding the philosophy of ISO 14000: 1996. It is necessary for the management system to conform to the required elements of the standard. However these elements are non-flexible, having been devised by the ISO Technical Committee TC 207 as generically acceptable factors for conformance.

The robustness of the accreditation procedure itself appears somewhat deficient, as there is no specific requirement for a benchmark environmental review of the operation under scrutiny. However, in practice, this is carried out by many organisations that intend to seek accreditation [Phillips, 2000], as it is a fundamental exercise that allows a baseline evaluation of the environmental performance of the organisation to be established.

The Eco-Management and Audit Scheme (EMAS) 761/2001 EEC

The Eco-Management and Audit Scheme (the EMAS Regulation) was originally published in its entirety in Official Journal L168 dated 10 July 1993, and was formally launched in the UK in April 1995. The regulation was amended in March 2001 to promote a coherent approach between the legislative instruments developed at Community level in the field of environmental protection. The foresight of the EU provided an opportunity for organisations to demonstrate, in a very public way, their

achievements with respect to environmental issues detailed in published EMAS brochures. It was hoped that the release of detailed information based on a publicly available, third party-validated, environmental policy statement would induce companies not just to achieve legal compliance, but also to go beyond minimum legal requirement. The uptake of EMAS as a management standard within the UK has been very poor in comparison with that of BS EN ISO 14001 [ENDS, June 2000].
There is no written requirement in BS EN ISO 14001 or EMAS for an organisation to be legally compliant, although a plethora of environmental legislation exists and is continuously being added to. Both BS EN ISO 14001 and EMAS require the formulation of a register of applicable environmental legislation to be constructed and maintained. Both standards, however, do not require continuous legality of operations to maintain registration verification. However the "Polluter Pays Principle", Best Practicable Environmental Option (BPEO), and Best Available Technique Not Entailing Excessive Cost (BATNEEC), derived from the Environmental Protection Act 1990, all lead to the supposition that the ethos of the legislation lends itself to the inclusion of an additional factor, such as the availability of a quantitative indication of pollution management.

The need for exposure of environmental effects in a way which responds to the views and concerns of society [Rothermund[a], 1997], ensuring that everyone understands both the benefits and costs of organisational activities [Rothermund[b], 1997], is a key element that is currently absent from many organisations. The measurement and reporting of unit emissions [Herkstroter, 1998] allows a balance to be drawn against many human activities that hitherto have brought huge benefits in terms of economic and social development.

BS EN ISO 14031:2000 'Environmental Management - Environmental Performance Evaluation – Guidelines'
The attempt by ISO to produce a standard on environmental performance evaluation (EPE), prepared under the secretariat of the American National Standards Institute (ANSI), was published as a standard in 2000. It was prepared by the ISO TEC 207/C4 leadership, based on the discussions and decisions of the 1997-04-20/24 meetings of the sub-committee and its working groups in Kyoto. The draft EPE guidelines, while introducing Environmental Performance Indicators (EPI's) and Environmental Condition Indicators (ECI's), only achieve an internal reporting function for management information. This lacks the structure that would allow external evaluation for visible conformance, being an internally focussed system.

The EPE Process model is an internal management process that uses a selection of indicators to provide information comparing an organisation's past and present environmental performance with its environmental performance criteria, based on the 'Plan, Do, Check, Act' or 'PDCA' Cycle of W. Edwards Demming [Kolaric, 1995]. The standard describes two general categories of indicators of EPI's and ECI's, these are enhanced by a further division of EPI's to Management Performance Indicators (MPI's) and Operational Performance Indicators (OPI's). EPI's are intended to provide information about management efforts to influence the environmental performance of the organisation's operations, while providing information about the actual performance of the organisation's operations. ECI's are intended as a form of indicator that will provide information about the condition of the environment. ECI's are intended to provide information about the local, regional, national or global condition of the environment. The condition of the environment may change from time to time or with specific events. While ECI's are not measures of impact on the environment, changes in ECI's can provide useful information on relationships between the condition of the environment and an organisation's activities, products or services.

Environmental performance evaluation (EPE) has not been prescribed by BS EN ISO 14031:2000 in terms of defined criteria, resulting in an organisationally specific selection of relevant determinants when it is applied. No methodology has been given for analysing and converting data and assessing information, and no quantitative or qualitative outcome publication format is shown for the derived data.

In most production processes, there are two outputs, the product and the waste. They must both be disposed of in the safest and most environmentally acceptable way possible. Waste is a measure of organisational inefficiency. The level of pollution reduction that maximises the difference between the benefits and costs of cutting back waste release is known as the "optimal level of pollution abatement". Many environmental managers have made this 'value judgement' by speculation [Ortorlano, 1997; Arnold, 1995]. The aggregate level of waste tends to fluctuate with economic upsurge [Beaumond *et al.*, 1994]. This is indicated by the increase in the number of waste management companies, whose methods of operation head upward in the hierarchy of waste management options.

The analysis of any product system (inventory analysis) ends, in general, in a comprehensive inventory table including possibly hundreds of different environmental interactions [Hofstetter *et al.*, 2000]. This vast amount of information on resources used, substances emitted to air, water or soil, and noise and radiation will in most studies not easily lend itself to ranking and assessment alternatives.

Use of life cycle assessment (LCA) as a decision support tool is a damage-oriented approach, where interventions are assessed according to their modelled potential damage to the environment [Hofstetter *et al.*, 2000]. The damage potential is expressed in explicitly defined safeguard subjects and quantified in respective damage indicators. In the example of rising CO_2, human health as well as ecosystem quality may be selected as environmental safeguard subjects, as they are both affected by the consequences of global warming. These consequences are modelled and quantified in two damage indicators, one indicating the damage to human health, the other to the quality of eco-systems. Such damage-orientated approaches end up with three damage indicators (compared to 10-20 impact categories) in former approaches [Goedkoop *et al.*, 1998]. In a final step these damage indicators may be aggregated to a single (eco) index. However, depending on the degree of correlation between the results of applying the damage indicators, high correlation would not change the rankings between product alternatives, and modelling and quantification of one of the damage indicators would be sufficient for the assessment of alternatives. If the correlation is low, decision-makers have to add additional information on the importance of the selected safeguard subjects. A related proposal is the dominance analysis suggested by Lundie and Huppes [1999]. Their approach uses statistical analysis based on the normalised category indicators according to CML methodology [Heijungs *et al.* 1992].

It is important to make a distinction within the environmental performance evaluation, of the classification of managerial activities [Anthony, 1965]. A framework that differentiates between the information requirements of management planning and control activities enables decisions to be made for the requirement of quantitative or qualitative information [Gorry and Morton, 1989]. Sources of environmental data are both internal and external to an organisation [Charter, 1992].

Quality Awards Frameworks

The European Foundation for Quality Management (EFQM) Business Excellence Model is the most widely applied model in Europe used to measure and implement total quality management [Westlund, 2001]. The EFQM model is based on the underlying idea that customer satisfaction, employee satisfaction, and beneficial impacts on society will ultimately imply excellent business results. Another basic principle is that the EFQM approach enables the description of cause-and–effect relationships. There are two main criteria used, the 'enabler' elements consider business management, and the 'results' criteria describe what the organisation has achieved. Environmental issues are dealt with in both criteria, but have their most significant role within one of the results categories, namely society results. This provides a conceptual platform for the evaluation of a company for actual and perceived performance, using both enabling management and actual results, which assist the evaluation of 'cause and effect' relationships.

The Malcolm Baldridge National Quality Improvement Act, signed by President Reagan in 1987, established an annual USA quality award [Kolaric, 1995]. Award applications are examined in seven major categories with a maximum total score of 1000 points, and evaluated *via* three elements or dimensions, approach, deployment and results. The Malcolm Baldridge Award uses the concept based on assessment under three dimensions on the precept of 'promoting awareness, recognising achievements and publicising strategies'. Both awards are concerned with the implementation of a company wide system, and use a self-assessment process prior to examination.

Conclusions

Currently, organisations implementing either BS EN ISO 14000:1996 or EMAS do not need to comment on overall environmental performance. The United Nations Environment Programme (UNEP) views environmental management as the control of all human activities that have significant impact on the environment. Neither standard comments on the degree of control exercised, the approach taken, or the effectiveness of that control. Both standards advocate that participating organisations should have viewed each particular function of their business process and have applied a self formulated quantitative/qualitative analysis to the function in question. It is this requirement for 'self formulation' that fails to provide positive incentives to the organisation to add a level of independently verifiable transparency to the analysis process.

The deriving of an indicator that illustrates the overall environmental efficiency of an organisation is an element that is currently not included in either BS EN ISO 14000:1996 or EMAS. Organisational environmental performance evaluation requires not only the detection of damage potential, as expressed in explicitly defined safeguard subjects and quantified in respective damage indicators, but the evaluation of a company for actual and perceived performance, using both enabling management and actual results. The concepts and methodologies expressed in both the EFQM model and the Malcolm Baldridge Award enable this view to be taken of an organisation's overall performance, and are considerations that would enhance both environmental management systems.

Aims and Objectives of Further Research

The aim of further research should be to develop and apply a model for environmental management from which quantifiable indication of overall environmental performance for an organisation may be derived. This would assist in allowing environmental performance to become a strategic factor in business planning. Direct comparisons may be made between the operational characteristics of organisations, and how those organisations impact on the environment *via* pollution, providing direct business benefits to organisations that manage their business and protect the environment. Following the development of a quantifiable pollution management (QPM) indicator, customers/consumers would be able to make a purchase decision which takes into account environmental concerns. These unique QPM indicators will assist in promoting a sustainable management strategy with preventative/minimisation approaches to pollution.

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