Isn’t it wonderfully ironic? To improve their own quality levels, IS people have to conceptualise, design, build, implement and utilize some critical information systems of their own. This, of course, is exactly what IS is trained to do on behalf of others...but they rarely have had to do it for themselves before. (Huff, 1992, p 3)

Abstract

Analysis of the software/IS literature highlights the importance of software quality to global software development industries and supports the improvement of software quality through structured and holistic quality models such as Total Quality Management (TQM). The literature also largely supports the view that a critical success factor for most of these initiatives is the availability of relevant quality-related data and information to guide and support quality management efforts. Quality performance measures, measures of software quality characteristics, quality-related data, documentation, reports and analysis tools can be said to comprise an organisation’s Quality Information System (QIS). This paper examines the features of prescribed QIS models and frameworks and investigates their applicability to a software development context. The paper also reports the findings of an on-line and postal survey of 60 mostly small to medium sized Australian software development companies regarding the attributes of their QISs, and integrates these findings with the theoretical QIS models with the view of developing a relevant QIS model for the software development environment.

Introduction

Analysis of the software and information systems literature highlights the importance of software quality to global software development industries and supports the improvement of software quality through structured and holistic quality models such as Total Quality Management (TQM) (Ashrafi, 2003; Isaac, Rajendran and Anantharaman, 2004; Wilkie, McFall and McCaffery, 2005; Work, 2002, Yang, 2001).
The literature on TQM and other quality models relevant to software, such as ISO 9000-3 and the Capability Maturity Model (CMM), also largely supports the view that a critical success factor for most of these initiatives is the availability of relevant quality-related data and information to guide and support quality management efforts (Aggarwal and Lee, 1995; Bartel and Finster, 1995; Bencher, 1994; Carroll, 1995; Chou and Chen, 1998; Harrison, Raffo, Settle and Eickelmann, 1999; Huff, 1992; Kan and Basili, 1994; Parzinger and Nath, 1998; Phan, 1998; Ravichandran, 1999; Visconti and Cook, 1998; Ward, 1994).

Quality-related information may include quality data, measures, and metrics that may be quantitative or qualitative in nature. Examples of software quality data may be customer feedback reports, market reports, employee time records and customer requirements documents. From these data focused, quality related measures or reports might be produced. Examples of software quality measures or metrics are customer satisfaction measures (e.g. number of customer complaints), errors per line of code, amount and cost of rework due to customer complaints, and the cost of quality.

It can be said that quality performance measures, quality software characteristics measures, and quality-related information, documentation, reports and analysis tools comprise an organisation’s Quality Information System (QIS). For the purposes of this paper, a QIS is defined as “an organised method of collecting, storing, analysing and reporting information on quality to assist decision makers at all levels” (Forza, 1995, p 7).

Available evidence suggests that Australian firms are lagging behind in generating the types of information that the literature suggests is vital to effective quality management and control (Viger and Anandarajan 1999, Asubonteng Rivers and Bae 1999). A study by the Australian Software Engineering Institute (1996) points to a disturbing lack of documentation and use of quality-related measures and metrics in the Australian software industry. The study, involving South Australian firms found very little use of software metrics and 60 percent used little or no development documentation, rendering themselves “...vulnerable, as their intellectual property (the
rationale and design of their software) is retained only in the memories of their staff” (Australian Software Engineering Institute, 1996, p. 7).

Given the suggested importance of information in managing and improving software quality, it would appear useful to examine the features of prescribed and actual QIS models and frameworks, and to investigate their applicability to a software development context. This paper summarises and integrates the limited literature on QIS models and frameworks and evaluates their relevance to software quality. The paper also reports the findings of an on-line and postal survey of 60 mostly small to medium sized Australian software development companies regarding the attributes of their QISs, and integrates these findings with the theoretical QIS models with the view of devising a relevant QIS model for the software development environment.

The Role and Nature of QISs in the Software Development Literature

Kan and Basili (1994) claim, “What is measured is improved. Data and measurements are the most basic prerequisites for the improvement and maturity of any scientific or engineering discipline” (p 11). Yet, possibly due to the software industry’s reluctance to identify itself as a scientific discipline, “this area is perhaps one that has many critical problems and one that needs concerted effort for improvement” (p 11).

Most software quality models adhere to a “fact-based management” approach, which involves the identification and elimination of quality problems and process wastes by analysing collected data on quality parameters and quality outcomes (Ravichandran, 1999). For example, the ISO 9000-3 guidelines clearly emphasise the importance of documentation, record keeping and the collection and analysis of quantitative product and process measures. The CMM holds that a mature organisation monitors the quality of software and customer satisfaction and uses an objective and quantitative basis for judging product quality and analysing problems, all of which rely on effective data collection, documentation, and record keeping. The Software Quality Function Deployment (SQFD) model relies heavily on the accurate documentation of
customer requirements, and TQM’s success is fundamentally based on the measurement and analysis of data encompassing all relevant quality parameters.

Parzinger and Nath (1998) conducted a study of the critical factors of successful TQM implementation in a software development context. They found 8 key factors: employee empowerment, quality measures, executive commitment, general methods training, customer needs assessment, process evaluation, specific skills training and cycle time reduction. Their paper also presents the findings of other similar studies (reproduced in Table 1), which confirm the important role of quality-related information in the successful implementation of TQM.

Table 1 - Quality Information as a Critical TQM Implementation Factor

<table>
<thead>
<tr>
<th>Study</th>
<th>QIS/Information Related Factors Found</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malcolm Baldridge Award (from Porter and Parker [1993])</td>
<td>Information and Analysis</td>
</tr>
<tr>
<td>Saraph, Benson and Schroeder (1989)</td>
<td>Quality Data and Reporting</td>
</tr>
<tr>
<td>Powell (1995)</td>
<td>Measurement and Benchmarking</td>
</tr>
<tr>
<td>Ahire, Golhar and Waller (1996)</td>
<td>Benchmarking and Internal Quality Information Usage</td>
</tr>
<tr>
<td>Fox and Frakes (1997)</td>
<td>Data Driven Basis</td>
</tr>
<tr>
<td>Parzinger and Nath (1998)</td>
<td>Quality Measures</td>
</tr>
</tbody>
</table>


Parzinger and Nath (1998) propose a number of common defect measurement metrics appropriate in a software development environment. These include errors per line of code, errors per function point and amount of rework due to customer complaints (p 254). Additionally, they refer to a number of software quality indicators. For example: number of program errors, customer approval, reusability of code, and ease of expandability (p 239).
Kan and Basili (1994) refer to “data-based decision making”, a management approach that, like fact-based management, may be used for software project and quality management. However, they warn against the collection of excessive, and arbitrarily developed metric data. They emphasise the importance of developing focused, accurate and useful measures or metrics, which are based on specific managerial models. For example, the Goal/Question/Metric (GQM) model links metrics or measures with the operational goals of the organisation. The goals of the firm are more clearly defined through their translation into a set of “quantifiable” questions. The questions then define a “specific set of metrics and data for collection and provide a framework for their interpretation” (Kan and Basili, 1994, p 12).

As demonstrated above, numerous papers in the software quality literature attest to the importance of information in software quality management, and give examples of types of data, measures, and information that may be useful. However, this literature does not contain prescriptive or descriptive information system models or frameworks, which can be applied, or which have been applied in a software development environment. In fact, there is very little even in the broader quality literature in relation to Quality Information Systems, or information systems responsive to quality management activities. Forza (1995) laments that the: “.... literature on quality management rarely considers “quality information systems” as a specific dimension of quality management frameworks.” (p 7)

The next section of the paper overviews the albeit limited literature on QIS models and frameworks and evaluates their relevance and applicability to a software development context.

**Quality Information Systems Models and Frameworks**

*The Matta, Chen and Tama TQM- Responsive Information System Model*

In the first section of their paper, Matta, Chen and Tama (1998) provide anecdotal evidence suggesting that TQM is an “information-intensive management system” (p 445) impacting on the information requirements of three major organisational

To ‘build’ quality into a product through effective Product Design and Testing (a key tenet of the TQM philosophy), Matta et al (1998) suggest that information is needed on customer requirements, the design of components procured externally, internal manufacturing process capabilities, and employee suggestions on improvement opportunities. The relevant decision makers can use this data together with historical information on previous models and information on competing products.

In Process Control and Improvement, the primary objective is defect prevention. TQM promotes process improvement through employee training, empowerment and participation. Process data (relating to volume, setups, throughput, yield etc) needs to be captured and then disseminated to the relevant decision makers (e.g. employees). The data can be fed into quality control models such as Flowcharts, Fish-Bone diagrams, Pareto charts, Histograms and Control charts to further enhance decision-making.

Under the TQM paradigm, Customer Service is not only about dealing with customer problems, but also about analysing these and identifying their cause with the aim of preventing their recurrence, if feasible. Matta et al (1998) aptly describe this as “primarily a fact finding exercise” (p 449) necessitating the documentation of the specific details underlying a reported problem, such as the product item involved, customer details, and the raw materials and/or components involved.

In the second section of their research paper, Matta et al (1998) utilise the data collected from seventeen companies that had won the coveted Malcolm Baldridge Quality Award, to model a TQM information system. The model incorporates the primary information requirements of organisations with TQM programs, as determined from the data collected in the study sourced from Baldridge applications, on-site visits and interviews, and surveys with personnel from these organisations.

Data Flow Diagrams are used to map the flow of information between the organisation and four types of external entities – customers, suppliers, employees, and
competitors and other market ‘players’. Quality-related information flows in both
directions between the organisation and these four entities. The model organises
quality-related data flows according to the three major processes of a production-
oriented firm – Planning, Making (Production) and Selling.

Figure 1 identifies the flow of quality-related information or data sourced from the
four entities, and captured by the firm’s (TQM-responsive) information system.
Conversely, Figure 2 shows the reverse flow of information generated by the
organisation’s information system, and communicated to stakeholders such as
Customers, Suppliers and Employees.

In enhancing the effectiveness (and quality) of an organisation’s Planning activities,
the model proposes that certain quality-related data flows occur between the
organisation’s information system and the various entities listed above. These
interactions result in the periodic development of organisational plans (including
Quality Improvement Plans), which are used by the organisation to establish and
ultimately achieve its objectives. Data is sourced from inside (employees) and
outside (customers, suppliers and market players) the organisation from various data
stores, and in various formats (e.g. requirements/expectations, performance measures,
plans, feedback, benchmarks, systems capabilities). This multitude of data must be
merged and integrated. The firm must develop an information system that first,
effectively captures and integrates this data, and second, generates and communicates
the resulting reports and information to interested and authorised parties.

Similar challenges exist for the provision of information to enhance the quality of the
Production process. Again, relevant data is obtained from various entities to perform
the Production process-related steps outlined below. Examples of the types of data
relevant to each step of the Production process are in the brackets:

---

1 Although the organisation can source relevant market data, such as strategic benchmarks from market
‘players’, the model does not prescribe the reciprocal provision of quality-related information to
competitors and other market players, by the organisation. An explanation for this may be that the
organisation is seeking to protect its competitive position by withholding confidential internal
information from certain external parties, like competitors.
Figure 1 - Quality-related data flows from relevant parties to the Organisation’s Information System

Figure 2 - Quality-related information flows to relevant parties from the Organisation’s Information System

CUSTOMERS

Planning:
- Improvement plans

Production:
- Customer product and quality data
- Organisational process data

Sales:
- Problem resolution

SUPPLIERS

Planning:
- Organisational suggestions for improvement
- Organisational strategic plans
- Organisational quality expectations

Production:
- Organisational performance evaluations
- Organisational process design suggestions

Sales:
- Organisational defined requirements
- Supplier-related inquiries

EMPLOYEES

Planning:
- Organisational expectations
- Employee-related goals

Production:
- Employee evaluations

Sales:
- Inquiries
- Employee-related satisfaction indicators

1. Acquire customer requirements (customer requirements, relative [product] satisfaction indicators);
2. Translate customer requirements into product requirements (customer requirements, product and process benchmarks, production plans, customer performance evaluations);
3. Design product (product requirements, product and process data, operational evaluations, supplier product and quality data);
4. Design production processes (product design requirements, employee process evaluations, supplier process design suggestions); and
5. Manufacture product (process design, product design, historical production data).

The information output of this process includes product and process quality data, and employee and supplier performance evaluations (see Figure 2).

Finally, the Selling process requires data and information focused on customer satisfaction, customers’ needs and requirements, and overall organisational quality performance evaluations. Market-sourced logistics benchmarks may also prove useful in improving the quality of Sales activities. One important information output of this process is employee-related satisfaction indicators (i.e. customer satisfaction with individual employees).

Matta et al’s (1998) model also prescribes an information exchange between the three organisational processes. Information generated during the Planning process, such as production plans and marketing and sales plans, is communicated to Production and Sales respectively. From Production, information on internal/external (productive) capacity is offered to support the Planning process, as well as information facilitating operational and technical support to the Sales function. Finally, from Sales, service requirements and customer satisfaction reports are made available to Planning, and customer requirements and relative (product) performance satisfaction indicators are communicated to Production.
Two significant observations can be made about these proposed, TQM-responsive information frameworks. First, information often needs to be communicated horizontally between functional departments – for example, to facilitate work team and employee empowerment efforts. Second, selected information must be sourced from and be accessible to external parties such as customers, suppliers and competitors. For example, the firm must have access to customer expectations and feedback data, competitors’ benchmarking data, and suppliers’ design and reliability data.

The Naveh and Halevy Quality-Oriented Information System Framework

Naveh and Halevy (2000) propose a framework for a quality-oriented information system, developed by borrowing relevant concepts from the industrial engineering, quality management, information systems, organisational psychology and industrial statistics disciplines. It is a three-level hierarchical framework encompassing the areas: (1) Process Control, (2) Process Evaluation, and (3) Organisational Assessment. Figure 3 provides a diagrammatic description of this framework.

As with the information model proposed by Matta et al. (1998), Process Control information relates to non-financial quality indices describing actual process results (physical and managerial) and facilitating process analysis (causes and goals). This framework also specifically proposes financial quality indices arranged and analysed within a Cost of Quality (COQ) framework. The COQ is divided into two types of costs – those involved in maintaining the firm’s quality system (infrastructure) and those relating to losses resulting from poor quality (damages)\(^2\).

The second major area requiring information is Process Evaluation or Process Audit. As shown in Figure 3, this includes Internal, External and Supplier audits. This type of analysis goes deeper than Process Control in that it assesses the actual process design and process execution with the aim of identifying opportunities for process improvement.

\(^2\) This COQ classification schema is similar to the Control-Failure and Conformance-Non Conformance subclassifications used by many writers in the quality literature (for example, Morse, Roth and Poston, 1987).
This analysis is independent and often qualitative. In assessing processes, at the first level (process control) processes are evaluated in terms of being executed according to assigned criteria and policy (i.e. process specifications). At the second (less objective) level (process audit/evaluation), processes are evaluated in terms of their success in meeting customer needs. Combining these two levels of analysis, the overall aim is to evaluate processes from the following perspective: “Are the processes – when performing as intended – actually meeting customer needs?” (Naveh and Halevy, 2000, p 94).

Figure 3 - The Naveh and Halevy Hierarchical Quality Information Framework


In this way, process evaluation is viewed not only as a compulsory tool for auditing the quality assurance system (such as with ISO 9000), but also as a “comprehensive managerial tool” (Naveh and Halevy, 2000, p 94). The types of information required include audit checklists, quality manuals and job instructions, as well as information on the audit findings generated during the audit.
The third major area for information collection and dissemination in the Naveh and Halevy framework is Organisational Assessment, where overall organisational performance is monitored and assessed. Here ‘softer’ more qualitative measures are used including business and quality strategies, quality culture, customer feedback and employee attitudes. Broader and more general criteria are used to evaluate the firm’s performance from business, technological and human resource perspectives. The information generated at the Organisational Assessment level is primarily used by top management, and is less organisation-specific than the information used in the other two areas. Additionally, the evaluations in this area are also less frequent, normally annual or biannual.

_Cuppello’s TQM Maturity-Level Measurement Model_

Cuppello (1994) further refines the prescription of quality information models by proposing a TQM measurement paradigm based on the “maturity level” of the firm’s TQM program. He contends that a given firm’s TQM program will go through four progressive stages of development, and may be abandoned at any stage.

The ‘Playing’ stage is at the beginning where a firm is yet undecided about fully committing itself to implementing a full scale TQM program, and is assessing its feasibility. The ‘Demonstrating’ stage is next, where some preliminary improvement in processes or performance through the use of TQM techniques, has been demonstrated. The ‘Committed’ phase is reached when changes in culture are experienced as a result of the TQM program, thus implying committed efforts by the firm’s employees. Finally, the ‘Actualised’ phase arrives when the firm has achieved “world class quality” status. For example, by winning a national quality award or by being otherwise publicly recognised and acknowledged as a “quality organisation” (p 81).

Figure 4 illustrates the ‘Measurement-Maturity Matrix’, which also classifies organisational measures into four discrete groups (as identified by the row descriptions). Control measures are similar to the physical, Process Control measures outlined in the
previous information models discussed. They measure the operational performance of the firm, i.e. employees, machines, products, services and processes, on a daily or even an hourly basis. Thus, these measures assist operational-level employees (workers). Screening measures assist middle management. They come in both financial and non-financial formats, and are usually generated monthly or quarterly. These measures are designed to evaluate whether the firm’s functional areas are performing consistently with organisational goals and plans. Planning measures are produced for senior management and relate to the accomplishment of long-term strategic plans and missions. These measures are usually financial or qualitative and are produced relatively more infrequently, such as yearly. The fourth type of measure in this framework is Diagnostic. This relates specifically to quality, and is designed to evaluate whether the organisation’s TQM activities are achieving their specific goals. Diagnostic measures relate to areas such as customer focus (customer satisfaction feedback), continuous improvement (number of successful improvement projects), employee empowerment (employee satisfaction, number of employee suggestions) and supplier involvement (supplier performance measures).

The matrix in Figure 4 shows the successive introduction of new types of quality-related measures into a firm’s information system as the firm’s TQM program ‘matures’. As the firm progresses through each phase, additional diagnostic and TQM-linked organisational performance measures are added to its quality information system. Where there are empty cells in the matrix, it is implied that the firm should continue to use its existing organisational performance measures, unchanged.
Figure 4 - Cuppello’s Measurement-Maturity Matrix

<table>
<thead>
<tr>
<th>Type of Measurement</th>
<th>Playing</th>
<th>Demonstrating</th>
<th>Committed</th>
<th>Actualised</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnostic</td>
<td>TQM Assessment</td>
<td>Customer Surveys</td>
<td>Supplier Assessment</td>
<td>All four</td>
</tr>
<tr>
<td>Planning (Senior Managers)</td>
<td>Strategic targets - internal, existing data</td>
<td>Strategic targets - external, new data</td>
<td>Paradigm shifts - new business, new customers</td>
<td></td>
</tr>
<tr>
<td>Screening (Middle Managers)</td>
<td>Functional targets - internal</td>
<td></td>
<td>Quality function deployment</td>
<td></td>
</tr>
<tr>
<td>Control (Workers)</td>
<td></td>
<td></td>
<td>Process capability targets for key products and processes</td>
<td></td>
</tr>
</tbody>
</table>


Keung’s Stakeholder-Driven Process Performance Measurement System Model

Keung (2000) argues that increased competitive pressures for higher quality have resulted in the proliferation of “process-centered” organisations (p 67). For such firms, the ability to assess and improve individual process performance is essential to continuing survival and success. He contends that traditional performance measurements models are outdated and too narrowly focused. He also contends that traditional performance measurement systems (PMS) are focused primarily on financial measures, disregard non-financial measures such as customer and job satisfaction, fail to link performance to processes, and fail to distinguish between control and improvement.

Keung identifies the need for an “integrated, holistic system for gauging business process performance on a regular basis” (p 67), which he calls a Process Performance Measurement System Model (PPMS).
Measurement System (PPMS). This system model borrows heavily from various other business management models including, Business Process Re-engineering, the Balanced Scorecard, the GQM model, the criteria of the Malcolm Baldridge National Quality Award, the European Foundation Quality Management (EFQM) model, the CMM, and Stakeholder Theory. Key features of the PPMS are as follows:

- It is focused on processes\(^3\), rather than the whole organisation or organisational units;
- It evaluates performance holistically by measuring qualitative as well as quantitative aspects, and utilises a variety of data collection ‘instruments’:
  - Observational (e.g. video recording)
  - Database (systems records)
  - Subjective (e.g. questionnaires/interviews);
- It is ‘stakeholder-driven’, such that the criteria/factors/measures of process performance differ, depending on each stakeholder’s (i.e. investors’, employees’, customers’, suppliers’ and society’s) perspective.

The model prescribes that process performance can be evaluated in terms of five different aspects, concerning one or more of the above stakeholder groups:

1. **Financial aspects** (investors) – by measuring, for example, return on investment and profits.
2. **Employee aspects** (employees) – e.g. job satisfaction, opportunities for growth, safety, and quality of working life.
3. **Customer aspects** (customers and suppliers) – e.g. customer expectations and customer satisfaction.
4. **Societal aspects** (society) – the impact a process has on society and how the impact is perceived.
5. **Innovation aspects** (all stakeholder groups) – degree of continuous improvement of processes.

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\(^3\) Processes are defined as a set of interrelated resources and activities which transform inputs into outputs (p 70).
Keung (2000) also suggests that it is unlikely that a universal set of performance indicators can be applied successfully to all business processes. Indicators must be process-specific and derived from strategic, enterprise-wide and process goals.

Other Studies Prescribing the Key Elements of a QIS

The two studies reviewed in this section make specific recommendations about the key elements of a QIS, but do not present these in the form of a formal model or framework.

Ittner and Larcker (1995) examine the implications of TQM for management accounting information and reward systems, and provide the following three recommendations:

(1) a greater distribution of information across the organisational hierarchy;
(2) the collection of new types of quality-related information; and
(3) the development and the use of reward systems which place more weight on quality and team-based performance.

There should be a “continuous flow” of relevant information to the firm’s operational-level employees – process information used to identify the source of defects and to track the results of improvement efforts. The horizontal transfer of this information facilitates more effective cross-functional problem solving. Employees should also have access to information on the strategic goals and plans of the firm and the quality strategies, plans and goals, which will contribute to the achievement of the firm’s overall goals.

The “new type” of information proposed by Ittner and Larcker is benchmarking data relating to competitors’ and industry leaders’ products, services and practices, giving the firm relevant and achievable performance targets.

The third significant change required is to the firm’s reward system. Rewards should be linked to quality-related performance, increasingly measured by non-financial performance measures such as customer satisfaction and based on team performance that
should “mitigate the ‘disincentives’ for cooperation caused by rewarding individual performance” (Ittner and Larcker, 1995, p 4).

Forza (1995) identifies the key “information flows for quality” (p 9), and also contends that a QIS should not only be concerned with information flows, but also the information technologies “which support managers and workers in their activities in order to improve quality performance” (p 8). He prescribes the following key elements for an effective QIS:

1. **Performance feedback at all levels of the organisation** – quality performance, waste reduction, defect rates, frequency of machine breakdowns, process data, in-house product performance testing.
2. **Visible information on machines** – information concerning maintenance, operation, set-up.
3. **Cause detection information tools** – Cause and Effect diagrams, Flow charts and Pareto charts.
4. **Quality control information tools** – run (trend) charts, histograms, control charts, scatter diagrams.
5. **Documentation of shop floor procedures** – written shop floor, operating and manufacturing procedures.
6. **Information exchange on quality with customers** – feedback on quality and delivery performance, customer requirements surveys, customer feedback on product design process.
7. **Information from suppliers on quality control** – data on quality of suppliers’ parts and components under purchasing consideration, data from quality tests conducted by a supplier or an independent laboratory, statistical evidence of process control from suppliers of critical parts, documents certifying the results of specified tests and inspections on materials.
8. **Information technologies for quality** – computerisation of seven tools of quality (e.g. Flow charts, Pareto charts, run (trend) charts etc.).
# Table 2 - Key Features of QIS Models, Frameworks and Other QIS Studies in the Quality Literature

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>KEY FEATURES OF STUDY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Primary basis of information classification</td>
<td>Value Chain, Function-Oriented</td>
<td>Hierarchical, Process-Oriented</td>
<td>Stakeholder-Perspective, Process Oriented</td>
<td>Hierarchical, Managerial Level</td>
<td>Not Available</td>
<td>Not Available</td>
</tr>
<tr>
<td>2. Type of quality improvement program designed to support</td>
<td>TQM</td>
<td>Quality Management Program (Generic)</td>
<td>Business Process Improvement Program</td>
<td>TQM</td>
<td>TQM</td>
<td>“Modern” Quality Management Practices</td>
</tr>
<tr>
<td>3. Quality data/information stored in separate QIS, or part of existing information system(s)</td>
<td>Part of Enterprise-Wide IS</td>
<td>Part of Existing Information Systems</td>
<td>Modular, separate IS, loosely coupled with other ISs</td>
<td>Part of Existing Information Systems</td>
<td>Not Specified</td>
<td>Not Specified</td>
</tr>
<tr>
<td>4. Information exchange with entities inside the organisation</td>
<td>Employees (includes Managers)</td>
<td>Workers, Managers</td>
<td>Employees</td>
<td>Employees (includes Managers)</td>
<td>Employees</td>
<td>Employees (includes Managers)</td>
</tr>
<tr>
<td>5. Information exchange with entities outside the organisation</td>
<td>Customers, Suppliers, Market Players</td>
<td>Customers, Suppliers</td>
<td>Investors, Customers, Suppliers, Society</td>
<td>Customers, Suppliers, Market (Competitors)</td>
<td>Competitors and Industry Leaders</td>
<td>Customers, Suppliers</td>
</tr>
<tr>
<td>6. Use of (non-traditional) qualitative and non-financial measures</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>7. Use of information to promote process control and improvement</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Process control only</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>8. Emphasis on documentation of procedures as key element of QIS</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>9. Reference to Cost of Quality as key element of QIS</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>10. Specified applicability of model/framework/recommendations to other (non-manufacturing) environments</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Developing a Theoretical QIS Model for a Software Development Context

Although the information system models and frameworks outlined above are discernibly different from one another, they share some common features that can be extracted for analysis. Furthermore, although developed to suit primarily a mass-production manufacturing environment, these models and frameworks can be adapted to suit a software development environment. The key features of the models and frameworks reviewed in the previous section of the chapter are summarised in Table 2, and discussed in this section.

The QIS models and frameworks reviewed utilise hierarchical, process-oriented, function-oriented, and stakeholder-oriented schemas to classify the data and information captured and generated by the information system. All of these schemas are useful and relevant to the quality improvement paradigm. The hierarchical structure of Naveh and Halevy’s and Cuppello’s information models ensure that information is produced to satisfy the needs of every level of worker and manager in the organisation, including operational-level employees. This is consistent with the TQM concept of employee participation in quality-related decision-making. The process-oriented structures of the Naveh and Halevy and Keung models highlight the importance of process control and improvement in improving the quality of products and services. This structure is also consistent with the TQM concept of ‘building in’ quality into every process and making quality everyone’s business. The value-chain (function) orientation of the Matta, Chen and Tama model also reflects the importance of this concept – that quality is built into every stage of production, from product design down to post-delivery customer service. Keung’s stakeholder-perspective performance measurement structure highlights the increased significance of employee, customer and supplier roles in improving the quality of processes and products. In fact, when assessing these studies in terms of which entities provide quality-related data or information to the QIS, and to whom information is provided, Employees, Customers and Suppliers are almost unanimously selected (see Table 2).

This is consistent with contemporary quality improvement practices such as customer focus, supplier partnering and employee empowerment and participation. Most of the

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4 Although Ittner and Larcker do not specifically identify customers as a source and/or user of QIS information, it is very unlikely that the intention was to exclude them.
studies also extended information system boundaries to include quality-related data sourced from competitors, industry leaders and the broader society. This reflects increased competitive pressures faced by organisations, and the need for organisations to be aware of the societal impacts of their actions.

Consistent with the observations made thus far about the QIS studies, not surprisingly, all of the models and frameworks prescribed are designed to support either a TQM program specifically, or contemporary quality improvement programs which are not called TQM, but have many key TQM characteristics. All studies promote the use of non-traditional, qualitative and non-financial quality data and information, and all of them espouse the importance of using information for process control and improvement.

Although the Quality literature suggests that the documentation of procedures is vital to quality control, only two of the six studies made specific reference to documentation as a key element of the QIS. However, other types of documentation, such as that of customer requirements and product specifications were implied in most models. There was also very little reference to Cost of Quality measures, with only Naveh and Halevy incorporating this into their framework.

Another important issue relating to the design of a QIS, is whether it should be built to be a ‘stand-alone’ system serving only the needs of quality information customers, or whether quality data and information should be integrated with the organisation’s other existing information system(s). Contemporary thinking is that organisations should strive to build one centralised, integrated, enterprise-wide information system, which stores data centrally and is accessible by all authorised users with various information needs. Most of the studies agreed with the idea that the QIS should not stand alone, but rather should form a part of the organisation’s existing system(s), enhancing accessibility and of course data integrity.

5 With the exception of the Cuppello model which does not specifically refer to Process Improvement, but again, it may be argued that it is implied, while not expressly stated.
<table>
<thead>
<tr>
<th>Attribute</th>
<th>Quality Principle Underlying Feature</th>
<th>Examples of Software-Related Data or Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. QIS sources from and provides relevant information to employees at every level – operational to Board.</td>
<td>Employee empowerment and participation.</td>
<td>Errors per line of code, employee suggestions, performance reports, quality improvement plans.</td>
</tr>
<tr>
<td>2. QIS sources from and provides relevant information to employees and processes at every step in the value-chain – product design to customer service.</td>
<td>Quality is everyone’s business.</td>
<td>User requirements, technical specifications, analysis of customer complaints, defect analyses.</td>
</tr>
<tr>
<td>3. QIS generates information to assist with product design and testing.</td>
<td>Quality is ‘built’ into the product through effective product design and testing.</td>
<td>Customer requirements, internal process capabilities, test plans, competing products.</td>
</tr>
<tr>
<td>4. Process related data and reports generated by the QIS to assist with on-going process analysis and improvement.</td>
<td>Process control and innovation central to quality improvement.</td>
<td>Documented processes, process flowcharts, process data, process evaluations, audit checklists.</td>
</tr>
<tr>
<td>5. QIS generates information to support and improve customer service.</td>
<td>Quality requires a strong customer focus.</td>
<td>Customer quality expectations, customer requirements, customer complaints, customer inquiries.</td>
</tr>
<tr>
<td>6. QIS sources from and furnishes appropriate information to relevant external parties – customers, suppliers, competitors.</td>
<td>Customer focus, supplier partnering, benchmarking.</td>
<td>Supplier product and quality data, competitor/industry benchmarks.</td>
</tr>
<tr>
<td>7. QIS captures and generates non-financial and qualitative in addition to financial and quantitative data and information.</td>
<td>This follows from the principles outlined above.</td>
<td>Customer satisfaction, supplier ratings, user requirements, the cost of quality.</td>
</tr>
<tr>
<td>8. QIS part of a centralised, integrated, enterprise-wide information system, which stores data centrally and utilises information technologies.</td>
<td>Enhanced accessibility, efficiency and data integrity.</td>
<td>NA</td>
</tr>
<tr>
<td>9. QIS evolves with quality improvement techniques and practices.</td>
<td>Quality improvement is guided by relevant information.</td>
<td>NA</td>
</tr>
</tbody>
</table>
The analysis of the QIS studies presented in Table 2, and the subsequent discussion has helped to narrow down and identify the key attributes and aspects of the QIS models/frameworks reviewed. These broad observations can form the foundations of a relevant QIS model for the software development organisation. Incorporating software industry-specific factors, such as the use of software metrics, would of course, further refine such a model. Table 3 summarises the key attributes derived and applies these to a software environment. The second column of the table provides a justification for inclusion of each attribute by relating the attribute to the quality principle it supports. The last column lists relevant examples of data or reports, which may be generated in a software environment where that attribute is incorporated in a QIS.

Refining the Theoretical Model – Incorporating Recent Empirical Evidence from the Australian Software Environment

In order to develop a QIS model relevant to the software environment, it is useful to analyse what software development firms currently practice, and what their views are in relation to QISs. A survey of 310 software development companies operating in Australia, completed in May 2005, asked respondents essentially to describe their QISs. The survey addressed the types of quality performance measures, measures of software characteristics, quality-related documentation, process quality control tools, quality-related reports and other quality information generated by these firms.

The survey was administered primarily through on-line access or, when the respondents preferred, via postal mail. Potential respondents were emailed a covering letter introducing the study and the researcher. The email also contained a linked http address\(^6\) enabling access to the questionnaire.

Sixty of the 310 companies surveyed provided usable responses via the on-line and postal questionnaires administered. This constitutes approximately 20 percent of the survey sample.

The average respondent company was small to medium sized (90 percent), employed between 20 and 200 full time staff, earned between 1 and 10 million dollars in annual sales revenue. It was independently owned and not a subsidiary (77 percent) and was primarily Australian owned (77 percent). It serviced the Communications, Finance and Insurance industries (65 percent) and developed retail software packages to suit a client/server environment (70 percent) and intranet/internet/web applications (43 percent). Only one in three exported their software overseas, primarily to New Zealand and North America (67 percent), earning an average of 34 percent of their revenues from this activity.

Few respondent companies report having a formal Quality Information System (26 percent), however most respondents generate some type of quality-related data. Those that have QISs are polarised in their opinions on QIS’s importance to quality management, and those without QISs are generally neutral, or perhaps undecided, on their importance. For those with actual experience with QISs, opinions are either resoundingly positive or negative, almost an equal number rating them ‘very important’ as ‘not at all important’.

The survey asked respondents to identify which measures, external and internal information, documentation, charts and diagrams and reports they use to assist them in their quality management and decision making. A pattern emerges as the responses to these questions are analysed. First, the major information focus of respondent companies appears to be in the areas of:

- the defectiveness (52 percent) and reliability (33 percent) of software,
- customer complaints (43 percent) and customer satisfaction (30 percent), and
- product quality (33 percent) and other performance analyses.

Significantly, those who do not currently generate these measures also consider them useful information for quality management. Software companies use cost information least (12 percent) in quality-related decisions, however, costs are identified as an

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7 This is consistent with the findings of a report published by the Australian Computer Society (Houghton, 2003), which stated that the Australian ICT industry is dominated by small business.

8 The percentages shown reflect the proportion of respondents generating these measures on a periodic (as opposed to an ad-hoc) basis.
emerging area of interest by some respondents. By and large, non-financial information is of much greater interest to respondents than financial information for the purposes of quality management and improvement.

Sourcing of quality-related information from customer feedback (87 percent) and employee feedback and suggestions (76 percent) is quite prevalent, and this is consistent with the findings outlined earlier regarding the perceived importance of customer and defect related information. Operational employees at the ‘coalface’ of software development are well equipped to provide feedback and suggestions regarding bugs and defects in software in process. Operational employees are, however, greater providers than consumers of quality-related information, with most of the quality-related reports targeting senior and middle level management.

Documentation of processes and software-related specifications are widely recognised as good management practice in modern-day software development firms. The vast majority of respondents (87 percent) claim to document at least some of their processes, with over 60 percent documenting most of their processes. About one in three respondents also produce software process flowcharts, which illustrate the flow of software development processes, and assist with process analysis and improvement.

Quite a high proportion of respondents document their product-related specifications, particularly functional (86 percent) and user requirements (75 percent) specifications. This is in contrast to the findings of the study by Australian Software Engineering Institute (1996) reported earlier in the paper.

Figure 5 models, through a context diagram, the common and important features and characteristics of the quality information systems of software development companies operating in Australia, as revealed by this survey. The QIS sources relevant, non-financial data primarily from employees and the processes they undertake, and from customers, and generates reports and documentation in the key focus areas discussed earlier.
Figure 5 - Context Diagram of Quality Information Systems in Software Development Companies in Australia

- **Employees / Processes**
  - Feedback, suggestions, functional and technical specifications, process documentation, check sheets.
  - (Very limited, e.g., process flowcharts, defect analyses)

- **Customers**
  - Feedback - functionality and reliability, complaints, satisfaction, user requirements.
  - (Very limited, e.g., Compliance reports)

- **Quality Information System**
  - Software problems, issues and defects; customer feedback and complaints analyses, performance analyses, quality reports, compliance reports, software process documentation and flowcharts.

- **Senior and Middle Management**

- **Reports generated by the QIS**

- **Data sourced by the QIS**

**Entities interacting with the QIS**
Most of these reports are used by middle and senior management for quality management and decision-making, and limited information such as compliance reports are given to customers and process flowcharts and defect analyses are fed back to operational employees and processes.

The model describes an information system, which in some ways satisfies the key requirements of QISs espoused in the literature, and in other ways falls short.

The next section contrasts the characteristics of the empirical QIS model developed from the findings of this survey (Figure 5), with the attributes of the theoretical models reviewed earlier (Table 3), with the aim of developing a refined QIS model suitable for a software development environment.

**Comparison of Empirical QIS model with Theoretical QIS Model**

The first key attribute of the theoretical models refers to the need for the QIS to interact with and service employees at all levels of the organisation. The empirical model shows some evidence of this occurring in software companies, with quality-related reports targeting middle and high-level managers. However, as discussed earlier it is more a one-way interaction between the QIS and operational level employees. The QIS will source data from employees, but has little to offer as information to them. There is much to be gained by a QIS that provides employees with relevant quality performance related information that can be used to motivate employees (perhaps by linking certain performance measures with reward systems), inform them, and encourage continuous improvement in their performance.

The second attribute in Table 3 relates to the requirement that the QIS interacts with and provides relevant information to all stages of the value chain. This is consistent with the principle that quality is everyone’s business, and not just the domain of the QA department. This principle is relevant to software development companies, which commonly have QA personnel to conduct various testing and de-bugging activities. Quality must be a focus of those that design the software, code it, compile and package it, deliver it to the customer and provide post-sale support. This feature again
raises the issue of the lack of quality-related information made available to operational employees in software development companies. Examples of information that would assist may include documented user requirements, technical and functional specifications, defect analyses and statistics, and customer complaints analyses.

Features three to five reflect the importance of effective product design and testing, process evaluation and improvement and customer service to quality management and improvement. There is some evidence in the empirical QIS model that there is a focus on customer service, however, there does not appear to be adequate support for product design and process improvement. Most respondents claimed to produce specifications documentation, which is important, however there was not much in the area of testing, nor was there use of information regarding competing or competitors’ products to guide the design. Information guiding process improvement was even scarcer. Even though respondent companies claimed to document many of their processes, there was little evidence of the use of information to evaluate and analyse these processes. As mentioned, software companies appear to appreciate the importance of customer focus, and attempt to garner as much information from customers as they can, through customer surveys and complaints reports.

The theoretical QIS models also promote the interaction of the QIS with other external parties, such as suppliers and competitors. There was little evidence of this from the results of the survey. It may be argued that the importance of supplier partnering in a software environment is diminished, if not eliminated, by the fact that there are less suppliers in the software development cycle than in the manufacturing of other products. That is, software production does not usually require significant quantities of raw materials or components. However, more use could be made of competitor information, such as competitor or industry benchmarks or competitor product/quality information, when making quality-related decisions. Obviously, the desired interaction of the QIS with competitors would be a one-directional one, as software companies would seek to protect their competitive position by minimising provision of information to their competitors.

There is evidence that software companies do generate and use non-financial and qualitative information to guide their quality practices, however, as discussed earlier
the types of non-financial information could be expanded to satisfy the needs of particularly operational-level employees. The survey also revealed that there might be room to develop the types of financial quality related information that can be generated, for example, an analysis of the costs of prevention versus the costs of failure.

The survey did not address the final two features shown in Table 3 - whether the QIS was integrated with the company’s other information system(s) and whether the QIS had evolved with changes in quality management practices – these characteristics will be addressed in future research (interviews) conducted with the respondent companies. These features, however, seem inherently relevant and appropriate for a software environment.

In summary, a revised and refined QIS model for the software industry based on the features espoused in the literature would:

- incorporate greater information provision to operational employees,
- provide more information to support product design and testing and process evaluation and improvement,
- source more information about competitors and their products,
- generate more quality-related financial information, such as the cost of quality,
- utilise current information technologies which integrates the QIS with the organisation’s central information system, and
- evolve to meet the information requirements of an evolving quality program.

**Summary and Conclusions**

This paper has integrated the relevant characteristics of prescribed theoretical QIS models with those of a recently devised empirical software development QIS model to derive a refined QIS model for the contemporary software development firm. The empirical model, when compared with the theoretical models, shows deficiencies particularly in the provision of quality-related information to support and promote
product and process quality improvement. Broadly speaking a relevant QIS model for the software context would interact with and service employees at all levels of the organisation (including operational), with all stages of the value chain (from product design and testing through to customer service), and with external entities such as customers and to a lesser degree, competitors and suppliers. It would support process evaluation and improvement and the use of useful financial quality frameworks such as COQ. Finally, the QIS should form part of the firm’s central information system thereby enhancing its accessibility and data integrity, and should continue to evolve to support the firm’s evolving quality management strategies.

REFERENCES


