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A conceptual model and IS framework for the design and adoption of environmental compliance management systems

For special issue on governance, risk and compliance in IS

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Abstract Environmental concerns have led to a significant increase in the number and scope of compliance imperatives governing electrical, electronics, and IT products across global regulatory environments. This is, of course, in addition to general compliance and risk issues generated by the Sarbanes-Oxley Act, data protection and information privacy legislation, ethics and integrity regulations, IT governance concerns, and so on. While the latter dimensions of enterprise-wide governance, compliance, and risk (GRC) are far from straightforward, the complexity and geographical diversity of environment-based regulatory sources cause considerable problems for organisations in the electrical, electronics and IT sectors. Although a variety of enterprise-level information systems are presently available to help manage compliance and reduce risk across all areas, a majority of firms still employ ad-hoc solutions. This paper focuses on the very-much underexplored issue of environmental compliance and risk. The first objective of this exploratory study is to delineate the problems facing GRC and Environmental Health and Safety (EH&S) functions in dealing with environmental regulations globally and to identify how these problems are being solved using Environmental Compliance Management Systems (ECMS). The second objective is to propose a process-based conceptual model and related IS framework on the design and adoption of ECMS that will inform future research and, it is hoped, the IS adoption decisions of GRC and EH&S practitioners.

Keywords Environment · Governance · Risk and compliance · IS framework · IT · Enterprise systems · Environmental compliance management systems

1 Introduction

Electrical, electronic and IT manufacturing firms are not only confronted with governance, risk and compliance issues of a general or financial nature, they also face increasing institutional and societal pressures to go 'green'. Such pressures include (a) RoHS, WEEE, EuP or REACH-type legislation from governments[1]; (b) product monitoring and/or analysis by non-government organisations such as Greenpeace; (c) environmentally aware customers; (d) 'green' downstream users of products/components; and finally, (e) financial institutions or individual shareholders looking to invest in and support 'greener', 'environmentally sustainable' companies (cf. Greenemeier 2007; Campbell 2007; McGovern and Butler 2008). Just as Sarbanes-Oxley (SOX) and Basel II make corporate disclosure requirements and financial audits more stringent (Smith and McKeen 2006), the aforementioned pressures are having electrical, electronics and IT manufacturers look to their governance, risk and compliance (GRC) functions to meet their

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[1] Restriction of Hazardous Substances Directive (RoHS), Waste Electrical and Electronic Equipment Directive (WEEE), the Registration, Evaluation and Authorisation of Chemicals (REACH) Regulation, and the Eco-Design for Energy Using Products (EuP) Directive.

regulatory and corporate social and environmental responsibilities (Brown 2006).

Industry analysts argue that firms in the electrical, electronics and IT manufacturing sectors need to implement information systems (IS) that account for rapidly changing environmental regulations on a global basis (Brown 2006; Avila 2006). This argument is founded on the belief that such systems are important for managing product compliance and associated risks, reducing the cost of compliance, and in helping organisations make the transition to 'green' eco-friendly businesses (cf. Schroder and Turnbull 2008; McGovern and Butler 2008; Bachmann and Clese 2008). A study by the Aberdeen Group in 2006 revealed, however, that nearly 80% of electrical and electronic manufacturing companies, including high-tech IT manufacturers, lacked cohesive information systems to track, audit, and manage product compliance (Brown 2006). The report indicates that most companies were relying on a variety of solutions that were not properly integrated, and which did not provide the information needed to manage product compliance with global environmental regulations. The authors' parallel stream of research on Green IT, which inquires into the solutions currently available in the marketplace, indicates that in 2009 things have not changed much, with, for example, Fortune 500 companies in the industry still employing a variety of ad-hoc solutions based on, for examples, Excel spreadsheets, basic database systems, and point solutions from a range of vendors (cf. Butler and McGovern 2008).

The first research objective of this exploratory study is to delineate the problems facing GRC, Environmental Health and Safety (EH&S), and other practitioners in dealing with environmental regulations globally and to identify how these problems are being solved using Environmental Compliance Management Systems (ECMS). The second objective is to propose a process-based conceptual model and related IS framework to inform both researchers and practitioners concerned with the design and adoption of ECMS. In order to achieve these objectives, the first research question (RQ1) posed by this paper is: "What is the scale and scope of global regulations governing products in the electrical, electronics and IT sectors?" The second research question (RQ2) focuses on how GRC and Environment officers in these sectors are addressing global regulations using a study of a Compliance Knowledge Management System (CKMS) deployed by one IT manufacturer viz. "How is Napa Inc. addressing GRC problems posed by the global regulatory environment in which it operates?" This study's third research question (RQ3) concerns the general category of ECMS available to electrical, electronics and IT firms to manage product-related GRC issues viz. "What types of IS are argued to support product compliance with environmental regulations?" In answering this question, the experiences of Niagara Inc., the second embedded unit in this case study, provide valuable insights into the challenges posed by organisations addressing the problems posed by a global regulatory environment. The fourth research question (RQ4) focuses on the second research objective while building on RQ1-3 to enquire "What process-based IS framework best meets practitioner needs in the design and adoption of an Environmental Compliance Management System (ECMS)?" The answers to these questions should inform future research while offering practical advice to electrical, electronics and IT manufacturers, both large and small, who are considering adopting IS to support their GRC strategies.

The remainder of this paper is structured as follows: The next section outlines the research method and its conduct. Section 3 answers RQ1 by describing the global regulations targeting environmental issues in the electrical, electronics, IT and related sectors. Section 4 answers RQ2 by delineating the experiences of a major IT manufacturer in transforming its GRC processes by co-designing and adopting one particular type of ECMS—a Compliance Knowledge Management System (CKMS)—to deal with the challenges posed by environmental regulations. Section 5 answers RQ3 through its analysis of the general category of ECMS available to electrical, electronics and IT firms to manage product-related GRC issues; here, the recent experiences of a Fortune 100 conglomerate illustrate how the IS needs of GRC and other practitioners differ when it comes to managing product compliance. Section 6 then answers RQ4 by delineating a conceptual model of compliance knowledge management processes and identify related elements of an IS framework which together to inform the design and adoption of enterprise-wide an Environmental Compliance Management System. The final section then offers several conclusions and offers an integrative model of an enterprise ECMS.

2 Research method

An exploratory, instrumental participatory case study design was chosen for a longitudinal study (Yin 2003; Stake 1995) of Compliance and Risks' (C&R) Ltd. activities in developing its Compliance-to-product (C2P) environmental compliance management system and, on from this, its planned integration with enterprise systems. Two university researchers participated in this study (the first author is the lead researcher in this project), while four practitioners from the company played active roles as "co-researchers".

Data gathered at two embedded units of analysis also informs the findings of this study. The first of these is Napa

Inc. a Fortune 500 IT manufacturer, where data was gathered from co-designers and users of the pilot version of C2P. The second of the embedded units of analysis is a Fortune 100 pharmaceutical and life sciences conglomerate, Niagara Inc. Napa Inc. and Niagara Inc. are pseudonyms and refer to the general locations in the US where these major multinational corporations have their headquarters[2]. The data for the present study was gathered using semi-structured interviews during numerous meetings and on-site visits in Europe and the US, spanning the period from August 2005 to January 2009: participant observation was also employed throughout (Yin 2003). Additional data was gathered from delegates of the Electronics Goes Green (EGG+) 2000 conference held in Berlin, and included contributions from representatives from the EU Commission, Siemens AG, Intel Corp., Cisco Systems Inc., Panasonic, and several vendors of Design for Environment (DfE) and Product Life Cycle Management (PLM) tools. Internet-based teleconferencing technologies were employed to facilitate meetings, in addition to emails and instant messaging. A pragmatic perspective was adopted to the interpretation of data (Butler and Murphy 2007). Following Ihde (1990), such approaches give primacy to the understandings of practitioners. A Grounded Theory approach was applied in that the systematic coding procedures of open coding, axial coding, and selective coding were employed to identify and elaborate the themes and categories in the data (Strauss and Corbin 1990). The data was interpreted and analysed on an ongoing basis, and augmented by official company documentation, training manuals, technology architecture documentation, and so on. Additional data was sourced from the various reports and sources listed in the cited references.

3 Environmental regulations in a global context

This section answers the first research question posed above. In so doing, it describes the regulatory environment in which firms like Apple Inc., Hewlett Packard Inc., General Electric Inc., Siemens AG, Sony Corp., Intel Inc. and their myriad of suppliers operate. It also indicates the challenges for GRC in a global context.

3.1 Complexity and the global regulatory environment

Recent European Union regulations such as the Restriction of Hazardous Substances Directive (RoHS), the Waste Electrical and Electronic Equipment Directive (WEEE), and the Registration, Evaluation and Authorisation of Chemicals (REACH) Regulation have enormous implications for diverse industry sectors operating globally (Hristev 2006; European Commission 2007). The implementation of WEEE and RoHS Directives resulted in highly complex legislation in EU member states, which does not lend itself to easy comprehension, application, and integration into an organisation's research, development, manufacturing and logistics processes (Pecht 2004). However, the task of maintaining compliance will become even more onerous for the IT manufacturing industry and related sectors, not only because of the recent moves to include 46 new hazardous substances on top of the original six under EU RoHS, but as the new REACH Regulation came into force in June 2007. This new law requires organisations to specify the possible dangers of combinations of chemicals present in their products not only on disposal, but also while in use (Bush 2007). It will also place new disclosure requirements on companies under Article 33 by ensuring customers, and also interested NGOs, like Greenpeace, can insist on disclosure on a black list of substances. While the EU's environmental laws have received much attention, others are no less stringent. The Environmental Protection Agency (EPA) in the US has issued a raft of legislation covering all hazardous substances across the whole range of manufacturing sectors, while Japan also has highly demanding laws (Hristev 2006). Over the last two years, Korea, Australia, Canada, and US states such as California, have introduced legislation similar to the RoHS and WEEE directives, while in China, a similar directive known as the China RoHS or the Methods for the Control of Pollution by Electronic Information Products Directive, came into force in March 2007. The need to address compliance legislation in different geographical locations adds complexity for global IT manufacturing organisations; however, determining the applicable regulation for a given geographical area can be complicated by the problem of understanding which products are covered, or are exempt, by sets of seemingly conflicting regulations (Kellow 2002).

Figure 1 presents a simple graphical representation of the growing complexity of the various categories of regulations across major jurisdictions and their consequences for firms. It is clear from the figure that the wealth of compliance legislation globally has significant implications for governance, risk and compliance for electrical, electronics and IT manufacturers. Understanding which products are covered by or exempt from sets of complex and apparently conflicting regulations is, therefore, an intimidating task (Goosey 2007; Kellow 2002:cf. Kellow 2002; Kerrigan and Law 2003). Take, for example, the scenario where an IT manufacturer wishes to evaluate its compliance status vis-à-vis the RoHS extension, or deal with the variations of

[2] The authors undertook to keep the names of both organisations anonymous. This approach was also applied to participants in informal conversations where particularly sensitive observations/data were gathered at meetings or at the EGG + 2008 conference.

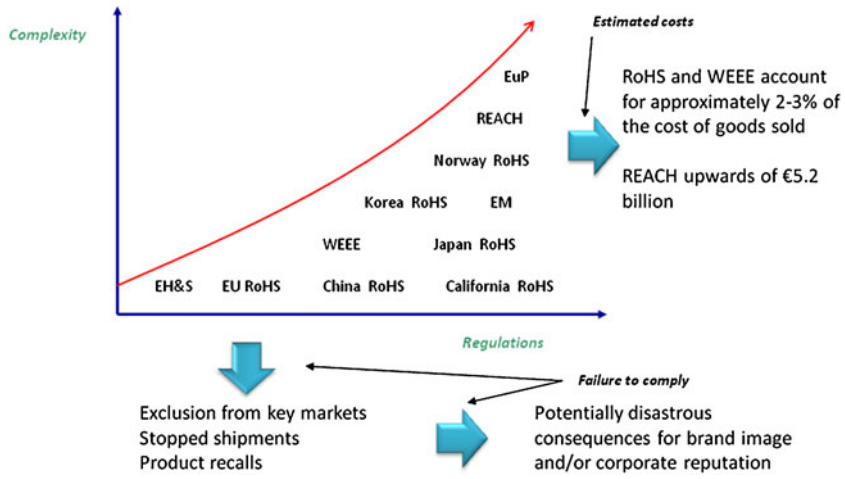

Fig. 1 Complexity of the regulatory environment and its consequences

WEEE in EU members states. Such a company might, for example, ask its legal department, (if it has one) to evaluate the implications of this new regulatory source of compliance imperatives. More often than not, external legal experts will be consulted at great expense, and with significant time lag in terms of a response. One way or another, the implications or issues created by the requirements in each section of the directive/regulation/legislation in 27 member states will have to be enumerated, if they are to be properly addressed. This, however, only scratches the surface of the regulatory mountain facing Governance Risk and Compliance (GRC) officers.

Data from this paper's study of Compliance and Risks' Ltd. Compliance-to-Product (C2P) application indicates that there are well in excess of 4,000 sources of legislation across a range of compliance areas globally, and many more providing interpretation and guidance. Each of these legislative sources gives rise to a range of compliance-related issues to be addressed, depending on the company concerned. Each compliance issue will have related impacts on products/sub-components/materials, through the regulatory requirements generated by each source. Addressing such issues will, in turn, generate a range of related contexts to be identified and described, in addition to any tasks GRC officers must undertake to resolve said issues. Thus, this study concludes that electrical and electronics firms face enormous complexity at what we call the consumption side of the compliance equation—that is, in consuming and applying environmental regulations to products.

3.2 Costs of compliance

A recent study by AMR Research of 424 line-of-business executives across all sectors in the US, Germany, Japan indicated that spending on GRC activities will reach $30 billion in 2008, of which just $6.2 is accounted for by SOX (AMR 2008). While an exact breakdown is unavailable, AMR report that most of the costs will be people-based—hence, companies will turn to IT-based solutions to lower such costs. Likewise, the European Commission estimates that the cost of compliance with REACH legislation will be in the region of €5.2 billion (European Commission 2007); however, it looks like these estimates cover reporting only, and constitute the tip of the compliance iceberg. Independent research also reports that the cost of compliance with RoHS and WEEE is approximately 2–3% of the cost of goods sold, a not insignificant amount given the size of the electrical, electronics, and IT sectors, where margins continue to tighten (Spiegel 2005). While these costs are considerable, the costs of non-compliance are even more significant, with companies facing the risk of exclusion from key markets, stopped shipments, product recalls, with a corresponding loss of revenue, and potentially disastrous consequences for brand image and/or corporate reputation (Brown 2006; Avila 2006; Goosey 2007). In cases of a serious breach of compliance regulations, firms may also be faced with hefty fines and/or criminal prosecutions (Brown 2006; Hristev 2006).

4 Compliance knowledge management in the IT sector

The spread of regulatory controls across all business and industry sectors has given rise to an integrated set of GRC activities across enterprises whose functions are to ensure corporate governance, risk management, and regulatory compliance (Taylor 2006). It is clear that SOX provided a focal point for software vendors to integrate existing compliance and risk platforms (e.g., those serving the pharmaceutical industry and the life sciences in general) with emerging corporate governance solutions (cf. Hayward 2007; Sammer 2005; Volonino et al. 2004). This led to the development of enterprise GRC systems for use by corporate functions across all industry sectors (McClean and Rasmussen 2007) and enterprise compliance manage-

ment systems which are targeted at the life science industries (Hayward 2007). There is, however, another emergent category of GRC system that helps manage the impact of environmental regulations on electrical and electronic products and, by extension, IT artefacts such as computers, telecommunications, and internetworking equipment (cf. Bachmann and Clese 2008). The following embedded unit of analysis describes the experiences of one organisation in adopting an Environmental Compliance Management System (ECMS) called Compliance-to-Product (C2P).

Napa Inc. is a household brand name and a major player in the global IT industry worldwide. Head quartered in Silicon Valley, it operates production and distribution facilities globally and sources the component parts and sub-assemblies for its products from thousands of suppliers operating in diverse regulatory environments. Due to the dearth of suitable ECMS in the market, it agreed to deploy the pilot version of the nascent Compliance-to-Product (C2P) application, which was in the design stage at Compliance and Risks Ltd. in late 2005. In order to ensure the success of the pilot application, the software design team at Compliance and Risks Ltd. worked closely with key staff at Napa to obtain detailed system requirements in order to tailor their high-level architectural model and system design to the users' needs. The following section describes the particular challenges faced at Napa Inc. in addressing the aforementioned global regulatory environment.

4.1 Managing environmental compliance and risk at Napa Inc. Pre-C2P

As with the majority of companies, then and now, Napa Inc. was managing product-related compliance and risks using spreadsheet solutions. Napa was unhappy with using spreadsheets to support such vital tasks. Indeed their fears appear to be well founded, if the reports on the practitioner literature on GRC are accurate. Take, for example this observation by Cummings (2008) writing in Business Finance Magazine: "Every now and then a new story of corporate embarrassment, or worse, caused by spreadsheet errors hits the business headlines. Sometimes the mistakes are on a scale that can only be described as monumental, like Fannie Mae's $1 billion-plus underestimate of total stockholder equity in 2003, the result of errors in a spreadsheet used in the implementation of a new accounting standard." It is clear from the literature that good GRC practice is not, generally speaking, constant with the use of spreadsheets (Bloem et al. 2006). It is no surprise then to find Napa Inc. seeking a robust solution to manage environmental compliance and risks.

Dissatisfaction with the use of spreadsheets was only one of the issues facing Napa Inc., another was that it was relying on external sources (legal and otherwise) for detailed information on compliance imperatives in the global market in which it operated. This approach was not working, as one member of staff at Napa's Environment Department commented "we're ploughing a field and being handed a spoon", when it comes to dealing with regulatory issues. According to a practitioner at Napa's Environment Department, the company's major challenge in dealing with this problem is that "Policy imperatives are exponentially growing, in the environmental arena the policy is focusing increasingly on product issues (RoHS, Power management, labeling, packaging design, batteries, design for recycling) and has been steadily moving away from end-of-pipe policy typical of the 1980's and 1990's [Environmental Health and Safety] regulations. Added to this, unlike other policy areas, environmental policy is enforced at multiple levels adding regional, national and local level data points (e.g. Battery marking and recycling is enforced by European Commission, UK DEFRA and DTI, UK Regional Environment Agencies, Local authorities, City councils)." All this meant that Napa faced significant challenges in ensuring due diligence was observed in its product design and manufacture, quite apart from ensuring that its suppliers in broader the electrical and electronic sectors were compliant. While the company now positions itself as a leader in the Green IT movement, product recall and exclusion from particular markets were cited by Napa Inc. as being some of the ongoing threats to the company in the face of such demanding regulations.

Three specific challenges confronted Napa's Environment Department in 2006: the first was how to avoid compliance officers and R&D manufacturing engineers spending 100% of their resources on tracking policy, associated standards, and regulatory measures, as opposed to maintaining delivery of higher value-add activities such as compliance assessments, addressing and managing related issues, and implementing compliance with imperatives. The second challenge was how to tie the actions and decisions taken at a product team level with the requirements, terms, definitions, and guidance provided by legislators. The third challenge was how to reduce the time (i.e. latency) and cost associated with getting independent guidance and assessment on regulatory definitions and requirements.

Prior to its adoption of the Compliance-to-Product (C2P) application, Napa adopted a five stage process in order to help it manage compliance viz. (1) Track and monitor all relevant regulations in the global marketplace; (2) Assess all related risks in terms of process and product; (3) Raise awareness across the organisation, especially in engineering/design/R&D and manufacturing, and enhance intra-

organisational communications across all relevant functions; (4) Implement compliance solutions in engineering and design functions at the earliest possible opportunity; (5) Review the effectiveness of the steps taken and the level of compliance achieved (see Fig. 2). These steps were proving to be difficult to manage in terms of the scope and complexity of the global regulatory environments in which Napa operates. In sum, it was managing compliance using information gleaned from reports provided by legal advisors and then mapping this on to Products/sub-components, and so on, using Excel spreadsheets. However, there were just too many gaps in its practitioners' knowledge and understanding of compliance imperatives and their impacts on products. Take, for example, that the legal reports on the various regulatory instruments and their compliance imperatives were often as impenetrable to practitioners at Napa as the original regulations. Furthermore, such reporting mechanisms were often limited in scope, untimely, and, more often than not, failed to signal future regulatory responses. The core of the issue was that Napa's Environment Department did not have the legal competencies to properly interpret the reports; consequently, they could not evaluate fully the consequences of particular compliance imperatives for products whether in the design stage or production.

4.2 Compliance knowledge management with C2P at Napa Inc.

Drawing on insights from the case study and the experiences of practitioners in both the embedded units of analysis, we argue that addressing the major challenges posed by global regulatory requires a Compliance Knowledge Management System (CKMS). Essentially, such an IS supports three fundamental compliance processes: (1) External Regulatory Requirements Gathering; (2) Compliance Management; and (3) Knowledge Management. At a high level, these processes concern themselves with assessing and managing the regulatory sources (e.g. RoHS, WEEE and REACH-like legislation), the issues they generate for products, associated risks, tasks required to manage compliance and risk, and support for compliance disclosure. In order to do this effectively, a CKMS should ideally support communication, collaboration, and document management. Practitioners argue that such IS support is required for all product stewardship-related activities in dealing with regulatory imperatives impacting an organisation (cf. Avila 2006; Bachmann and Clese 2008).

Fig. 2 Napa's environment GRC process

Given the aforementioned dearth of legal competencies in Tracking and Monitoring regulations at Napa Inc. (and indeed in all other Fortune 500 IT manufacturers that have adopted C2P since 2007), Regulatory Requirements Gathering Process is informed and supported by Compliance and Risks' Legal Data Team and contributing industry and data partners (such as law firms, consultants, policy area experts), and other knowledgeable sources. As of early 2009, this global team of legal experts have collated and documented over 4,000 sources of global regulatory imperatives impacting all possible product components, sub-components, sub-assemblies, constituent materials and substances, including packaging, energy efficiency, CO2 emissions, and so on. The scope of this process is global, and in Napa's case it encapsulates all of the business markets in which it operates, in addition to all juridico-political territories, future regional implementation areas, and so on. The complexity of capturing these types of data stands in stark contrast to the type of support provided by the majority of extant ECMS (e.g. SAP's Compliance for Product or CfP—cf. Bachmann and Clese 2008), where users or their data partners create static 'lists' of regulated substances, materials, and so on. Such approaches stand in stark contrast to C2P's multi-dimensional data structures needed to model compliance sources, their related imperatives and requirements, and their relationships to products, present and future. C2P therefore captures global regulatory imperatives, and represents them not as one or two dimensional lists, but in sophisticated time-sensitive data structures, which nevertheless can be easily interpreted by environmental and GRC officers at Napa's compliance officers, as the system was designed with usability in mind. Hence, users can navigate to and map compliance imperatives onto Napa's internal GRC specifications (in C2P format), products, subassemblies, parts, materials, and substances. These points are underpinned by feedback from Napa's Environment Officer, who indicated that C2P "adds value" to the company's compliance management processes, as the application ensures that "source regulatory data is delivered pre-formatted, structured and ready to use out of the box." Staff at Napa also argued that the output of C2P's

Regulatory Requirements Gathering Process provides "a universal panoramic view of all relevant impacts to product or company operations" and it "gives instant, live snapshots on policy areas that are not adequately covered or understood—[C2P] helps guide management to allocate resources to appropriate risk areas."

In order to manage compliance, C2P's Compliance Management Process supports Napa's GRC, Environment staff, R&D Engineers and other users by providing them with full visibility into the status of its compliance activities using a customisable dashboard with complex search and report features. Thus, another important feature of C2P is its ability to allow Napa to view the impact of regulations on, and issues around, products/sub-assemblies/parts/materials and substances in real time. This means that once a regulatory requirement changes, or a new one emerges, or new data is fed into the system by the Legal Data Team or C&R's global data partners, the status of all related products can change, down to constituent materials, and on to parts provided by suppliers—this is communicated to 'responsible' users using dashboard-based and email alerts. In addition, C2P's analysis features helps users analyse compliance imperatives and requirements impacts on products/sub-assemblies/parts/materials and substances.

Napa's user community felt that one of the strengths of C2P was its knowledge sharing tools which underpin the application's Knowledge Management (KM) capabilities. These KM tools were designed to provide users with enhanced understandings to inform compliance-related decision-making by: (a) capturing discussion threads in instant messages and e-mails, (b) providing users with the capability to capture background information on all compliance-related issues, product impacts, and tasks; (c) building a history of all regulatory imperatives, requirements, and associated changes to products/sub-assemblies/parts/materials and substances; (d) Automatic alerts via the dashboard or e-mail; and (e) a document attachment feature to provide links to, or to attach directly, all compliance related documents.

The following comments from Napa's Environment Officer indicate the effectiveness of this ECMS/CKMS in that "C2P has shown us that the era of paying external organisations to dump information on our doorstep has come to an end." He maintained that the application "enables our compliance team to move away from the inordinate amount of time spent on tracking and monitoring activities and to focus on activities 2, 3, and 4 [see Fig. 1] which are the bits that really add value to the company." The remainder of this section helps answer RQ3 by focusing on the extant solutions employed by organisations such as Niagara Inc. to manage compliance and risk.

5 Generic IS solutions to environmental compliance and risk management

This section provides an overview of extant GRC-based IS with particular attention to those dealing with environmental regulations. The recent analysis of enterprise GRC systems conducted by Forrester Group's McClean and Rasmussen (2007) did not identify any IS that could be categorised as ECMS. Vendor offerings reviewed in that study tended to target compliance management in financial and IT governance and in the life sciences. It is clear from the report that environment-based compliance and risk management is the poor relation of corporate GRC initiatives. For example, McClean and Rasmussen evaluated the top 15 enterprise GRC vendors out of a total of 114 major application providers (however Oracle and SAP declined to participate in the study). Only once in this extensive report was there any reference to environmental compliance, and this was only in passing. A closer examination of the top six vendors—BWise, AXENTIS, MetricStream, OpenPages, Paisley, and QUMAS—revealed that they were not encompassing environment regulations in their solutions. AXENTIS, for example, focuses on the implications of the SOX Act, information privacy, ethics and integrity, and IT governance in its enterprise system, while QUMAS offers much the same in the financial and life sciences sectors.

5.1 From excel spreadsheets to enterprise-wide ECMS

Niagara Inc. is a Fortune 500-listed conglomerate operating in the pharmaceutical and life sciences sectors. This business enterprise's corporate Environmental Health and Safety (EH&S) function manages compliance and risks globally. In 2008, GRC, R&D/product design staff, product stewards, and so on, were employing an Excel spreadsheet solution to manage product compliance from the design stage to manufacturing; this solution covers all of its products from personal hygiene and medical products to electrical and electronic healthcare items. This was proving a complex endeavour as the spreadsheet solution was not well-suited to managing over 15,000 substances and mapping them across multiple regulatory jurisdictions globally, creating upwards of 800,000 data cells in the process. Specific information on regulations was accessed via embedded hyperlinks to the company's document management system. Here, practitioners in Niagara from GRC officers to product stewards faced the same challenge in interpreting complex legislation as those in Napa Inc. The EH&S function was also unhappy with the frequency and manner in which compliance-related data was updated to the spreadsheet—such data was being imported bi-annually from an external provider, but was not

automatically mapped onto regulatory sources in the spreadsheet. This left the company open to increased risks of being out of compliance in a rapidly changing, environmentally regulated, global marketplace.

In 2008, Niagara Inc.'s EH&S function considered several replacements for its spreadsheet-based solution: the two most favoured were (a) the Global Environmental Management System (GEMS) from Foresite Systems Inc. and (b) the aforementioned Compliance-to-Product (C2P). It is interesting to note that the GEMS system was being advocated by product stewards across the corporation, while C2P was being championed by the corporate-based EH&S function. A consideration of GEMS functionality will highlight the major difference between the two IS—it will also provide background information to help answer the fourth research question.

GEMS is not an Enterprise System, such as SAP, it does, however, integrate with ERP systems like SAP, Oracle and JD Edwards to import Bills of Materials (BOM) and other product-related data; it also manages supply chain data requests via forms such as IPC 1752. The system's Web Connector and other data integration technologies allows the importation of compliance-related data and declarations from suppliers, which GEMS then integrates with the BOM and other product-related data to evaluate product compliance. From this, it also enables the creation of compliance declarations and reports by practitioners. GEMS also supports Design for Environment (DfE) functionality, which Niagara Inc. also required. The only problem with GEMS, that is from the perspective of EH&S managers at Niagara Inc., is that the system does not come preloaded with environment-related regulatory information and related data on materials and substances used in production processes. While easy-to-interpret structured data is unavailable 'out-of-the-box' with GEMS, Foresite Systems Inc. provides consultancy services to adopters of GEMS to "help translate the technical 'jargon' of environmental legislation into practical directions."[3]

GEMS is not the only product of this type in the market. SAP AG currently has a comprehensive suite of environment-based solutions; namely, SAP Environment, Health, and Safety (SAP EH&S); SAP ×App Emissions Management (SAP ×EM) compliance management; SAP Compliance for Products (CfP); and SAP REACH solution (cf. Bachmann and Clese 2008). Oracle's recent acquisition of Agile Inc. is a signal that it is serious about competing in the environment space, as Agile's Product Governance and Compliance solution is aimed at helping organisations manage product, substance, and material compliance against standards and regulatory requirements[4]. As with general purpose GRC systems (e.g. QUMAS[5] which based its Enterprise GRC System on the firm's document management solution), many of the ECMS currently available emerged from either: (a) Product Life-cycle Management (PLM) or Product Life Cycle Assessment Tools (see, for example, the Product Governance and Compliance application from Agile, EMARS from Synapsis Technology Inc., or the GaBi4 solution); (b) Enterprise Resource Planning (ERP) (SAP AG/TechniData AG's Compliance for Product (CfP) solution is a good example here, as indicated above); (c) and Supply Chain Management (SCM—here, for example, E2Open Inc.'s Eco-Compliance solution is based on the firm's supply chain and logistics capabilities).

Hence, like their counterparts in other organisations who adopted PLM-, ERP-, or SCM-based environmental compliance solutions, product stewards at Niagara Inc. were impressed by data and information features of the GEMS application. The major difference, however, was that GEMS is not an Add-in Module to a PLM, ERP or SCM. This made it attractive as an overarching solution a large diversified conglomerate such as Niagara which had a multiplicity of IS deployed in its companies globally, often serving idiosyncratic information needs.

GRC and EH&S officers at Niagara Inc. took a different perspective on potential ECMS solutions, however, due to their particular information requirements in assessing the risks associated with product compliance. Thus, because GEMS did not have the capabilities to enable this key activity out of the box, their preference was for an ECMS that did. Consequently, like Napa Inc. before them, practitioners at Niagara Inc. decided to adopt the C2P application, as they considered it effective in providing direct support for GRC activities in addressing regulatory compliance imperatives, while also supporting compliance knowledge management through a suite of collaborative tools.

It is clear from the above analysis, that while extant PLM-, ERP- or SCM-based ECMS do not support the provision of comprehensive, up-to-the-minute information on global regulations or Compliance Knowledge Management processes, alternatives like the C2P system do not, at the time of writing, support logistics compliance activities, such as data analysis on BOMs, supplier compliance documentation (e.g. Material Composition Declarations), and other data management functions. The application does, however, have the capabilities to integrate with PLM, ERP and/or SCM IS in order to manage logistics compliance issues. Likewise, it may be only a matter of time before the afore-mentioned vendors (SAP AG, Oracle/

[3] http://www.foresitesystems.com/foresitev3/services.htm
[4] http://news.thomasnet.com/companystory/480123
[5] http://www.qumas.com/products/index.asp

Agile Inc. and so on) add Compliance Knowledge Management features.

5.2 Additional factors in the adoption of ECMS

In keeping with industry GRC trends, ECMS vendors are offering their solutions as either stand-alone applications (i.e. fully purchased off-the-self packages, either configured or customized) or hosted solutions that deliver software-as-a-service (usually on an annual rental basis). Either of the above may be integrated with existing PLM/ES systems (Avila 2006; Brodkin 2007). The decision to rent or buy is not inconsequential. In his analysis of Enterprise GRC system adoption for the life sciences sector, Hayward (2007) argues that firms need to take into account Return on Investment (ROI) and the Total Cost Ownership (TCO) when choosing a compliance management system. Such issues should also exercise the minds of executives in the IT and related sectors. Indeed, companies increasingly appear to have a preference for hosted software-as-a-service solutions e.g. Fortune 500 companies such as DuPont, Chevron and Johnson & Johnson adopted software-as-a-service tools to manage Environmental Health and Safety (EH&S) compliance (Brodkin 2007). However, it is our experience that IT executives may complicate matters in ECMS adoption by wishing to adhere to existing corporate standards (cf. Butler 2003). For example, one client of Compliance and Risks Ltd. is a Fortune 500 corporation using SAP as is its enterprise wide resource planning system (this company is neither Napa Inc. nor Niagara Inc.). As SAP was a corporate standard, the company's IT function recommended the adoption of SAP EH&S, ×EM, CfP, and REACH solutions for environment compliance. However, GRC officers wished to adopt C2P due to relative ease of use and suitability to purpose; i.e. as an ECMS it focuses on core compliance processes. In the end, the GRC function won out and it is notable that one of the reasons for their success was not that C2P met its requirements, rather the low TCO helped negate opposition.

6 Towards a process-based IS framework for environmental compliance management

The section builds on the findings of the previous three to propose a process-based conceptual model and IS framework for governance, risk and compliance management in the electrical, electronics, and IT sectors. First we briefly describe the proposed model which is then articulated as a process-based IS framework in the following sections.

6.1 A process-based conceptual model of an ECMS

The proposed model conceptualises an Environment Compliance Management System as being composed of a particular configuration of people, processes and technologies. The people dimension includes a variety of users: e.g. GRC and EH&S practitioners, R&D and design engineers, logistics and supply chain practitioners, legal experts, and so on. Enabling information technologies may be stand-alone client/server and Web-based systems, packaged software (e.g. PLM or ERP modules) or software-as-a-service solutions. It is, however, the processes that the people participate in, and which are enabled by IT, that we consider as being of key importance. Thus, we make the following general theoretical proposition:

> If Due Diligence in Environmental Governance Risk and Compliance is to be achieved, then an ECMS should provide comprehensive support for (1) Compliance Requirements Gathering Processes; (2) Compliance Management Processes (including Supply Chain or Logistics Compliance Management); and (3) Compliance Knowledge Management Processes.

Figure 3 presents a high-level conceptual model that underpins this proposition. We conceptualize Due Diligence as the outcome concept for compliance and risk in manufacturing enterprises—this is due to the complexity of the compliance and risk management processes and the uncertainty surrounding complex, global supply chains. As previously seen, much of the former complexity arises due to the nature of regulatory legislation and its interpretation. Complexity is, however, also a function of the diversity and length of supply chains in globalized markets (cf. Eisner 2004; Kleijnen and Smits 2003; Schroder and Turnbull

Fig. 3 A process-based conceptual model of environment compliance management

2008). Take, for example, a recent unpublicised incident whereby a major electronics OEM (Original Equipment Manufacturer) discovered that its Asian supplier of printed circuit boards had used lead-based solder, which is now banned in all major markets, in the production of components. The OEM was faced with an instant product recall, but not, perhaps, regulatory sanction or penalties, as it could show due diligence in meeting its compliance obligations. This incident prompted the authors to pose a question to over 40 delegates who attended the Compliance and Materials Declaration Technical Session (5.6) at the Electronic Goes Green + 2008 conference on the issue of trust in supplier compliance with global regulations. The answer to the question "How do you ensure that your suppliers are in compliance with regulatory imperatives?" emerged in the discussion that followed. The ensuing debate illustrated that there was consensus among participating delegates to the effect that since OEMs could not test all batches from thousands of suppliers, all that could be done was to prove to regulators that an OEM had exercised due diligence in its GRC activities. Significantly, the Vice President of one division of a well-known Fortune 100 company admitted privately to the authors that of his division's 5000+ suppliers, he only trusted one. Hence, we conclude a company may have taken all possible steps to have their products in compliance with all known legislation governing their chosen markets, but may, through the actions or ignorance of suppliers, not be in full compliance with respect to particular products in particular markets. In recognition of the problem, several IT manufacturers, such as Napa Inc., have begun to set their own firm-specific thresholds for regulated substances and materials, energy efficiency, and so on, which exceed those in all known regulatory instruments. Furthermore, they are communicating these targets to suppliers unambiguously. Hence, we recognize that because it is still an aspiration for the majority of firms, 'due diligence' is a reasonable substitute for 'full compliance' as an outcome concept.

The following sections elaborate on the above conceptual model by delineating each of the three processes in terms of the enabling features of an ECMS—these features constitute the various elements of the proposed IS framework.

6.2 Compliance requirements gathering processes

The findings of this study illustrate that core issue facing GRC officers, EH&S personnel, and product stewards is that they do not possess the required legal knowledge or capabilities to understand, assess, and record pertinent compliance-related information from a mountain of regulatory and other sources. Related issues also exist in connection with the assessment of compliance and risk issues of sub-components and materials from suppliers. It is clear that robust legal capabilities are required in order to deal adequately with the legal basis of compliance imperatives, relevant jurisdictions, instrument types, and so on. The above findings indicate that almost all of the ECMS currently available merely help users to create static 'lists' of compliance requirements, rather than provide the multi-dimensional data structures needed to model the complexity of compliance imperatives and requirements, and which are updated on an on-going basis. As indicated previously, it is typical of Enterprise GRC vendors to offer sophisticated functionality and consultancy services to help customers deploy and use their systems (cf. Foresite Inc.), while also recommending the services of legal data partners to populate the aforementioned database 'lists' of substances/materials and compliance requirements.

We, therefore, argue that the compliance requirements gathering process of an ECMS should be tightly integrated and support legal experts, GRC and EH&S officers to collaborate in capturing compliance regulations from all sources globally and model them as complex data structures that can be easily navigated. Choo (2006) argues that sense making is a key activity in 'knowing organizations'. It is evident from the case study and the embedded units, that if an organisation is to make sense of and attribute meaning to compliance imperatives from diverse legal sources, then its ECMS must have robust legal definitions management capabilities. (This is a key factor in the attractiveness of structured data provided by Compliance and Risk's legal data team through C2P.) Only then can such imperatives be mapped onto products, subassemblies, parts, materials and substances with the degree of accuracy required of an ECMS. Hence, while external legal services cannot be dispensed with, they, and the legal experts that deliver them, should, ideally, be incorporated into the ECMS. Thus, we propose that if an ECMS is to be used to illustrate the exercise of Due Diligence in compliance requirements gathering, then it should incorporate the following:

1. Features that facilitate legal experts and other users to create database representations of all sources of regulatory/legal compliance information, including all relevant legal requirements, associated organisations, geographical areas affected, exempted materials and substances and their consequences.
2. Features that help legal experts to enter and present the meaning of legal terms and definitions in order to facilitate their analysis and understanding by GRC officers.
3. And, features that would illustrate the link between regulatory sources, their requirements, and their impacts on products (or activities).

6.3 Compliance management processes

GRC and EH&S officers, R&D engineers, production and logistics staff and other users need full visibility of a company's compliance status and activities. Electrical, electronics and IT manufacturers will typically arrive at product specifications, including sub-components and materials, at the R&D/product design stage. Hence, an ECMS should play a key role in these activities, as design specifications must be matched against all known legal and regulatory compliance requirements to establish compliance or non-compliance. However IT manufacturers may dynamically change product sub-assemblies in line with customer requirements (e.g. mass customization as with Dell) or by procuring from different suppliers at different times. Thus, a product's compliance profile may change during production from that of the original design. There may, therefore, be a requirement for an ECMS to be integrated with the production module of the adopting organisation's PLM or ERP system.

Prior to a product being 'put on the market' disclosure may/must take place. Thus an ECMS should, ideally, support appropriate document/data exchange formats; e.g. the IUCLID (International Uniform Chemical Information Database) XML schema for REACH, and so on (cf. Kubin 2005).

A key feature of an ECMS would be its ability to allow users to view the impact of regulations on products/sub-assemblies/parts/materials and substances dynamically. Thus, if an existing compliance imperative changes, or a new one emerges, then there is a requirement for the status of all related products, including parts provided by suppliers, constituent materials and substance held in the ECMS to change. An ECMS should then alert key users to this change in circumstances immediately—automatic email alerts and personal dashboard alarms/flags could be used here.

A variety of analysis features should also be incorporated so as to facilitate evaluation of regulatory compliance imperatives and requirements impacts on products/sub-assemblies/parts/materials and substances. A key analysis feature would be the ECMS' ability to compare supplier data such as a Materials Composition Declaration (MCD, and so on.) against known compliance imperatives in order to identify noncompliant parts, materials, or substances. Capturing compliance-related details on substances and materials in product sub-assemblies and component parts etc. sourced from third parties is a significant process. Thus, an ECMS should facilitate the transfer and processing of all Materials Composition Declaration (MCD) documents from upstream suppliers. The scale and complexity of this sub-process cannot be underestimated due to the many thousands of materials/sub-assemblies etc. that IT manufacturing organisations source from hundreds if not thousands of suppliers. Of course, the information gathered in MCDs need to be mapped unto the actual quantities of components etc. supplied. Here, information from Bills of Materials (BOM) has to in incorporated to calculate the amounts of controlled materials being put on the market in products. When the organisation is itself a supplier, the ECMS should produce MCD documents and BOMs to customers.

In order to execute electronic data transfer of MCDs and other documents from suppliers, an ECMS would need to be integrated with an organisations' Supply Chain Management (SCM) system. In the absence of such as system, the ECMS would therefore need to support a range of data transfer standards for direct data transfer. For example, the industry-wide IPC-1752 data standard provides an XML schema for data transfer, while RosettaNet (a standards organisation that promotes collaborative B2B commerce) also has XML schemas of PIP 2A15 (Request) and PIP 2A13 (Declaration) data exchange. There is, in addition, a new international standard based on the JIG (Joint Industry Group) and IPC-1752, which may need to be supported. While these standards are in the formative stage, it is also clear that legacy standards which are still in widespread use, such as Excel.

As data exchange standards do not yet exist, or are incomplete for the purpose at hand, ECMS vendors such as SAP employ proprietary standards; see for example its Compliance for Product (CfP) Data Exchange Format CfPXML[6]. It must be noted that this data exchange format does incorporate some existing standards. In a general context, proprietary standards may be deployed easily to suppliers and related organisations using Web Services. In the case of data transfer from, for example, the database holding Bills of Materials (BOMs), an ECMS might need to integrate with and transfer data from an ERP system. If the ECMS vendor is not the ERP vendor, then integration, typically via XML, is required.

It is common for Enterprise GRC systems and ECMS to include a personal dashboard as the primary point of access for users (cf. Evans and Benton 2007). The basic features of an ECMS dashboard should include the ability to display compliance issues, ECMS searches, bookmarks, reminders, watches, alerts, action plans or to-do lists, and instant messages, so as to enable decision making. It should constitute a key nexus of the ECMS work-flow capabilities. In this context we propose that if an ECMS Dashboard is to be used for compliance management, then it should incorporate the following features:

1. The ability to identify, create and manage issues relating to compliance imperatives would help GRC

[6] http://www.technidata.de/compliance_for_products/xml/rel10/cfpxml.xsd

and EH&S officers, product design engineers, and logistics staff to collaboratively evaluate, escalate and address product/materials compliance and their impacts.
2. The ability to allow users to delegate and monitor issues and responsibilities to relevant staff by assigning tasks.
3. An action plan feature to associate milestones with and manage tasks for each issue.
4. A risk ratings feature to permit users to display a product's risk status for each compliance issue identified.
5. An alarm feature to help users track the status of assigned issues and tasks and other areas of responsibility.
6. The ability to create custom reports according to the issues identified and affected products, sub-assemblies, materials, and so on.
7. As a dashboard can grow, it must have the ability to incorporate multiple views so that users can navigate between summary data and detailed information.
8. Finally, an ECMS would need to catalogue and retain RoHS-related documentation and compliance reports for 4 years and REACH reports for 10 years. Alternatively, if the ECMS system does not provide such features, it would need to be integrated with a document management system.

6.4 Knowledge management processes

Knowledge management (KM) and sharing capabilities and tools are, we argue, key requirements for a full-featured ECMS. The purpose of KM features is to enhance users' understandings in order to make better-informed decisions (cf. Choo 2006). In keeping with best practice, KM features should be accessible from the ECMS dashboard (cf. Evans and Benton 2007; Palpanas et al. 2007); hence, we propose that if an ECMS is to support compliance knowledge management, then it should incorporate the following features:

1. The facility to create contexts, i.e. background information, for classifying and reporting the evolving impact of compliance issues on products, and so on.
2. A history of all changes to regulatory imperatives and requirements, regulatory updates and associated changes to the design and makeup of products /sub-assemblies /parts /materials and substances.
3. An audit trail of supplier declarations (MCD and compliance) for liability management and due diligence reporting purposes.
4. The ability to capture instant messaging and/or e-mail discussion threads between users on any topic.
5. Automatic e-mail and/or instant messaging notification to any changes in the regulatory status of products/ sub-assemblies/ parts/ materials and substances. The ECMS should trigger alerts on relevant personal dashboard, while also highlighting the relevant areas affected.
6. Detailed search features will allow users to run queries and produce detailed reports based on specific parameters.
7. Finally, another important KM tool is an attachment feature that users employ to attach related documents that detail, or provide links to, legal interpretations or advice, industry journal articles, reports etc. These may explain in greater detail particular regulatory compliance imperatives, issues, requirements, and impacts; they may also detail data on products/ sub-assemblies / parts /materials and substances. One important aspect of this feature would be the capacity to append/cross-reference independent laboratory analysis reports with supplier MCDs for validation of content and accuracy.

Collectively, these three groups of process-based features constitute elements of the proposed IS framework for ECMS design and adoption.

7 Conclusions

This paper argues that firms in the electrical, electronics and IT sectors need to move beyond basic spreadsheet and database technologies and adopt sophisticated Environmental Compliance Management Systems (ECMS) to manage the complexity of the global regulatory environment. The answers to RQ1-3 support this contention while achieving this study's first objective; significantly, however, they also indicate two major issues that underpin the requirement for an ECMS to address the GRC issues facing such firms.

The first of these issues is that organisations need to address the challenges posed by the global regulatory environment by first understanding the complexity and scope of compliance imperatives and their impact on products. This task is significant, as organisations generally do not have the necessary in-house legal capabilities to interpret, evaluate, capture, and store all relevant compliance-related information from a growing number of regulatory sources (over 4,000 and counting). Traditionally, this activity has been out-tasked to external legal experts and consultants who respond with voluminous reports that often do little to lift the burden on GRC and EH&S officers. Thus, organisations require IS support to address what is, essentially, a dearth of firm-specific knowledge on environment regulations and their impact.

The second issue is that a typical Original Equipment Manufacturer (OEM) will produce numerous products, which are, more often than not, composed of hundreds of sub-assemblies/ subcomponents often supplied by

thousands of suppliers. In any one period, many thousands of Bills of Materials (BOMS), Materials Composition Declarations (MCDs), compliance declarations, and so on, will be generated through a supply chain in logistics transactions. Thus, while the first issue is essentially a knowledge management problem, the second concerns data and/or information management problems. However, in so much as the latter issues can be addressed by IS, the information asymmetry between OEMs and their suppliers cannot be easily solved. It is significant that practitioners appear to be ignoring what all they agree is the 'elephant in the room' when it comes to compliance management.

It is clear from the answers to research questions RQ2 and RQ3 that the majority of ECMS currently in use approach GRC from a data/information management perspective. In this scheme of things, complex regulatory instruments are reduced to simple lists of relevant regulations, controlled materials and substances, operating specifications, energy parameters, and so on, with consultants attempting to fill the knowledge gaps at great cost to adopters. Our findings indicate that while users such as product stewards and logistics managers may find comfort with such approaches, other users such as GRC and EH&S officers demand greater knowledge and understanding of the impacts of global regulations, present and future, and in real time—thus, they look for ECMS that support such activities.

The answer to RQ4, which helps achieve the second of this paper's objectives, provides a conceptual model and IS framework that should inform the design of an ECMS which addresses the systemic requirements of both the above types of users/adopters. In keeping with the role of exploratory case studies (Yin 2003), the conceptual model, related theoretical proposition, and the delineation of IS support for processes delineated in the model, may be used to inform future theory building and testing on the design and adoption of ECMS.

While the answer to RQ4 also informs practice, Fig. 4 elaborates on, and provides a practical synthesis of, the conceptual model and IS framework described above to present an overarching architecture for an ECMS. This model takes account of key enterprise-wide GRC processes (drawn from the process-based conceptual model) and illustrates how an ECMS might be integrated with internal and external systems. The architectural model assumes that a corporate GRC solution addressing SOX/Basel II compliance, information privacy, ethics and integrity, IT governance and other legal and regulatory issues has

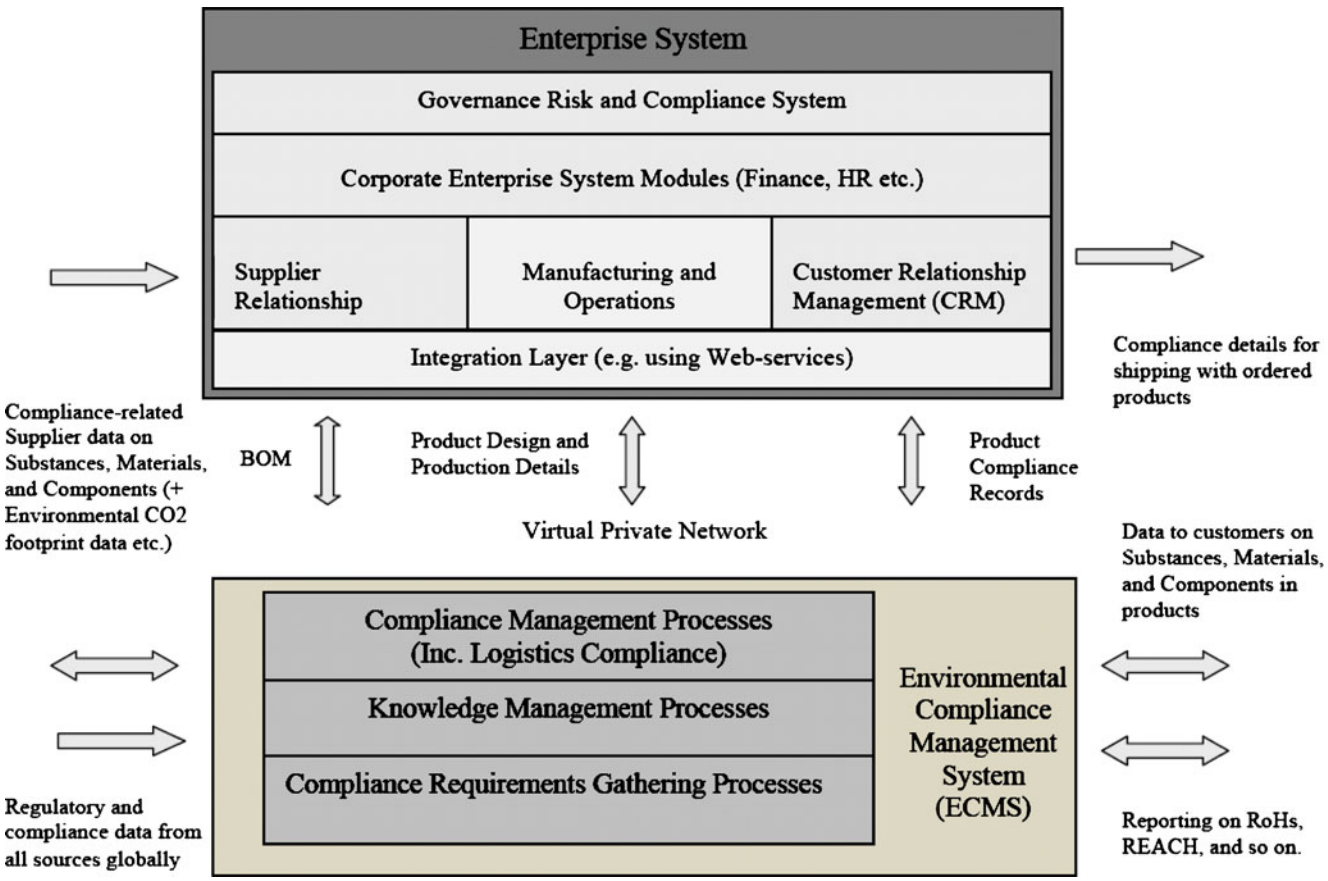

Fig. 4 An overarching ECMS architecture

already been integrated into the enterprise system. However, it is just as likely that such general GRC applications may be standalone solutions using a Service-Oriented Architecture (SOA), or hosted solutions using a combination of Web-services/XML, to integrate with an Enterprise System (cf. Taylor 2006). This point also applies the ECMS component, as another practical implication of the architectural model in Fig. 4 is whether this is a stand-alone off-the-self software package or a hosted solution offering software-as-a-service. Here, the total cost of ownership (TCO) and return on investment (ROI) will exercise the minds of business decision makers, as indicated previously.

Building on this last point, the findings indicate that the adoption of an ECMS, whether as a stand-alone package or as software-as-a-service, may have political consequences (cf. Markus 1983), as an IT function may wish to standardise on existing platforms such as SAP and employ EH&S, CfP and other modules. If GRC officers, EH&S officers, product stewards, and logistics people all have different compliance-related requirements, then there is the potential for conflict around the adoption decision and implementation, as different motives, rationales and alliances will inform the discourse surrounding the such decisions.

In conclusion, while the conceptual model and IS framework is aimed at researchers and GRC practitioners focusing on the electrical, electronics and IT sectors, we believe it is also relevant to the general category of GRC processes in all organisations in that the three core processes— Compliance Requirements Gathering, Compliance Management, and Knowledge Management —share many of the features required of, say, applications dealing with SOX/Basel II and IT governance risk and compliance. Thus, this paper has the potential to contribute to a wider body of research on GRC. This paper also contributes to emergent IS research in that it identifies the functions and features of a recently posited type of information system—a Green IS (cf. Boudreau et al. 2008). Finally, we believe that the architectural model presented in Fig. 4 has the potential to impact on practitioners' decision making, whether in the design or adoption activities, because as of early 2009, no systems vendor is offering the ECMS solution depicted in this model.

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