

# Adaptive Sustainable Enterprises: A Framework, Architecture and Implementation

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**Abstract.** Enterprises that want to compete in today's dynamic markets need to be able to respond to the ever-increasing rates of change. At the same time enterprises strive to be ever more sustainable in terms of economic, environmental, societal, and cultural concerns. Enterprises are being challenged at all levels to meet the demands for sustainability and in a manner that can handle the complexity that is present. In this paper we suggest that enterprises need to integrate sustainability objectives with adaptive approaches to manage complexity and uncertainty. The overarching objective of the research is to explore how an enterprise can become both adaptive and sustainable by interweaving the deliberate and emergent in the context of strategy, organization, process, and information. This research seeks to model and develop several artefacts that assist with responses to complexity and uncertainty while also supporting goals of sustainability. In particular, we propose context aware adaptive and sustainable concepts, framework, lifecycle, architecture, and a prototypical implementation.

**Keywords:** Enterprise · Adaptive · Sustainable · Strategy · Organization · Process · Information · Framework · Architecture · Lifecycle

## 1 Introduction

We live in a world that is characterized by complexity and uncertainty. Enterprises that want to compete in today's dynamic markets need to respond to ever-increasing rates of change. Simultaneously, enterprises are being challenged at all levels to meet demands to be more sustainable in terms of economic, environmental, societal, and cultural concerns and in a manner that can handle the ever present business volatility. The subject of organizational adaptation as a means to survive has been a research topic for researchers over the past two decades. There is a good amount of published literature that supports the theme of organizations being adaptive. However, this research goes beyond to explore how adaptive enterprises can incorporate the four dimensions of sustainability to become not only adaptive but sustainable as well. This research seeks to model and develop several adaptive enterprise artefacts that assist with responses to complexity and uncertainty while also exploring four dimensions of sustainability. The research explores the resources and constraints of an adaptive and sustainable enterprise. We will look into research lacunas of sustainability in terms of

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adaptive strategy, organization, process, and information while attempting to address the question; how can an enterprise become more sustainable and adaptive? And can it be done by interweaving deliberate and emergent aspects in the context of strategy, organization, process, and information? In the next section we first explore adaptive enterprises (Sect. 1.1) followed by an investigation of what it means to be a sustainable enterprise (Sect. 1.2). Integrating ideas, theories, and models from these two concepts we propose a model of an Adaptive Sustainable Enterprise in Sect. 2. The framework (Sect. 3), architecture (Sect. 4), and implementation (Sect. 5) that supports these theories, models, and concepts are the subject of discussion in the remainder of the paper.

### 1.1 Adaptive Enterprises

Scott-Morton [1] suggests that an organization can be thought of as a complex system comprised of interrelated forces that is constantly adapting to influences from its external and internal environment. This interrelated organizational system can be thought of in terms of strategy, organization (individuals and roles), process, and information. These elements, together with the influence of culture and the external socioeconomic and technological environment, enable an organization to function and evolve. Scheer [2] proposes a model which illustrates the intensity of control versus connectivity between internal and external organizational groups. He suggests that organizations with top down, hierarchical management structures have high levels of control and low connectivity. These organizations, although inflexible, succeed in stable environments and follow a deliberate approach. Conversely, organizations that follow an emergent approach are very flexible and reactive. Their levels of connectivity are high while control is low. Scheer [2] argues that the best place to be is on the edge of chaos where organizations balance flexibility and stability. This equates to a balance between the deliberate and emergent approach, which in this research we define as the adaptive approach. The adaptive approach is applied to the four key elements proposed by Scott-Morton [1].

### 1.2 Sustainable Enterprise

Sustainability is about the ability to continue, to endure, and to strategize for the present and future. In economic terms, that means an enterprise takes the necessary measures for it to stay in business. In terms of the influence an enterprise may have on the environment, to be sustainable means to attempt to be a caretaker of the planet, to maintain the natural world, and be responsible for not harming the environment. In terms of societal sustainability, it means an enterprise should make decisions based on the knowledge of how those decisions will affect people and society in general. Cultural sustainability encompasses ideas as broad as other cultures and basic human rights [3]. Many societies have cultural, religious, and community beliefs and practices that are very important to them. To be truly sustainable an enterprise needs to

successfully balance the four dimensions of sustainability, namely the economic, environmental, societal, and cultural dimensions.

## 2 Adaptive Sustainable Enterprises

There is little understanding of how adaptive and sustainable systems can be leveraged and interwoven with enterprise systems designed around strategy, organization, process, and information. There is sparse literature on how to design and support such systems along with their development. We propose a new model of an Adaptive Sustainable Enterprise that attempts to interweave the adaptive, sustainable, and enterprise dimensions in a seamless way (Fig. 1). The overarching objective of our research is to explore how, “an enterprise can become both adaptive and sustainable by interweaving the deliberate and emergent in the context of strategy, organization, process, and information along with enterprise systems that support the four main sustainability dimensions” In the following sections we explore each of these components in more detail. First, we explore the enterprise dimension (strategy, organization, process, and information) in terms of deliberate, emergent, and adaptive approaches. And finally, we explore how the four sustainability dimensions can be interwoven into the enterprise and adaptation dimensions.

**Strategy:** In rapidly changing environments managers struggle to develop an approach that allows an enterprise to maintain its chosen strategy while providing the necessary flexibility required to avoid organizational decline [4, 5]. Mintzberg, Lampel and Ahlstrand [4] introduced the idea of a strategy as consisting of two elements: deliberate strategy and emergent strategy. Deliberate strategy is when the enterprise develops a strategic plan that is realized as intended. Emergent strategy is an unintended set of consistent actions that form patterns of behavior over time.

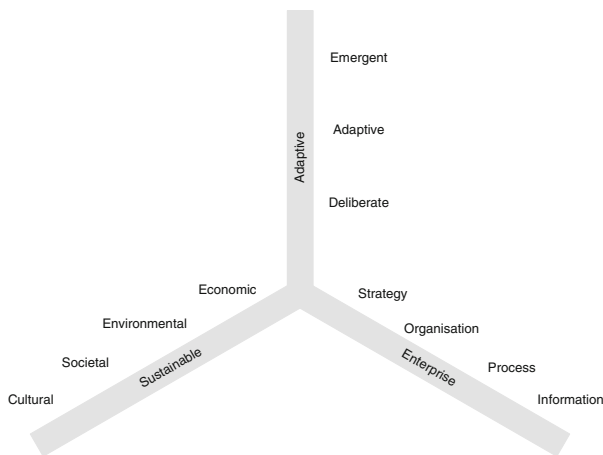


Fig. 1. Adaptive sustainable enterprise

The key concepts of a deliberate, intended strategy (plan and position) and emergent, unplanned strategy (as a pattern in a stream of decisions) are positioned at each end of the strategy formation continuum. Essentially, the main difference between deliberate and emergent strategy is the degree of intent about action. To create an effective strategy an interwoven adaptive approach is required that blends the deliberate approach with the emergent approach. It involves both intuitive and strategic thinking.

**Organisation:** An organizational structure exists for management and control purposes. It defines the work roles and how activities are grouped together [7]. Many enterprises are structured as functional organizations that support the deliberate approach [8]. An emergent organization structure is one where the enterprise employees interact with each other continuously. It allows for high levels of connectivity among individual members of the enterprise and with the environment. It is an extremely flexible structure that enables an enterprise to be reactive and innovative [9]. A matrix organizational structure supports both an emergent and deliberate management orientation. It consists of the horizontal management and control lines of a product orientated structure combined with the vertical lines of a functional structure. A matrix type structure supports an adaptive approach. It facilitates a project orientation and brings together the required expertise from different parts of the enterprise.

**Process:** Process is a way for an enterprise to organize work and resources to accomplish its goals [10]. Given that a business process exists to serve the customer, it can therefore be perceived as a key to remain competitive and sustainable. In dynamic business environments new business processes are constantly emerging [11]. In traditional enterprises the presence of rigid organizational structures and rules and a lack of communication and interaction mean work processes are set and people isolated. The management of processes is deliberate and the enterprise will be unable to react to change in a timely way. Conversely, there are enterprises with low levels of process control that are very reactive, connectivity between parties and the external environment is very high. They are constantly sensing the environment and trying to respond to change. Neither of these extreme positions is good. An enterprise should balance deliberate approaches to managing processes that support stable evolutionary growth with flexible approaches that support more opportunistic growth.

**Information:** Over the past twenty years enterprises have implemented enterprise resource planning (ERP) systems to support informational requirements. These ERP systems have replaced the stand alone business information systems applications in many enterprises [12]. They follow a very rigid structure and are predominantly based on a very deliberate approach to the management of the enterprise's transaction and business processes requirements. More common today are systems that support a purely emergent approach. These systems possess what is termed in literature and industry as an Event Driven Architecture (EDA). They enable event processing in real time and thus support an emergent approach. There are a number of systems architectures that support the adaptive approach. For instance, there are hybrid systems architectures such as Oracle's, which support both the emergent and deliberate approaches. These systems possess a whole host of components that explicitly support

the EDA paradigm and explicit components that support the deliberate approach through business process management. In addition, most enterprise system vendors are advocating the implementation of systems based on a service-oriented architecture (SOA), which is defined as “a technology neutral architectural concept based on generally re-useable services”. The SOA directly supports the adaptive approach.

In the following paragraph we explore how the sustainability dimensions of economic, environmental, societal, and cultural can be interwoven into the enterprise and adaptation dimensions discussed previously.

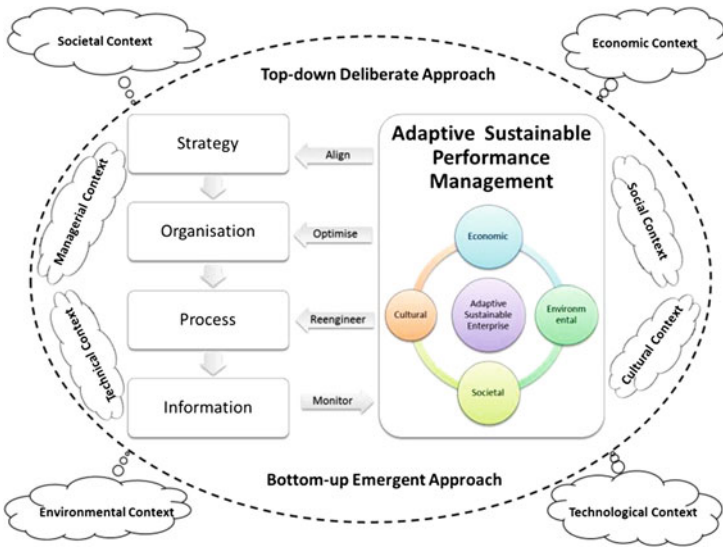
**Economic, Environmental, Societal, and Cultural Dimensions:** Truly economically sustainable enterprises are those with resilient visions, “built to last”. Our interpretation of what an adaptive sustainable enterprise is takes into account a local and a global focus, a deeper appreciation for the environmental, social, and cultural dimensions of sustainability along with the economic sustainability of the enterprise itself – the ability to continuously adapt and generate wealth. Social and cultural sustainability encompasses ideas as broad as other cultures and basic human rights. We can speak of social and cultural sustainability that promotes the capabilities of present people without compromising capabilities of future generations. Moreover, social and cultural sustainability is closely connected with economic sustainability. It relates to the internal and external stakeholders of an enterprise and the products and services it provides. The social, cultural, and economic dimensions of business involves the ability to attract, retain, and make best use of the skills and talent for the betterment of everyone involved on a community scale. Environmental sustainability involves the oceans, freshwater systems, land and atmosphere but following the sustainability principle of scale it can be equally applied to any ecosystem.

### 3 Adaptive Sustainable Enterprise Framework and Lifecycle

To synthesize the ideas proposed above and address the requirements of adaptive sustainable enterprises, we propose a framework and lifecycle approach that integrates ideas from management, operations, information systems, and computer science (Fig. 2).

**Context-Aware:** A key aspect of the framework is the emphasis on being aware of the context. The framework is cognizant of external and internal contexts from the economic, societal, environmental, and technological to the managerial and cultural contexts. Being aware of the context is crucial in being able to adapt in time. It is also vital in being aware of emergent phenomena – phenomena at the macro, meso, and micro levels.

**Deliberate and Emergent:** The framework integrates the top-down deliberate approach along with the bottom-up emergent approach into a middle-out adaptive approach. This approach balances the deliberate strategy and formal organizational structures, roles, and processes with emergent strategy and informal roles and processes. This interweaving at the edge of chaos between stability and flexibility is crucial for an enterprise to be adaptive.



**Fig. 2.** Adaptive sustainable enterprise framework and performance lifecycle

**Context-Adaptive:** The framework suggests that context is adapted through a sense-interpret-respond approach. The various contexts are sensed through a variety of mechanisms (formal and informal) and informational inputs (internal, external, structured, and unstructured). These are then interpreted by cybernetic systems made up of managers, analytical processes, and decision technologies. Based on the interpretation the cybernetic system responds at different organizational levels. This could either be an optimization of the organization structures and roles or it could be a reengineering of the processes or it could be an alignment or even a reformulation of the vision and strategy of the enterprise. The alignment, optimization, and reengineering are guided by sustainability principles keeping in balance the economic, environmental, societal, and cultural dimensions. Thus, the organization will adapt sustainably using a variety of mechanisms from organizational roles to processes to strategies and ultimately even the vision.

**Adaptive Sustainable Performance Management Lifecycle:** Beyond providing a framework the figure also illustrates a lifecycle approach whereby one could interweave the deliberate with the emergent through adaptive sustainable performance management. Adaptive sustainable performance management enables us to monitor the health of the enterprise (in terms of adaptively and sustainability) and correct, optimize, and align the organization, business processes, and strategy respectively on a continuous basis. Obviously an enterprise cannot achieve adaptively and sustainability overnight, it is an evolutionary maturing process. A cyclical process that involves (a) discovery and learning through information sensing, interpretation, and synthesis (b) strategizing (c) design of new and improved processes, organizational structures, and systems (d) transformation of the enterprise, and ultimately (e) monitoring and controlling in a holistic fashion.

### 4 Adaptive Sustainable Enterprise System Architecture

We propose an Adaptive Sustainable Enterprise architecture (Fig. 3) which realizes the proposed framework (Fig. 2) using context-aware technologies. In this architecture an adaptive sustainable enterprise is implemented through dynamic and open context-aware strategic management, business processes, and information systems. Business requirements and their support systems at different levels of an enterprise need to be addressed.

*Strategic Adaptive and Sustainable* planning and management requirements are manifold. They include the activities to create, manage, and change business strategies based on the goals derived from the vision and sustainability objectives. In the life-cycle of strategies, new strategies may emerge over a period of time. The emerging strategies need to be identified and integrated into deliberate strategies as adopted strategies. The implemented strategies are used to govern the business requirements at the lower levels.

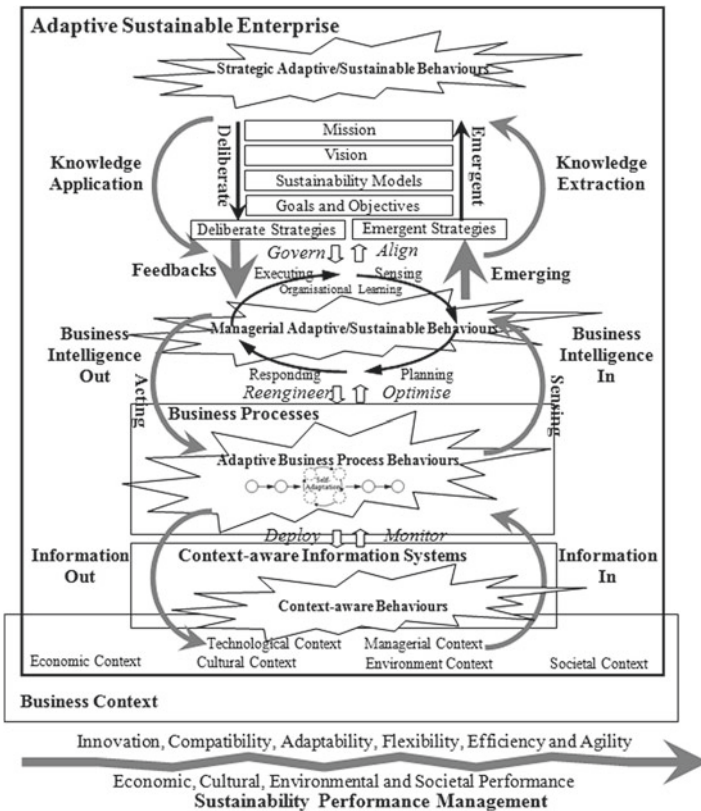


Fig. 3. Adaptive sustainable enterprise architecture



Integral to *Managerial Adaptive and Sustainable* operations is learning. Organizational learning involves single, double, and triple loop learning. Single loop learning involves reviewing operations to identify possible improvements in business rules. Double loop learning involves reviewing business operations and rules to identify possible improvements in organizational policies. Triple looping learning involves reviewing business operations, rules, and policies to identify possible improvements in strategies. These organizational learning loops are performed through Sense-Respond and Plan-Execute adaptive processes. The learning is implemented through adaptive business processes.

*Adaptive Business Processes* enable the business activities to be re-engineered easily and quickly in order to satisfy customers in a dynamic business environment. These business processes can be optimized automatically and manually to support and advance the enterprises sustainability objectives. Pre-set business rules and software agents support business processes to adapt automatically. Knowledge workers are also required to adapt business processes through manual interventions. The building blocks of business processes are enterprise services that are assembled and re-assembled into applications based on the contextual information collected from the internal and external environment.

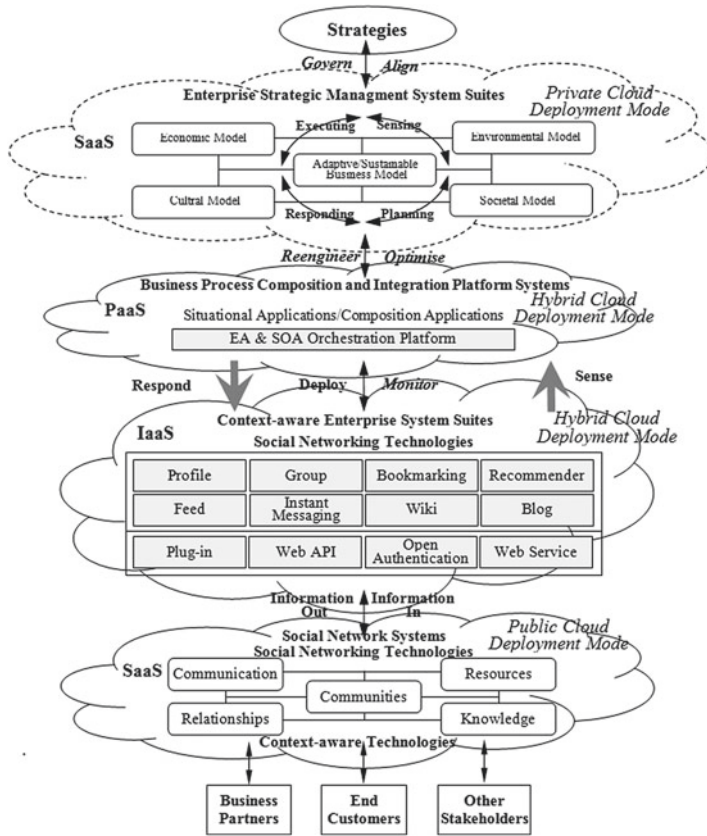
*Context-aware Mechanisms* continually monitor events and harvest information from business processes and the environment. Context aware technologies facilitate information collection and dissemination. Managers evaluate the performance of enterprise and make changes to rules and policies if required. This bottom-up review and interpret process is in response to emergent phenomena. The sense-interpret-respond process occurs at the micro, meso, and macro levels of the enterprise keeping in mind the sustainability imperatives. This culminates in the reengineering of processes, optimization of organization, and alignment of strategy. A prototypical implementation that exemplifies some of the key concepts espoused in the framework and architecture is described below.

## 5 Adaptive Sustainable Enterprise System Implementation

The adaptive and sustainability requirements of strategy, organization, process, and information in the framework and architecture are illustrated through a prototypical implementation. They are realized through utilizing cloud computing, service oriented architecture, social networking, and context-aware technologies. These technologies are used to build and deploy the (a) enterprise strategic management systems (b) business process composition and integration platforms (c) context-aware business activity monitoring systems, and (d) social network systems that in turn support the enterprise requirements.

The design of the prototype components is shown in Fig. 4. The *Strategic Adaptive and Sustainable* component and the *Sustainability Performance Management* component of the architecture are implemented by Software as a Service (SaaS) deployed on a private cloud. The *Managerial Adaptive and Sustainable* component are implemented by Platform as a Service (PaaS) deployed on a hybrid cloud.





**Fig. 4.** The implementation design of an adaptive sustainable enterprise

The *Adaptive Business Process* is realized by business process composition, integration, and management systems, which are implemented by Infrastructure as a Service (IaaS) deployed on a hybrid cloud. The *Context-aware Mechanisms* component is implemented by Software as a Service (SaaS) deployed on a public cloud.

The following systems and applications are used to build the prototype and to perform the business scenarios:

- Virtual workstation: VMware Workstation 9.0
- Host System: Ubuntu Linux 11.10 and Windows 7
- Cloud Computing platform: Openstack Nova Server and Windows Azure
- Business Process Application: ProcessMaker
- Web Services: Restful Web service
- Web Server: Apache 2.2.20 (Ubuntu) with PHP 5.3.6-13ubuntu3.2
- Database System: MySQL 5.1.58-1ubuntu1
- Social Networking Site: Elgg 1.8.1
- J2EE Web Application
- SAP Discovery System for SOA HP ProLiant ML370

A vertical prototype was implemented to validate the adaptability aspects of the architecture. The sustainability aspects of the proposed framework and architecture have been implemented as part of our ongoing research agenda into adaptive and sustainable systems.

## 6 Conclusion

Industry experts and academics have been researching and writing about adaptive and sustainable enterprise systems and how these systems can incorporate the core ideologies, values, and purposes that represent the enterprise as well as the processes and procedures to adhere to a sustainable future. From a practice perspective, the adaptive sustainable approach is still evolving to better support the enterprise dimensions of strategy, organization, process, and information. Virtually all of the literature on adaptability of an enterprise has focused on the economic dimension of sustainability only without much consideration of the implications for the environment or the effect on culture or society. This research takes a much wider approach to adaptability by incorporating all four dimensions of sustainability concerns into the mix. The significance of our research is that for an enterprise to be adaptable and sustainable it should focus on more than turning great strategy into great execution. An adaptive sustainable enterprise needs to interweave the deliberate and emergent aspects of strategy, organization, process, and information. Such enterprises will require systems that also support the environmental, economic, societal, and cultural dimensions of sustainability. Real sustainability occurs when the execution process and the strategy process are viewed as inextricably linked. In this paper we propose concepts and a framework, process, architecture, and system that attempts to proactively support an adaptive sustainable enterprise using deliberate and emergent mechanisms.

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