Agile Design of Sustainable Networked Enterprises

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Abstract. This paper reports on new agile approaches and methods for design modelling of collaborative networked enterprises, ranging from small manufacturing supply-chains to major public service organizations. Use-cases in selected fields have been implemented by agile modelling and holistic design of collaborative networking capabilities, and active knowledge architecture driven solutions. The active knowledge architecture is the knowledge base for collaborative planning, execution, validation, enhancement and reuse. Use-case projects are transformed from horizontally sliced, sequential activities supported by information flows to collaborative workspaces and knowledge-driven processes. Novel concepts, agile approaches, adaptive methods, open platforms, and emergent knowledge architecture-driven solutions are built and validated. The realization of agile workplaces and sustainable capabilities for collaborative networking open up for novel approaches to computing solutions. Use-case digital models to enhance human mental models and enable collaborative innovation and learning and competence transfer are implemented.

Keywords: Agile approach, Active knowledge architecture, Holistic design, Model-based, architecture-driven work environments, Sustainable solutions.

1 Introduction

Novel enterprise knowledge concepts, agile approaches, holistic design methods and digital technologies are now having disruptive impacts on most application areas. Improving the business and service delivery processes, capturing and visualizing information contents and flows, and supporting strategic decisions in IT governance have so far been the major focus of enterprise modelling and architecture frameworks.

Our focus has included holistic thinking, novel business models, and enhanced human capabilities and values, supported by emergent context-rich knowledge-bases, and implemented as Active Knowledge Architectures (AKA) [7, 9, 10]. User involvement in building application capabilities is supported by design modelling applying the Active Knowledge Modelling (AKM) technology rather than prescribing and programming applications and common data models and information sources [6].

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The reasons why most sectors are slow in absorbing novel approaches, methods and platforms are mostly due to the size of the organizations and the lack of practitioner and entrepreneur involvement in planning and design [1]. The fact that strategic and business objectives and values to be delivered are not visible to the developers of project platforms and methods are also barriers that must be removed. Users, stakeholders, designers and suppliers, and people responsible for operations and maintenance must be involved in design modelling across the entire life-cycle.

Enterprise modelling phases are redesigned as collaborative knowledge spaces and are now presented as agile approaches, adaptive methods, modelling principles and emergent platforms. The paper is composed of six sections:

Section 2, Towards the knowledge-driven society, summarizes the challenges facing Enterprise Modelling and Architecture. Section 3, Use-case pilots implemented, describes the use-cases implemented, the main objectives, and the capabilities demonstrated in these use-cases. Section 4, Novel paradigm-shifting concepts, describes the eight paradigm-shifting concepts discovered, implemented and validated in the use-cases. Section 5, Experiences and lessons-learned, summarizes the experiences and lessons-learned across all industrial and public use-cases. Section 6, Summary and future projects, describes business potentials and possible paradigm-shifts in ICT and digital technologies and human sciences.

2 Towards the Knowledge-Driven Society

Societies and public service organizations currently perform research and innovation based on traditional ways of working and organizing work and information flows.

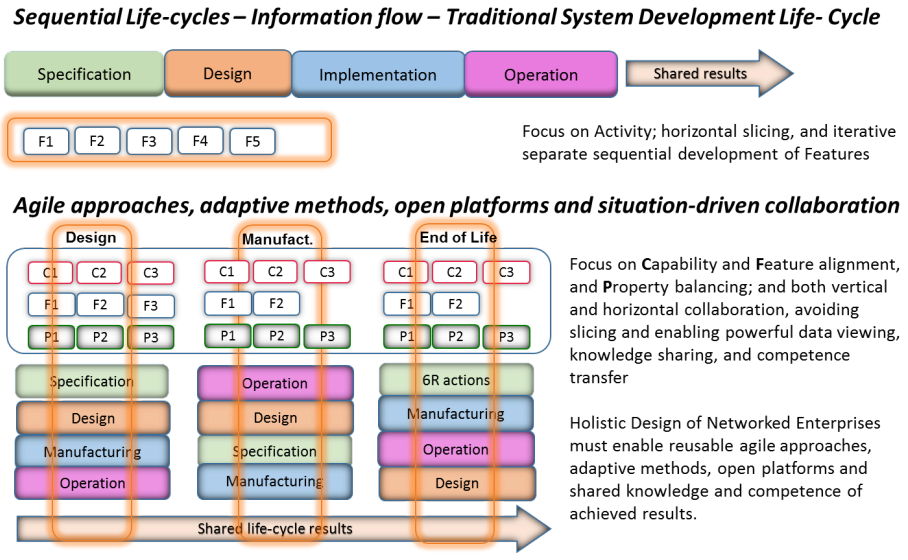

Figure 1 Emergent networked enterprises will be based on knowledge sharing.

How this traditional thinking have to change to let us relax hierarchic organizations and remove collaborative planning and design barriers is illustrated in Figure 1.

2.1 The Modern Networked Enterprise

Future enterprises must be able to participate in multiple simultaneous networks, ranging from research to collaborative partnering and customer delivery. Transforming data and information to knowledge by linking sources to role-specific workspaces, and eventually to architectures to drive collaborative innovation and learning across life-cycles must be supported. Practical approaches, work environments, and pragmatic learning must get much more attention from research programs and academia [1].

Capturing data and information sources, turning data into knowledge, linking it to workspaces for training and work execution will aggregate experiences and drive new methods, and feed continuous innovation and learning. Continuously enriched workspaces constitute what we call the pragmatic learning process. Collaborative networking will simplify work planning and execution and support continuous innovation and learning.

2.2 Capitalizing on Enterprise Knowledge Spaces

The discovery of enterprise knowledge spaces and workspaces [6, 8] has introduced a third organizational structure, the role-based organization, complementing the hierarchy and networking teams. Roles and their workspaces enable us to easily create data- and situation-driven collaboration and continuously capture and update data, information and knowledge from local context-rich work environments and situations.

Enterprise knowledge should be modelled in role-oriented workspaces and knowledge spaces composed of reflective views, repetitive task-patterns, repeating sources, and reusable models [7, 9]. Practitioner participation in project planning and design are challenges to be focussed on as they are important for our democratic services. The ultimate goal of sustainability is that the knowledge expressed in the design and production of a product or service can be replicated and adapted to new environments.

3 Use-Case Pilots Implemented

Present enterprise practices and management solutions are developed by consultants, ICT people and vendors focusing on data capture and document flows, and are not taking advantage of the AKM discoveries and technologies to capture practical workspaces and knowledge spaces [9]. Paradigm-shifting pilots were implemented in EU projects Athena, MAPPER and Co-Spaces, building aerospace and automotive use-cases, in projects for the oil and gas industry, and in public projects for the Norwegian Road Authority, and the Health-care Services.

3.1 Road Planning and Building

The Norwegian Road Authority (NRA) is responsible for all road planning, building and maintenance in Norway. Projects are based on 153 handbooks of road building principles, best practices, and experiences collected by the NRA planners involved.

A specific section of the E6 Motorway was selected as use-case for modelling a first road knowledge architecture [10]. An overview of the modelled architectures is shown in Figure 2. The left hand side of the model contains generic information that applies to all roads. This information was obtained from the relevant handbooks and discussions with NRA planners and experts. The right hand side of the model contains the actual road-case, i.e. contents specific to the particular part of the E6 Motorway.

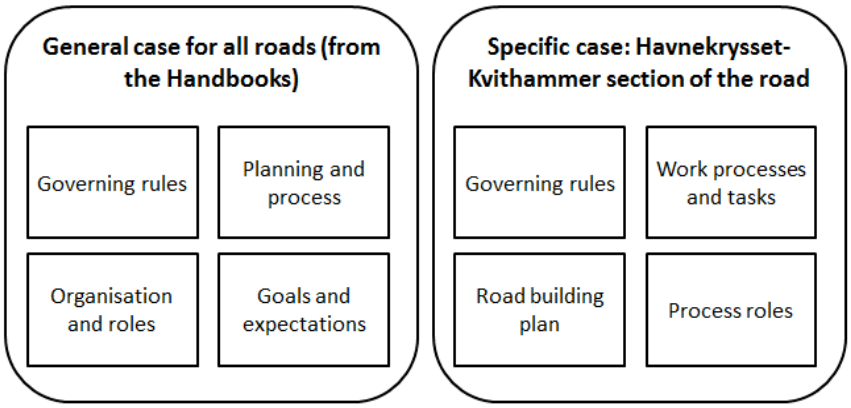

Figure 2 Modelling the planning and building knowledge architectures of roads.

The planning architecture and the specific use-case architecture, depicted in Figure 2, are composed of reflective knowledge dimensions, aspects and views. Design modelling to exploit visualization and the capabilities enabled give the planning and building projects ground-breaking new collaborative capabilities and benefits.

3.2 Healthcare Process Design Modelling

Current projects are based on business process and management activities. Best practices and experiences from treating patients are not yet included in the planning and operational architectures. There are many gaps between the ambition and planned services and solutions that present technology and methods are not able to close.

The Future Operating Model [13] must capture best practices derived from experiences, technological development and regulatory requirements etc., and show the ambitions and plans - on a general level. Knowledge models and architectures will be improved and used for future planning and operation.

3.3 Oil & Gas Production Planning

The major pilot project in the oil and gas industry was performed in 2009. A more detailed description is found in [9]. The intention was to fulfil these major objectives:

- Enable continuous supplier work planning and follow-up of production
- Improving collaboration and knowledge sharing and reuse across projects

The core active knowledge architecture contains models of many product and organizational aspects and process capabilities. Models of roles and responsibilities, the business, work processes, methods and results exchanged, and of the platform configuration are added. Model-Based Architecture-Driven (MBAD) workplaces enable agile approaches, collaboration and autonomous knowledge processing.

4 Novel Paradigm-Shifting Concepts

The experiences from the use-case pilots have lead us to eight paradigm-shifting concepts that will enable the generation of collaborative platforms for all life-cycle actors to design novel approaches, methods, platform capabilities, and solutions to meet growing needs and challenges, but also to pursue new business opportunities. The most important concepts enabling agile approaches and emergent solutions supporting concurrent enterprise design and operations are:

1. *Role-oriented Organizations - capturing work-centric contexts*
2. *Enterprise Knowledge Spaces - multi-dimensional spaces simplify modelling, collaboration and property parameter management*
3. *Context-rich Workspaces – enabling simultaneous model-based workplace design and execution*
4. *Active Knowledge Architecture (AKA)- integrating approaches, methods, services and platforms*
5. *Model-based, Architecture-driven (MBAD) Workplaces - configuring agile solutions*
6. *Holistic Design Methodology– working top-down, bottom-up and middle-out*
7. *Concurrent Modelling and Operation – close the gaps in design and execution*
8. *Visual Work Environment – simplifying networked collaboration*

The major concepts, their properties, enabling capabilities and business impacts will be briefly explained in the following sub-sections.

4.1 Role-Oriented Organizations

Existing organizations, composed of hierarchies, networks or static collaborating teams, were never designed to fit the design, manufacturing, customer usability and life-cycle support services of products and operational services for future demand. The people assigned to roles must be supported by agile MBAD workplaces, allowing them to perform at-the-workplace design modelling and task execution, closing the gaps between planning, design and execution.

4.2 Enterprise Knowledge Spaces and Context-Rich Workspaces

Smart networked enterprises cannot be built by application software systems alone, and adaptive services cannot be delivered by current methods. Future development, use and value of ICT will be managed by externalizing and sharing situated enterprise knowledge and reusing role-oriented workspaces, knowledge models, emergent networking architectures, and architecture-driven workplaces. The nature of practical knowledge spaces and workspaces must be exploited by users applying graphical modelling to capture work-centric local context. Graphic modelling of work-sensitive data and context enable humans to express their tacit knowledge as workspace models, enhancing their mental models for improved local work execution, coordination, collaboration and work management [3,4, 6].

4.3 Active Knowledge Architecture

An agile holistic design approach, based on the AKM discoveries, concepts and methods, will provide practitioners with model-based workplaces, the required adaptive visual working environment, and the methods and capabilities needed. The Active Knowledge Architecture (AKA) is based on holistic design, agile approaches, novel design principles, and active models of enterprise knowledge spaces and role-oriented workspaces. Visual modelling and new design methodologies enable new approaches to application solutions, whatever the application is.

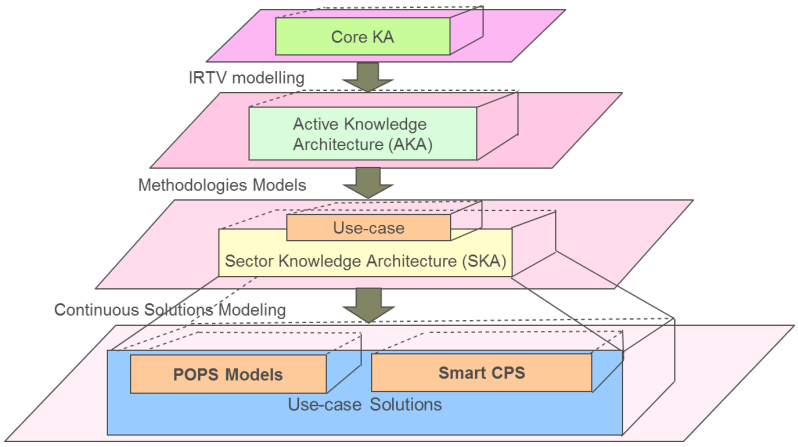

Figure 3 Levels of AKA development, operation and management

The Core Knowledge Architecture (CKA) is common to all knowledge architectures across sectors, methodologies and platforms, see Figure 3. By graphic modelling of knowledge spaces, applying the Information, Role, Task, and View (IRTV) language, the design of sector specific AKA is supported. Adding active models implementing agile approaches, adaptive methods and core roles and their workspaces, builds networked enterprise reference architectures.

4.4 Holistic Design

Holistic design is more than a simple move from the modern to the post-modern, as it represents both an ontological change in the consideration of organizations and an epistemological shift in our understanding based on Cyber-Physical Systems (CPS) and emergence. The people involved in enterprise design and management must adopt holistic design thinking, and become familiar with the AKM concepts, modelling principles and the collaborative product and process design methods.

Holistic design implies separate modelling of properties and their domain parameters. Modelling top-down to support planning and control, bottom up to capture work-sensitive data and context, and middle-out modelling to balance property parameters and capabilities across disciplines and partners, see Figure 1. Supporting conceptual design and design embodiment require novel fine-grained graphic modelling and support for novel IRTV modelling principles and constructs.

4.5 Concurrent Modelling and Operation

Capturing role-specific workspaces and knowledge spaces, applying holistic design methods, is performed by teams interacting and collaborating to influence the shared active models of approaches, methods, application domains and aspects [3]. Modelling for design will create conceptual objects, properties and domain parameters, capabilities, features and collected data in separate views, supporting design embodiment and creation of designed configuration and collaboration rules. Building and operating classes and categories of knowledge assets will be facilitated. So current gaps in life-cycles, modelling and execution, and in design and operation can be closed, and users can experiment with variants and families of solutions.

4.6 Visual Work Environments

Visual work environments allow users to observe and monitor status of work at related human and digital roles. Traceability, decision-support, predictability and assessment of trends and situations will give users enhanced capabilities to deal with uncertainties and risks. Powerful architecture-driven viewing of task-specific and common business situations provide effective support for collaborative design and execution, knowledge elicitation and overall knowledge and asset management.

5 Experiences and Lessons Learned

Many experiences, pragmatic methods and design modelling principles enhancing enterprise design and operation are derived from extensive collaboration between practitioners, engineers and modelling experts. The most important experiences and lessons-learned are described in the following. The discovery of enterprise knowledge spaces and design modelling of active knowledge architectures of kinds of enterprises has been the main contributions from the use-cases so far implemented.

5.1 Business and Organizational Challenges

Current hierarchic and networked organizations are not able to capture local work-centric context and pragmatics, such as considerations for environmental changes, method adaptations and overall enhancements. This is dependent on role-oriented organization structures and their workspaces, enabling holistic design and support of reflective views, repetitive task-patterns, reference templates and reusable models. This has high potentials for improved business models.

5.2 Human and Innovation Challenges

Configuring, adapting and reusing workspaces and knowledge spaces for training, learning and experimentation will enable students and researchers at any age to learn from the best practitioners. The knowledge assets of enterprises must be modelled and used to support execution to provide the capabilities demanded. Workspaces are the most context-rich work environments, where properties, capabilities and services are designed. In order to express the contents and the dependencies between them or dependencies and rules designed by users we must provide users with fine-grained graphic modelling tools and methods [2, 3, and 4]. Agile enterprise architecture, enterprise knowledge spaces and workspaces are described in more detail in [2, 6].

6 Summary and Future Projects

Future industrial collaborative networking applications should be based on visual modelling of roles, work environments and emergent knowledge architectures, involving stakeholders and users. A pilot AKA is the first target for any networked enterprise initiative. The scope of the pilot, core knowledge to be captured, roles affected, and competence and skills of teams involved must be captured to enable new tasks and local knowledge modelling. Stakeholder perspectives of capabilities, services, concerns and performance parameters may be needed, and are easily included in holistic design modelling of workspaces. This emergent agile approach enables users to build and adapt their own workplaces and ICT applications.

Practical work logic, parameter dependencies and working contexts cannot be prescribed and coded, so software applications have limited life-cycle flexibility and support for collaboration and harmonizing design solutions. The AKM approach uses software components to implement generic and easily adapted capabilities. Data- and knowledge-driven application domains must be captured by collaborative modelling using the IRTV language, supported by software components as generic enablers.

Visual work environments, models and knowledge architecture elements, are key assets for the coming knowledge and digital economy. All networked enterprises will eventually need to be proactively designed, and in this vein, continuous learning and innovation will be a decisive factor for commercial and technical success, but so will also classes of standardized proven knowledge elements that can be referenced and

reused whenever required. Present approaches to emergent Enterprise Architectures (eEA) and building of sustainable product life-cycles, will greatly benefit from enhancing the present EA frameworks by adopting the AKM approach and methods.

6.1 Exploiting Visual Collaborative Landscapes

Visual landscapes, supported by active knowledge architecture, facilitate concurrent distributed team composition, competence transfer, knowledge management as well as capability and services composition. The MBAD agile approach will remove interoperability barriers and have revolutionary impacts on existing approaches, methodologies and solutions to product, organization, process and platform design and operations across industries and public domains. People involved in networked enterprise design, development, operation and management must adopt holistic thinking, and become familiar with the AKM approach, methods, concepts and practices. The limitations of natural language, document flows and current systems development must and can be removed. The MADONE network, see http://www.MADONE-network.org is established to help build collaboration environments, methods and demonstrators to support projects.

6.2 Design Modelling Principles

Thirty-six modelling principles have been proposed and tested for validity across the implemented use-cases [6]. The majority of these principles were discovered in the MAPPER project, and are published [6]. We are working to redesign, extend and validate the components of the methodologies previously developed and the design modelling principles supported by an open modelling and execution platform.

6.3 Future Projects

The success of future projects will depend on the capabilities and methods implemented in extensible, architecture-driven collaboration platforms, and on use-cases built by and involving leading competence and skills. Capabilities are needed to allow projects to build their own knowledge models of products and processes, organizational roles, and business and work environments. Visual knowledge models of these aspects must be built by involving users modelling their own graphic symbols and enhancing the IRTV modelling language. Our experiences regarding role-orientation and user participation are supported by other researchers [1, 11, 12], for example, in their experience reports using agile enterprise modelling methods. The importance of a clearly stated mission, of team composition and in particular the role of the facilitator, and the importance of adequate tool support is emphasized. Furthermore, the need for combining modelling language and adequate modelling

principles are underlined, which fits our view that meta-models and modelling capabilities and processes should be adjustable before and during use-case modelling.

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