Holistic Design for Continuous Innovation and Sustainable Knowledge bases

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Abstract. Industry is facing the fourth revolution being forced to move from horizontal and vertical activity-sliced flows to instant data- and situation-driven communication and collaboration. To serve new markets and customers industry must deliver sustainable products and services to stay competitive, and new knowledge assets, design methodologies and ICT capabilities must be designed and implemented. Companies must be able to simultaneously participate in many diverse networks performing R&D in parallel with learning and innovation, business operations and customer service delivery. Novel digital innovations are driving demands for sustainable life-cycle capabilities. To meet these all actors involved must embrace new knowledge concepts enabling agile approaches to emergent solutions, and building open platforms to enhance human communication and collaboration. Agile approaches to holistic design depend on sustainable knowledge bases, built as active knowledge architectures. Prototypes have been built for life-cycle support, and best-practice reuse. Industries must be able to adapt data, knowledge, capabilities and services to new customers, and take care of environmental footprints and human preferences. Present horizontal and vertical flows are replaced by data- and situation-driven collaboration supported by effective knowledge sharing.

Keywords: Sustainable Knowledge bases, Business and Collaboration Models, Role-oriented Organizations, Active Knowledge Architecture, and Model-based, Architecture-driven Solutions.

1 Introduction

The purpose of this paper is to communicate new concepts, agile approaches, holistic design methods and emergent ICT platforms, enabling industry to implement new business models, sustainable knowledge bases and user-configured capabilities. Innovation and learning, communication and collaborative operations across industry, public sectors, academia and societal organizations will be enhanced and simplified.

The present systems and knowledge bases of industrial companies are not able to support collaborative networking, and dealing with the growing complexity and the impacts of change. Separate technology domains and projects for implementing Big Data, the Internet-of Things, Cyber-Physical-Systems, and Smart Services for monitoring situations must be federated. Users must be able to effectively exchange data and information, share knowledge and results, and transfer work environments with competence, experiences and lessons learned.

Novel enterprise concepts, approaches, methods and digital technologies have been innovated [4, 5] to enable new capabilities, but communication and collaboration across life-cycles and value-chains is not yet supported. Improving the business processes and knowledge bases of organizations, capturing, enhancing, and visualizing data, information and knowledge are huge common needs and challenges. Managing business and human knowledge assets, supporting decisions, and orchestrating project control and validation are the most critical application areas for implementing model-based, architecture-driven solutions applying the AKM technology [1,7]. Industry, in particular the aerospace and automotive sectors, have been very active participants in networked enterprise R&D projects, but only recently have other sectors and suppliers become involved in innovation projects.

2 Novel Knowledge Technology

Enterprise Modelling accelerated from the early 1990s with the implementation of Popkin's System Architect [2] and the METIS modelling tools [3]. The first ten years were spent using these tools to develop customized Enterprise Architecture (EA) frameworks and reusable knowledge bases. The goals were creating more specific contents to the Zachmann framework, published in 1988, and more values to the customers. The first versions of TOGAF had strong contributions from both Popkin and METIS founders, architects and tool developers.

A major issue with the EA framework perspective is that enterprise architectures are considered static, and their blueprints are unchanged unless purposefully revised. This view does not account for enterprises as emergent, complex adaptive structures, systems and organizations that require an agile design approach. Enterprises emerge out of the communication patterns that develop in the course of doing business and in response to environmental variables in dynamically changing business landscapes.

Contrary to the objective view is the recognition of organizations as complex adaptive knowledge models and systems that give rise to considerations of emergence, leading to a recent definition of "emergent enterprise architectures".

2.2 What is Holistic Design

Holistic design and management of changing situations and creative environments involving human collaboration and interaction must embrace agile architecting, and continuous learning and innovation, requiring new design and working concepts and methodologies [10]. Holistic design methods, collaborative life-cycle knowledge management, model-based, architecture-driven workplace composition, and learning and innovation have been developed in research projects since 2007 [4]. However, more innovation projects are needed to validate applicability and benefits. Holistic design will cover these life-cycle knowledge spaces and dimensions:

- Product design and manufacturing methods for sustainable operations and reuse.
- Enterprise roles and their workspaces, and collaboration spaces and shared views.
- Holistic process modelling to balance property parameters and building rules.
- Extendable platforms, based on agile approaches to network collaboration.
- Data and task dependencies as design, composition and configuration rules.

These are interdependent knowledge aspects that require continuous graphic modelling and agile approach to AKA designed networked enterprises. Holistic enterprise design, as illustrated in Figure 1 implies working top-down, bottom-up and middle-out, and focusing on workspace tasks and views changing with the expanding scope of design, and the problem and solution spaces. The top-down decomposition of objects and tasks, the bottom-up aggregation of tasks, their parameter values and dependencies, and the middle-out balancing of parameter values between disciplines and components are key principles of holistic design methodology.

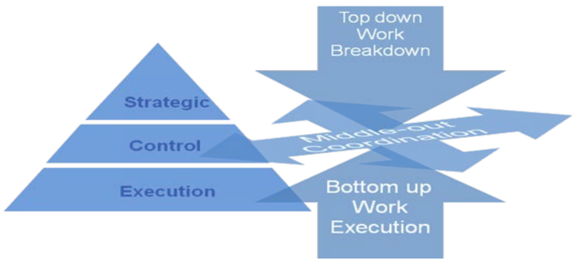

Figure 1 - Communicating dependencies of parameters and actions as agile rules.

Conceptual design must support users defining and experimenting with new ideas, separately modelling properties and parameters, and expressing relations, rules and dependencies as task-patterns. Planning, economy and quality control, and other management aspects employ methods that are mostly based on top-down decomposition, while practical dependencies, decision-making and work processes are decided by bottom–up aggregation of parameter values. Business and engineering methods work middle-out calculating and balancing discipline specific property values of alternative component and solution configurations.

Holistic design is performed by teams of enterprise architects, methodology experts, and users, supported by agile architecting methods and practitioner-driven approaches. The categories of models must be semi-autonomously maintained, built by and reused from workspaces in role-oriented AKA. Agile approaches are implemented as Model-Based, Architecture-Driven (MBAD) workplaces. At-the-workplace capabilities for human and digital actors to add and update data and knowledge, and capture pragmatic logic, dependencies, rules and context-rich workspaces are enabled by MBAD.

2.2 What is Active Knowledge Architecture?

Top-down management perspectives with object-class information structures and standardized data-models dominate knowledge capture and sharing in current systems. This gives us important system perspectives, but it does not capture the local work-sensitive contexts, alternatives and dependencies. Knowledge from many perspectives must be interrelated in active models allowing users to capture local contexts, manage data across tasks, adapt and support holistic design methodologies, and implement collaborative networking across processes and ICT platforms.

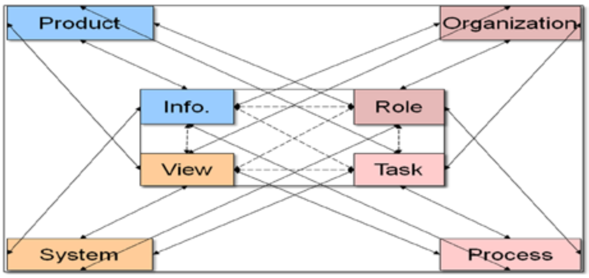

Figure 2 - Workspaces are modelled by IRTV methodology, giving executable models.

Context-rich workspace models are created using the IRTV language as illustrated in Figure 2. The workplace models are composed of contents that focus on the roles (R), their main tasks (T), supporting views (V) and relevant information elements (I). As architecting work is performed, context and content emerge, and the workspaces of Products, Organizations, Processes and Systems – POPS are captured by IRTV modelling.

Some of the advantages of developing an Active Knowledge Architecture (AKA) capturing agile approaches and building emergent AKA are:

- Enable model-based solutions, closing the gaps between design and execution
- Support work in context, modeling emerging workspaces and knowledge spaces
- Support roles and agile model-designed workspaces of work-sensitive knowledge
- Capture local nuances, practices and rules and rich context
- Giving users control over data, information flows and viewing
- Give control of IT solutions and services composition to practitioners
- Building extendable networking platforms supporting new partners
- Extend and integrate method and knowledge bases with pragmatics
- Integrate and provide role-specific operational as well as common views
- Enhancing human learning by combining mental and digital models
- Produce event- and situation-driven communications and views

An AKA captures the architecting workspaces modelled to support collaboration among architects and users, and the active models of operational enterprises. An AKA is the richest enterprise knowledge base that is currently known [6].

3 Use Case Examples

Five industrial pilots have since 2005 been prototyped to verify the agile approach and methods, and validate the user benefits of the Active Knowledge Modelling approach and methods [7]. The building and exploitation of Active Knowledge Architectures are explained in two use-cases, one from automotive system design and manufacturing and one from oil and gas project execution and management.

3.1 The Kongsberg Automotive Seat Heating use-case

Kongsberg [4] wanted to develop new solutions to enable sales people and designers to provide fast and safe customer responses, provide correct specifications, improve knowledge reuse, avoid repeating mistakes, and enable repeated successes. The expected benefits were to cut lead times by at least 30%, IT costs by 50%, and to avoid redesign, design changes and quality problems. Figure 3 shows the contents of the solution model for seat heating, developed by a team of product designers, and modelling and workplace engineers. It is a core model used to compose and configure the initial workplaces. More specific product structure and aspect models were built.

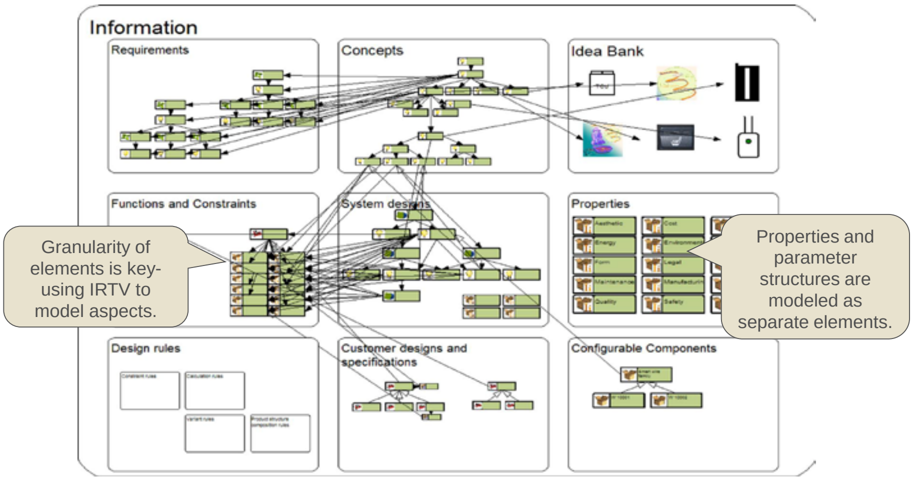

Figure 3 – The early layout and contents of the seat heating solution model.

Other models needed to design and configure role-specific workplaces are models for configuration and behaviour, and communication and collaboration services. The overall solutions model is the responsibility of the product designers and engineers, and can be updated and modified each time new customer solutions are specified.

After four months of modelling and platform building, prototype workplaces were deployed for user involvement and evaluation; one for material specifications, see Figure 2, one for customized product design with focus on configurable components, illustrated in Figure 3, and one for each system element delivered by suppliers.

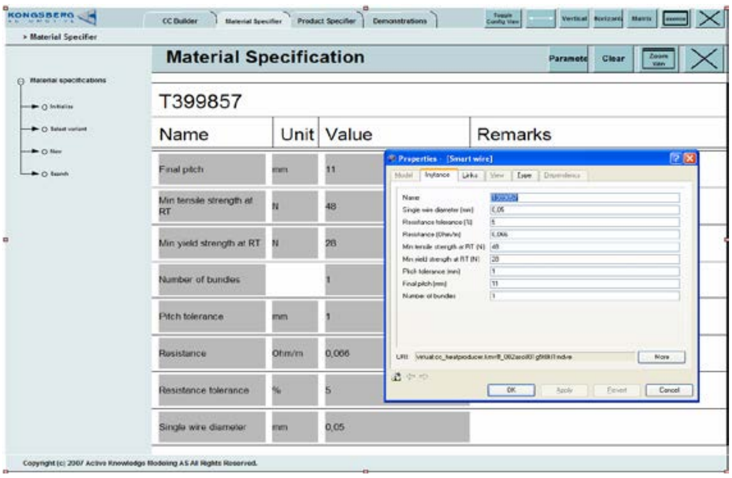

Figure 2 – Workplace for seat-heating designer proposed material specifications.

The workplace for heating element design, giving the “sales consultant” and designer the necessary dialogue to specify and evaluate customer requirements is shown in Figure 3 below.

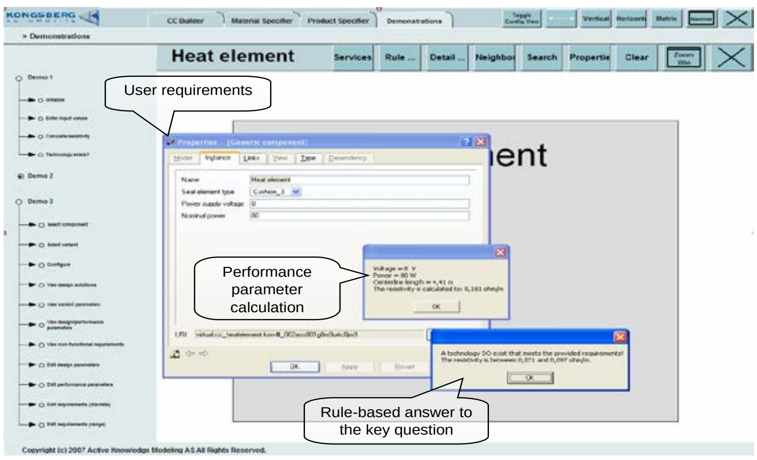

Figure 3 – Workplace for seat-heating and configurable component design.

During the four months period of modelling and development the model-building team discovered and resolved many issues. The most significant solutions being:

- New method for definition of product parameters and their value determination.
- Designers were able, from their workplaces, to define parameterization rules independent of the work processes applying them.
- Configurable product components, integrating many of the currently disjoint product structures was easily expandable to include other life-cycle aspects.

The IRTV methodology provides rich work-sensitive context. POPS denotes the knowledge dimensions of innovation team workspaces and collaboration environments. Figure 4 below shows the workplace for seat heating design, based on parameterized configurable components, applying colours to communicate design rules, analysis and design conformance.

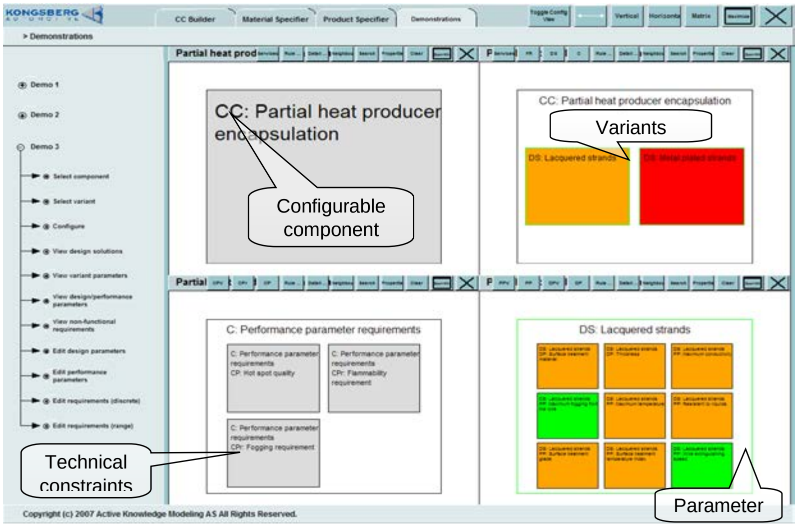

Figure 4 – Workplace for seat-heating element and overall system design.

Coherent product solutions, coordinated actions and collaborative workplaces for customers, seat manufacturer, Kongsberg and suppliers were prototyped, but never implemented.

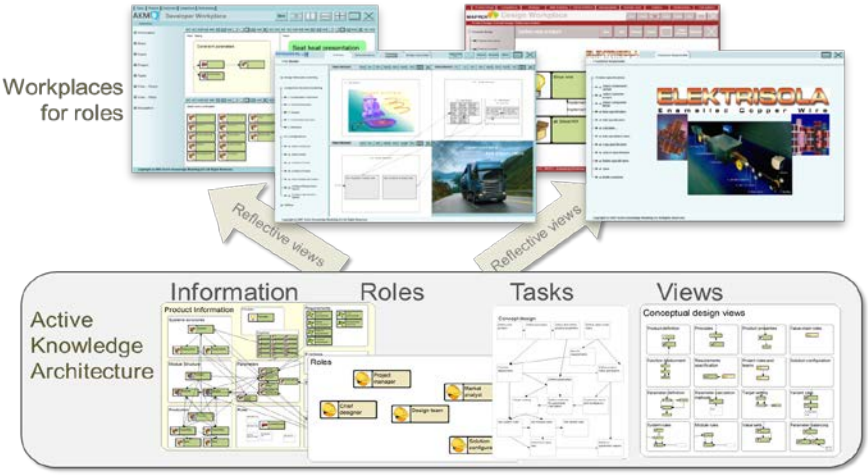

Figure 5 – Solution workplaces for seat-heating element and overall system design.

The prototype solution and workplaces, depicted in Figure 5, was demonstrated on several occasions, and great reductions in calendar time, errors and change management were validated. Qualities and choice of variants were rapidly agreed. Involving the seat manufacturer the seat heating system provider, and suppliers could reduce elapsed time design and manufacturing from months to days.

To deliver the overall system solution the teams, in parallel to building the customer solution model, developed models and services for these workplaces:

1. The Model Builder Workplace which can be enhanced for customer partner teams.
2. The Workplace Builder Workplace, for building and extending user workplaces.
3. The Knowledge Architect Workplace for reference models and templates.
4. The Methodology Developer Workplace for new and adaptive methods building.
5. The Platform Integration Workplace for integrating systems and linking services.

3.2 The Aker Solutions case

The oil and gas field engineering pilot, focusing the production phase, and three of the main roles involved was developed in late 2009. As indicated in figure 6, the main pump area, the piping disciplines involved, and their parameter-value dependent engineering rules and business aspects were first modelled.

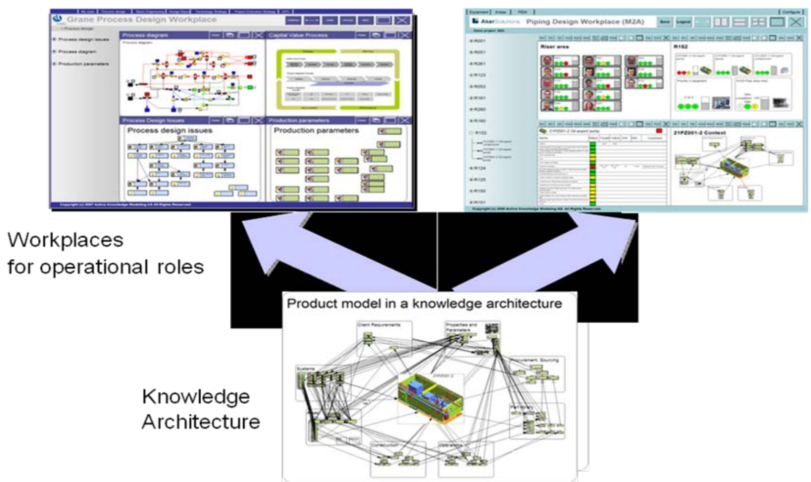

Figure 6 To start AKA development the initial scope of work should include roles and tasks where the client users have their core competence.

The workplace models are composed of contents that focus on the roles, their main tasks, supporting views and relevant information elements. The next step was to focus on collaboration and communication to manage key parameter value dependencies modelled in the product models, and then to create the overview for the roles involved. To achieve one-click drill-down a commercial Business Intelligence tool was selected, the workplace models were adapted to integrate and support the tool.

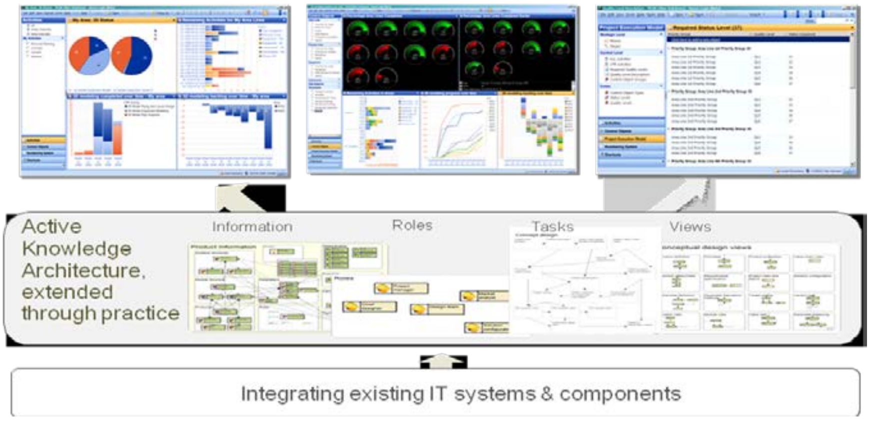

Figure 7 From left: - piping engineer, area manager, and methodology manager.

The three workplaces shown in Figure 7 were generated from the refined piping application and workplace models. The AKA supports novel design principles, self-adaptive methods, and enables agile spontaneous collaboration. The objectives of visual collaboration and coordination to improve work planning, monitoring and execution are achieved using IRTV modelling methodology to capture rich workspace contexts, modelling roles, tasks, views and contents of information sources.

3.3 Lessons learned

Practical approaches, methods, competence and working environments are not given priority by the majority of researchers in ICT and engineering disciplines. Conceptual design of adaptive products and autonomous processes for sustainable life-cycles, are just two examples of industrial application areas where current application systems development is not able to provide satisfactory solutions. Public sectors, military operations, police investigations and disaster management have similar strong demands for inventing new ways of working with computers and digital technologies.

To meet these and other challenges designers, architects and users must adopt an agile approach to emergent Enterprise Architecture (eEA)[i] and operational solutions development enabling human actors to gradually unveil and share knowledge about events and situations. Architects, designers and developers must be able to respond to the growing variety, emergence and complexity in markets, customer demands, economies, strategies, competences and capabilities. Agile approaches, replicable models of methods and applications, adaptable services, and autonomous architecture-driven workplaces must be made available to SMEs without requiring heavy investments in systems development, ICT hardware and software, and with no dependencies on ICT vendors.

4 Industrial Challenges and Innovations

The results and practical experiences from research and innovation projects in most industrial and public sectors have contributed to new agile approaches, methods, knowledge bases and work environments:

a. The Norwegian Oil and gas industry - exploring oil and gas fields [5].
b. The Norwegian Road Authorities - designing and building roads [6].
c. European R&D projects for capturing practical work-centric knowledge [4, 8].

A common objective of these projects was to develop and evaluate an agile knowledge base, supported by Active Knowledge Architecture (AKA), and driven by agile work environments for product design, manufacturing and operational services. Across any sector, we capture many aspects of each role-oriented work environment involved, aspects involved in different planning, work execution, innovation and learning and monitoring processes. This means working top-down applying activity slicing to support Cost, Time and Resource (CTR) analysis, bottom-up to capture workspace models for context-driven execution, and middle-out balancing for best-practise solutions across disciplines and practices. Novel methods for work process alignment and execution have been innovated as illustrated in Figure 8. Bottom –up IRTV modelling allows the capture of parameter-value dependencies as task-patterns. Instant collaboration and holistic design can thus be autonomously orchestrated.

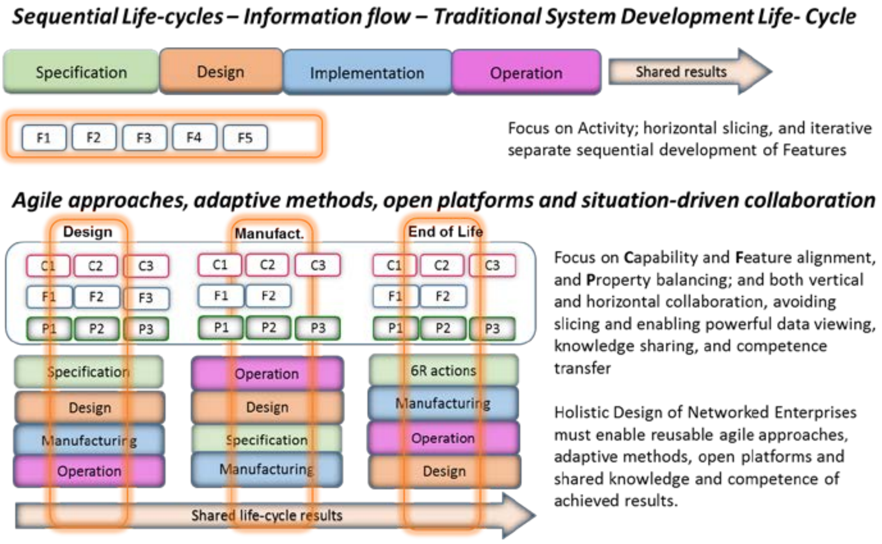

Figure 8 – Activity-slicing must be replaced by role-oriented workspaces and knowledge spaces.

Product design requires different structures to capture aspects of design, engineering, production, maintenance and operations. Now, process design may require at least these five structures:

i. top-down activity decomposition with focus on CTR analysis,

ii. top-down detailing of data and information flows, and jobs and tasks,
iii. bottom-up tasks for collection and aggregation of parameters and data,
iv. bottom-up communication of local dependencies and work-sensitive context,
v. Middle-out balancing of aggregated and planned values for key properties.

Organizational aspects are supported by hierarchic, networked, role-oriented, and various team-based structures. System and platform aspects are supported mainly by roles in these organizational structures.

4.1 User-driven Solutions

Agility and emergence can be achieved by Model-Based, Architecture-Driven (MBAD) workplaces, as illustrated in Figure 9, providing capabilities for extending and modifying AKA contents.

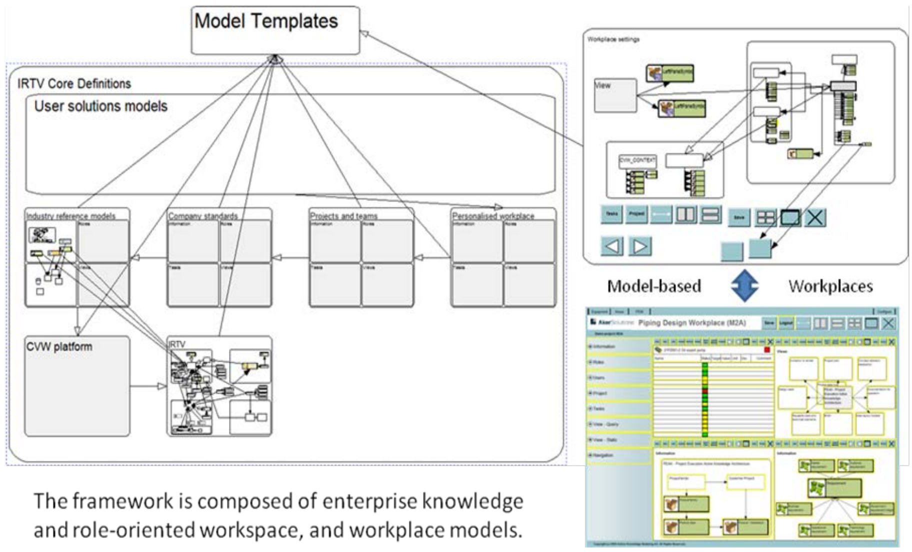

Figure 9 – MBAD workplace design and operation enables agile approach and continuous adaptation and innovation.

The current approaches and supporting ICT solutions are schematic and fragmented, based on formal methods and standardized enterprise modelling frameworks and data-models. Local work-centric context, pragmatic methods, and tacit knowledge are lost, making conceptual design, collaborative engineering, adaptive solutions, and innovation and learning from experience impossible to implement and support.

Modifications can be autonomously reflected in the workspaces of affected roles as changes in views and operations. A key characteristic of our approach is best summarized as "using visual modeling rather than software coding to capture global as well as local context". Another key characteristic is that role-oriented workspaces and active models support users in capturing work-sensitive data and knowledge in their local contexts. This opens up new application capabilities that can only be innovated and applied in performing practical project work. Change management will be minimized and replaced by variants and choice among alternatives.

5 Summary and Conclusions

Holistic thinking, knowledge spaces and role-oriented workspaces, are novel design concepts enhancing visual modelling and design methodologies. Model-based, architecture-driven workplaces and application solutions can be developed by teams of designers, architects and users. Future industrial collaborative networking application systems should be based on visual modelling of core competence roles, working with MBAD workplaces, involving stakeholders and their within scope users. There are many initiatives targeting enhanced industrial and public computing, but they are not based on the AKM concepts and collaborative networking principles.

One of the most promising initiatives could be the German Industry 4.0 program [9]. The research needs seen from the Industry 4.0 perspective are:

1. Horizontal integration through value networks
2. End-to-end engineering across the entire value chain
3. Vertical integration and networked manufacturing systems
4. New social infrastructures in the workplace
5. Cyber-Physical Systems development

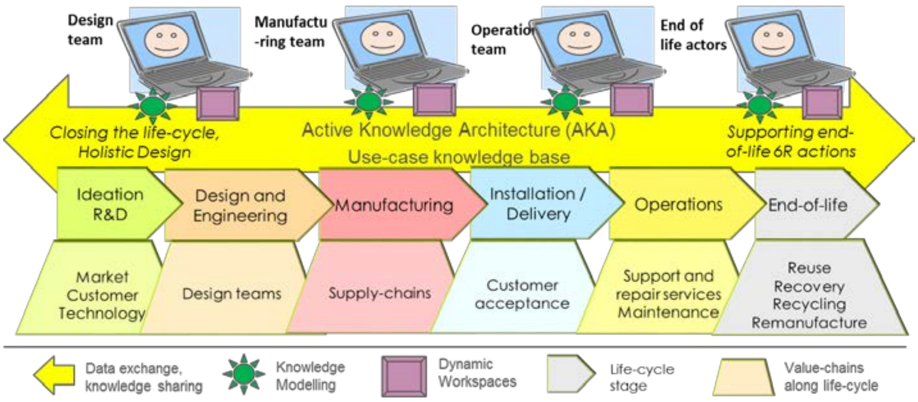

Figure 10 – Horizontal and vertical flows must be replaced by collaboration

Industry 4.0 briefly mentions the need for enabling the following key activities – and this and more is precisely what a holistically designed knowledge base enable:

- Holistic thinking and design to close life-cycles and value-chains.
- Agile Approaches based on model-based, architecture-driven workplaces.
- Model-based CPS development and modelling for planning and understanding.

- Closer collaboration and user involvement to create improved workplaces.
- Closing life-cycles and focusing extended knowledge base life-times.
- Need for continuous learning and innovation, and competence transfer.
- Need for designing and reusing best-practice knowledge architectures.

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 acquired to enable new tasks and local knowledge modelling. The agile approach to AKA, based on active knowledge models, must be realized to support continuous innovation and execution. A bottom-up work process design approach to building AKA should be performed in parallel with a top-down approach modelling visions, results and business aspects. Other stakeholder perspectives of capabilities, services, concerns and performance parameters may be needed, and are easily included in holistic design modelling of workspaces. This evolutionary agile approach enable users to build and adapt their own ICT applications, covering entirely new areas, such as conceptual design, building sustainable collaboration spaces and knowledge architectures, and supporting autonomous knowledge management.

Practical application 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 approached by active knowledge IRTV modelling using software components as 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 pro-actively 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. The present approaches to design of emergent Enterprise Architectures (eEA), building sustainable product life-cycles, will greatly benefit from enhancing the present EA frameworks by adopting the AKM approach.

Visual landscapes facilitate concurrent distributed team composition, competence transfer, knowledge management as well as capability and services composition. The MBAD agile approach, workplaces and solutions 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 concepts, approaches and methods. 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 will build collaboration environments and methods to proceed towards this vision.

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