The role of use cases in development of a reference framework for interoperability of data exchange in agriculture

R. M. Lokers[1], C. N. Verdouw[2], L. Pesonen[3], B. Fusai[4] and M. Schmitz[5]
[1]*Alterra Wageningen UR, PO Box 47, 6700 AA, Wageningen, The Netherlands*
[2] *LEI Wageningen UR, P.O. Box 35, 6700 AA, Wageningen, The Netherlands*
[3] *MTT Agrifood Research Finland, Vakolantie 55, 03400 Vihti, Finland*
[4] *Institut de l'Élevage, 149, rue de Bercy, 75595 PARIS Cedex 12, France*
[5]*KTBL, Barningstrasse 49, D-64289 Darmstadt, Germany*
rob.lokers@wur.nl

Abstract

The FP7 agriXchange project coordinates and supports the setup of a network for developing a system for common data exchange in the agricultural sector. One of the main objectives of the project is to develop a reference framework for interoperability of data exchange. Use cases have an important role in the development approach. The work focuses on data exchange harmonization on the Inter-Enterprise level, and thus, in these use cases, the end-users use dispersed systems consisting of several independent sub-systems. The use cases describe captured business cases uniformly and give support throughout the three identified phases of development work; 1) analysis of present situation, 2) constructing a basic design and 3) implementation of results in LivingLab actions.

Keywords: data exchange, information exchange, information integration, standardization, use case

Introduction

Information sharing is widely addressed as a crucial issue in the European agri-food industry (AMI@Netfood 2006, Food4Life 2007, GCI/IBM 2009, amongst others). Information becomes a competitive factor that enables a more demand-driven and knowledge-based production, needed to meet the various and changing needs of consumers and society (Kinsey 2001). In describing their vision on the future value chain for 2016, the Global Commerce Initiative (GCI, 2006) conclude that multi-partner information sharing among key stakeholders will be one of the main characteristics of the future supply chain.
The FP7 agriXchange project addresses the identified need for information sharing and information exchange in the agri-food sector by coordinating and supporting the setup of a network for developing a system for common data exchange in the agricultural sector through:

- establishment of a platform on data exchange in agriculture in the EU;
- development of a reference framework for interoperability of data exchange;
- identification of the main challenges for harmonizing data exchange.

This paper describes the methods used for the development of the reference framework for interoperability of data exchange and focuses on the role of use cases in that process.

A reference framework for interoperability

Need for a reference framework

Considering the fact that information sharing will be a key competitive factor in the current and future agri-food chain, it is essential for the European agricultural sector to improve on data exchange. This requires a common ground to analyze current information exchange practice and to subsequently harmonize data exchange between parties. It also demands for coordinated action between system developers. To facilitate this process, a common framework that guides this process in the right direction, is needed.

From an information-theoretical perspective, a reference framework is a combination of an architectural framework and a reference model. An architectural framework is a systematic taxonomy of concepts of how to organize the structure of information models (Sowa and Zachman, 1992). It is a meta-architecture, which defines the required model types in different views and at various levels of abstraction and shows how these are related (Verdouw *et al.* 2010a). A reference model is a predefined information model that captures 'recommended practices' and that is used as a 'frame of reference' (i.e. blueprint, template) to construct company-specific information models (Verdouw *et al.* 2010b). Consequently, a reference framework both defines the structure of information models (meta-model) and provides content in the form of predefined models of specific use cases. The purpose of the framework, discussed in this paper, is to support the implementation of interoperability for exchanging data in the agri-food sector. Interoperability is broadly defined as the ability of two or more systems or components to exchange information and to use the information that has been exchanged (IEEE, 1990).

Approach

The approach to be followed for the set up of a common framework is based on the method proposed by Wolfert et al. (2010) and that is depicted in Figure 1.

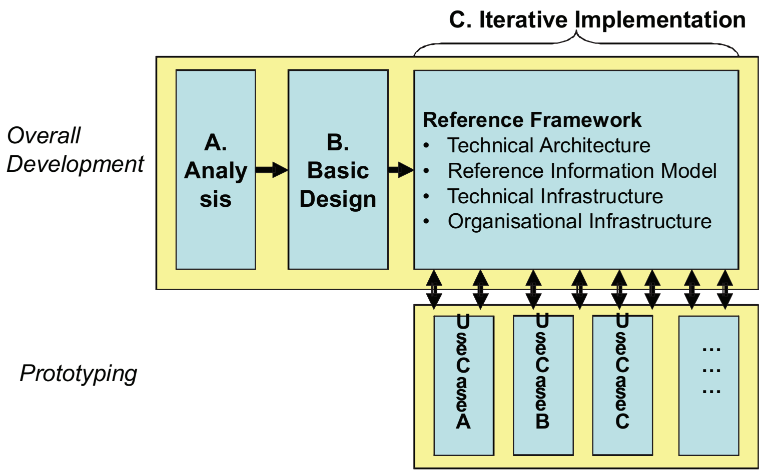

Figure 1. Overall method for development of the reference framework (based on Wolfert et al. 2010).

This approach is characterized by a combination of overall development and incremental prototyping and consists of the following phases:

A. Analysis
   In the analysis phase, the existing state of information integration is investigated and required improvements are planned.
B. Basic Design
   In the basic design, the core structure is set up. This core structure ensures the consistency of the pilot implementations to be implemented.
C. Iterative Implementation
   In the iterative implementation phase, parts of the basic design are implemented in pilots. Pilot results are abstracted into the reference framework, which serves as an incrementally growing knowledge base of 'best practices'.

Every phase develops a part of the reference framework. In the analysis phase, a conceptual model was developed that defines integration and possible levels of integration (among others based on Giachetti, 2004). Based on this so-called generic integration framework, more specific content is developed in the basic design and implementation phases.

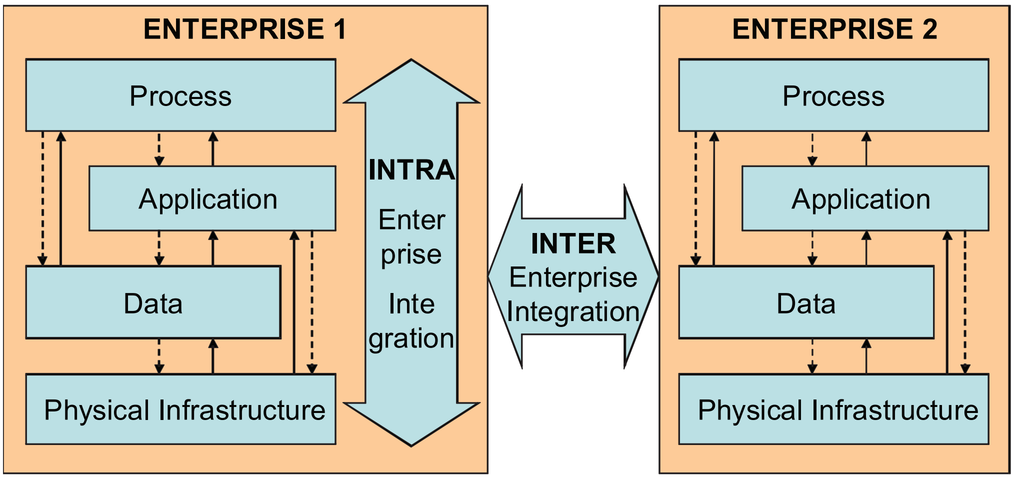

Figure 2. Generic Integration Framework (adapted from Giachetti, 2004)

Following the schematization of the generic integration framework as depicted in Figure 2, the reference framework distinguishes between:

Different integration levels:

- *Intra-Enterprise*: within enterprises to overcome fragmentation between organizational units (functional silos) and systems;
- *Inter-Enterprise*: between enterprises to move from operating as an isolated company towards a virtual enterprise that is integrated in multi-dimensional networks.

Different integration types:

- *Process Integration*: alignment of tasks by coordination mechanisms;
- *Application Integration*: alignment of software systems so that one online system can use data generated by another one;
- *Data Integration*: alignment of data definitions in order to be able to share data;
- *Physical Integration*: technical infrastructure to enable communication between hardware components.

A reference framework for interoperability of data exchange in agriculture in the EU should facilitate the harmonization of data exchange by effectively supporting the three phases of the development process. This demands a uniform and formal methodology that can be used as a sound basis to develop evolving implementations and to concurrently develop the reference framework by allowing feedback of evolving knowledge and experiences gained through the development work to again be integrated into that framework. The reference framework should therefore support the involved community in:

1) Structured documentation of the status of information integration for specific business cases relevant in the European agricultural sector.
   This methodology should also support the structured analysis and documentation of variants of a business case. Such variants can be of a very diverse nature. They can originate from:
   a. geographical differences
   b. different implementations of (part of) the business case on any of the integration levels (process, application, data, physical) mentioned in Figure 2.
2) Fitting the documented business case with the concepts laid out in the basic design as the basis for designing systems that support sound information integration.
3) An easy translation of the documented business cases to a real-life implementation, following the core structure set up in the basic design.
4) Feedback of the evolving knowledge and experiences gained in developing these real-life implementations in order to be picked up in following iterations, improving the existing implementation or to be re-used in other business cases.

The role of use cases in the reference framework

Uniform description of business cases

One of the key elements used in the reference framework for interoperability to be developed in the agriXchange project is the integrated use of use cases as a ways to document business cases throughout the three phases of the common framework development. Use cases are utilised commonly in software development as a specification technique for capturing functional requirements (Jacobson 1992, Cockburn 2001). In the agriXchange project the work focuses on Inter-Enterprise level data exchange harmonization. Thus, instead of a development of individual, local ICT systems, the scope of the use case descriptions is in the use cases where the end-user uses dispersed system consisting of several sub-systems. The sub-systems have many independent owners and sub-users. The investigated field is very large and plenty of use case analyses are needed to carry out. To document the defined use cases that are relevant in the context of information integration in agriculture, use case template is developed. Table 1 shows the metadata fields used in the use case template.

Table 1. Metadata fields of the agriXchange use case template

Metadata field	Description
Name of the use case	Short name (verb + object) plus context, country or region if relevant.
Short description	Short description of the use case in "natural language" to document the goal of the use case and the main actors and activities.
High-level graphical description	A simple and easy to understand graphical representation of the use case (e.g. in the form of a UML use case diagram)
Relevant countries or regions	Defines the geographical domain for this use case.
Relevance for European agri-sector	Percentage of EU countries where the use case is relevant at the moment and in the near future (within next 5 years)
Relevant parties	List of actors in the use case: The parties that are actively involved in the information exchange for the use case. List of stakeholders of the use case (parties that are not actively involved, but have a stake in efficient, harmonized data exchange).
Description of information exchange	Structured description of the information exchange processes and exchanged data (using BPMN)
Relevant "conditions"	a. Standards b. Dictionaries c. Regulations and legislation d. Technologies
Use case variants	Description of different implementations of the business case by BPMN graphs and short written descriptions.
Known issues and bottlenecks for harmonization	Description of known issues that hamper efficient information exchange, using "natural language" and graphical presentation, if necessary
Proposed recommendations and solutions for harmonization	Description of ways to improve and harmonize information exchange, using "natural language" and graphical presentation, if necessary

<u>Support of the reference framework phases</u>

The uniform documentation of business cases in the form of use case descriptions supports the development of the common framework in a number of ways. It allows the involved user and stakeholder community to communicate about specific business cases and the information integration aspects, captured in a structured manner. The use cases assist the involved stakeholders to also identify the indirect business opportunities, which may be difficult to come across otherwise. It provides a uniform and easy to use method to analyze and describe the aspects relevant for integration purposes, supported through natural language descriptions and dedicated graphical notations that are easy to use and understand. Thus, it allows such uses cases to be used as a means of communication not only among system developers, but also with parties and stakeholders that lack the technical background to fully understand the formal languages and notations used by ICT developers (e.g. UML, Unified Modelling Language). Moreover, it supports the three identified phases of the described approach for the development of the common framework:

Analysis – In this phase, the current status of the business processes and especially the relevant aspects from the viewpoint of information integration are uniformly described in the format of the use case template. Besides, the template allows describing relevant use case variant. Geographically determined variants can be described either as variants within the same use case description, or as separate use cases focusing on a specific country or region. Variants that are related to differences regarding on of the identified integration levels (see *Figure* : process, application, data, physical infrastructure) can be addressed by referring e.g. to relevant dictionaries (data level) or data exchange standards (application level) or by the inclusion of multiple process diagrams (process level). Existing issues and required improvements that originate from the analysis phase can also be documented.

Basic Design – The basic design for the common framework is based upon the use of Business Process Management (BPM) and reference information models. The technical infrastructure is based upon the principles of a Service Oriented Architecture (SOA) (Figure 3).
The use of Business Process Modelling Notation (BPMN) to model processes to be integrated, provides a sound method for documentation of the processes and the information exchange between parties acting in the use case. BPMN provides a common language for describing process behaviour, shareable by business and IT (Silver, 2009). It is easy to understand by non technicians and thus provides an excellent means of communication regarding process and information integration. Moreover, it allows IT experts, in later stages, to fully specify the details of processes even to the level of executable processes running in SOA architectures. In that way it also provides the means to translate process design to the level of applications and implementation of inter-enterprise information exchange by means of services.
The BPMN models define the sequence of activities of different involved actors and the exchange of data objects, in particular between the different involved actors. In the Basic Design, attention is paid to the description of standards and dictionaries used in the data transfer interactions between the actors in investigated use cases. In real world, there are and there will be many variants of business cases competing with each other to fulfil the user requirements. This is an essential feature of the markets. This is why data exchange harmonizing work concentrates on the single data transfer interfaces between the actors, identified in the use case models. These interfaces can be freely utilised according to different business cases. The business service layer in Figure 3 represents the focus of data exchange harmonizing work. It may be sometimes difficult for ICT developers to identify relevant business cases in distributed systems, which may hinder the motivation to actively develop new type of services for end-users, and thus, needed data exchange. SOA-based system design and its business service layer (**Error! Reference source not found.**) provide an approach to develop new intermediating services with harmonized data exchange interfaces. This provides possibilities to enhance creation of new services for the ICT developers and to improve service availability and system usability for the end-user.

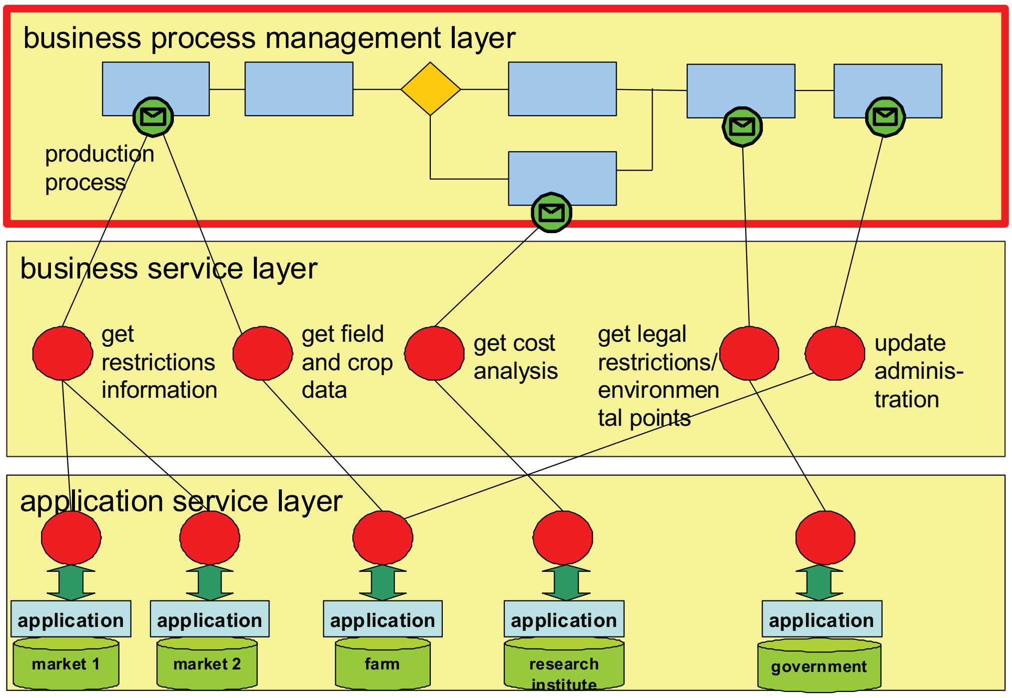

Figure 3. Service Oriented Architecture as an essential part of the Basic Design (based on Wolfert et al., 2010).

Iterative Implementation - In the implementation phase, the modelled use cases will be used as a guideline for the detailed design and subsequent implementation of pilots. In the previous phases, the emphasis in framework development has been on the technical architecture and information modelling (in particular process and data models). Implementation demands also an organisational method, suitable for iterative, open and user-driven development of the framework. For this, the so-called 'living lab approach' has been adopted. The Living Lab (LL) is a user-centric innovation approach for sensing, prototyping, validating and refining complex solutions in multiple and evolving real life contexts (Wolfert *et al.* 2010). It can be characterized by an iterative, design-oriented approach in which incremental solutions are re-used, sometimes leading to unexpected results or changes in intended innovation directions. LL promotes an alternative innovation paradigm: the end-user's role shifts from research object to a pro-active position where users, researchers and other stakeholders collaboratively document learn and develop. To facilitate this process, the agriXchange platform will be used as the technical infrastructure that facilitates joint communication, documentation, learning and development (http://www.agrixchange.org/).

In the agriXchange project, four use cases are selected to be elaborated. Three of these use cases will be integrated as pilots supporting the iterative development of the reference framework. A fourth use case will be used as a test case in order to verify the completeness and usability of developed framework. The four selected use cases are the following:

LPIS update – describing the process of updating the LPIS (Land Parcel Identification System) between farmers and government.
Geo-Fertilizer – describing the process of variable rate application by farmers, supported by data served by government and service providers.
Animal registration – describing the (registration) processes involved in importing and exporting cattle.
Animal identification – describing the processes involved in collecting and registering animal production information throughout the production chain, supporting tracking and tracing and consumer information.

It is important to notice that the added value for the implementation phase lies in the fact that also new implementations and the experiences gathered while setting up these implementations can again be documented in the form of use cases, leading to an evolving knowledge base. Therefore, according to the LL approach, The project encourage users, experts and any other stakeholders to join the agriXchange community, to make use of the framework, to comment and discuss work in progress, to re-use developed concepts and components and to bring forward such additional use cases.

In the following section the AgriXchange use case "Geo-Fertilizer" is described, focussing on just a few of the relevant fields of the described use case template. It mainly serves to illustrate how specific parts of a use case can be documented.

An example use case: Geo-Fertilizer

Short description / Variant
The Geo-Fertilizer use case describes the business case in which a farmer optimizes his fertilizing practice through variable rate application, considering the local conditions on a parcel. As such, this use case functions as a general model for on-farm precision agriculture practices where spatial information is used to optimize on-field processes and where external parties are involved to provide the required information and knowledge.

One of the possible implementations, or variants, of the business processes and the related information exchange in this business case involves the farmer, commercial service providers and national or regional government as data exchanging parties and could have the following process steps.

1. The farmer requests and receives the geometries of his LPIS parcels from the LPIS and parcel registration system provided by his national government.
2. The farmer requests a farm advisory service to provide a fertilizer advice. A request for advice, including the spatial information of the parcel, is sent to the system of the service provider.
    a. The farm advisory service provider sends out a request for the soil information required for the specified parcel to a soil data service provider. The soil information is delivered to the farm advisory service provider.
    b. The service provider requests information on the measured leaf area index (LAI) data for the specified field from a remote sensing data provider. He receives a LAI map covering the specified field.

c. An agronomic model processes the available datasets (parcel data and geometry, soil data, LAI map) and generates a fertilizer application advice for the farmers' field.
d. The fertilizer application advice is sent back to the farmers FMIS
3. The farmer receives the fertilizer advice and stores it in the data repository of his FMIS.
4. The farmer, through his FMIS, transforms the fertilizer advice to an application map that can be entered into the board computer of his machinery. He loads the dataset onto the machinery and fertilizes the field. During the operational process, the local application rates are logged and stored.
5. The farmer transfers the logged data from the machinery to his FMIS. The FMIS processes and stores the dataset in the repository.

Description of information exchange

Figure 4 shows how the business process, or better the described implementation variant of the business process, can be visualized in the form of a BPMN graphical notation. The BPMN concepts of pools (in
Figure 4: farmer, government, N-advice provider, LAI service provider and Soil data service provider) and swimming lanes (in
Figure 4: farm management system and farm machine within the pool farmer) are used to model the participating parties and relevant local components respectively. The model clearly shows how processes are built up of interconnected tasks and how information flows from task to task (intra-enterprise) and between different parties (inter-enterprise). As such it provides an efficient means to further elaborate on use case variants and specific details on information exchange among ICT and non-ICT experts.

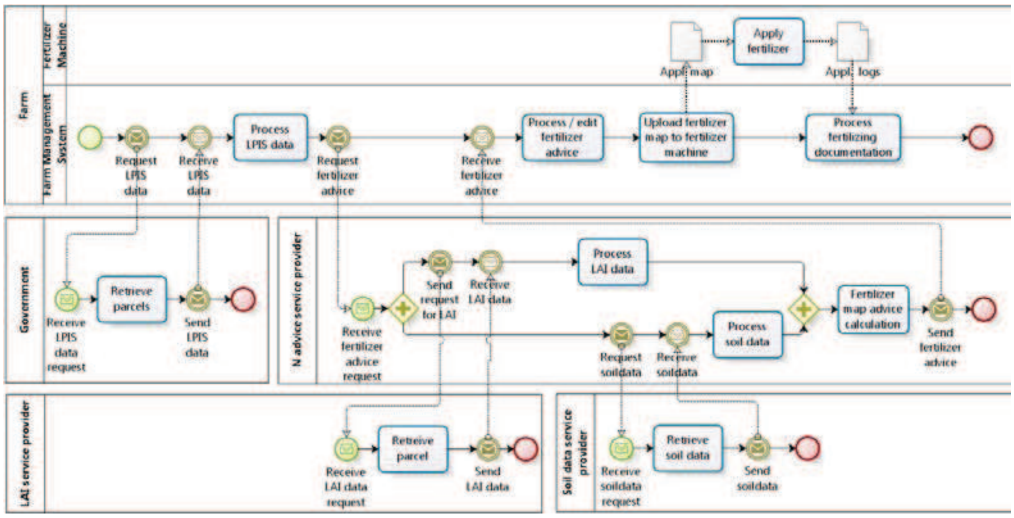

Figure 4. Description of information exchange in BPMN of the Geo-Fertilizer use case.

Relevant standards

The most relevant standards that support information integration for the Geo-Fertilizer use case are:

ISO-11783 or ISOBUS - a world-wide recognized and widely implemented standard for on farm data communication. It supports standardized data communication and automated process execution on farm machinery. Moreover, it supports the exchange of (operational) data from FMS to farm machinery and vice versa by defining the data elements and code lists required in on-farm data communication.
AgroXML - the German standard for data exchange in the agricultural sector. Although it still has a low implementation grade, it seems to be the most evolved standard in the area of pre-harvest data exchange between FMIS and other business parties. Current implementation supports FMIS to government and FMIS to soil data provider.
EDI-teelt - a Dutch standard for data exchange in arable farming which is mostly used in post harvest agri-business and tracking and tracing applications. Although it's fairly wide spread in the Netherlands, it does not support the Geo-Fertilizer use case. A new version of the EDI-teelt standard is currently developed that will support data exchange between farm and other parties for pre-harvest business processes.
UN/Cefact - the standards developed by UN/Cefact support "electronic business". They cover a wider range of domains (financial, administrative, technical). In the technical working group on agriculture, a few agricultural business cases are covered or in development. Although they do not directly cover (parts of) the Geo-Fertilizer use case, it is good practice to at least consider reuse of generic core components and of relevant code lists.

Known issues and bottlenecks for harmonization

Regarding the bottlenecks for harmonization, a few conclusions can be drawn based upon the analysed use case. First of all, focussing on the Geo-Fertilizer use case, no generally accepted set of standards is available at the European level that supports this use case. Commonly used standards in agriculture in general (UN/Cefact, AgroXML, EDITeelt, (E)Daplos) have a strong focus on aspects like trade, logistics and tracking and tracing and not so much on on-farm data exchange and process integration. The ISO-11783 standard is widely accepted and supported for standardized data communication and automated process execution on farm machinery and for the exchange of data from FMS to farm machinery. However, implementation of these standards by machine manufacturers and FMIS providers is still under development in many cases. In general, the support of spatial data standards (e.g. the standards developed by the Open Geospatial Consortium) as part of standardized data exchange is still immature.

Conclusions

Information sharing will be a key competitive factor in the future value chain of agri-food sector. In order to facilitate information sharing and data exchange in agriculture, The FP7 agriXchange project develops a reference framework to guide the improvement of information sharing and data exchange in agriculture. The approach is characterized by a combination of overall system development and incremental prototyping. Use cases have an important role in this approach throughout three different phases of development of the generic framework; 1) analysis of present situation of data exchange in different countries and system implementations, 2) constructing the Basic Design for the generic reference framework and 3) implementation of results in LivingLab actions to get feedback for further harmonization work. Use cases capture functional features of dispersed systems composing the value chain, and assist to define and analyse specific business cases. They are uniformly structured and comparable and they provide a good means of communication among the community of the network in workshops, living labs, WEB2.0, etc. As such they provide a way to discuss and analyze business cases from an integrated business and technical perspective. The use of business process modelling pinpoints the generic data exchange interfaces for further harmonizing work. Use cases provide a means of further research, but via the BPMN modelling also the first step to implementation of information sharing and data exchange systems based upon a Service Oriented Architecture.

Acknowledgements

The work leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement no 244957.

References

AMI@netfood. 2006. European ICT Strategic Research Agenda for Agri-food & Rural development; a vision for 2015.

Cockburn, A. 2001. Writing Effective Use Cases, Addison-Wesley.

Food4Life. 2007. European Technology Platform on Food for Life - Strategic Research Agenda 2007-2020, CIAA.

GCI. 2006. 2016: The Future Value Chain, Global Commerce Initiative / Capgemini / Intel.

GCI/IBM. 2009. Global Commerce Initiative Information Sharing Report.

Giachetti, R.E. 2004. A framework to review the information integration of the enterprise. International Journal of Production Research 42(6), 1147-1166.

IEEE. 1990. IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries. New York: Institute of Electrical and Electronics Engineers.

Jacobson, I., Jonsson, P., Christerson, M. and Overgaard, G. 1992. Object-Oriented Software Engineering - A Use Case Driven Approach, Addison Wesley Longman, Upper Saddle River, N.J.

Silver, B., 2009. BPMN Method & Style, Cody-Cassidy Press.

Sowa, J. F. and Zachman, J. A. 1992. Extending and Formalizing the Framework for Information-Systems Architecture. IBM Systems Journal 31(3): 590-616.

Verdouw, C. N., Beulens, A. J. M., Trienekens, J.H., Verwaart, T. , 2010a. Towards dynamic reference information models: Readiness for ICT mass customization. Computers in Industry 61(9): 833-844, http://dx.doi.org/10.1016/j.compind.2010.07.008

Verdouw, C.N., Beulens, A.J.M., Trienekens, J.H., Wolfert, J. 2010b. Process modelling in demand-driven supply chains: A reference model for the fruit industry. Computers and Electronics in Agriculture 73(2): 174-187, http://dx.doi.org/10.1016/j.compag.2010.05.005.

Wolfert, J., Verdouw, C. N., Verloop, C. M. and Beulens, A. J. M. 2010. Organizing information integration in agri-food - a method based on a service-oriented architecture and living lab approach. Computers and electronics in agriculture 70:389-405, http://doi:10.1016/j.compag.2009.07.015.