Information systems Architecture: creating links in the chain with IT

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Introduction

The rapid evolution of information technology enables new opportunities and optimization of processes in the production chain. The production chain is an area of enormous potential for integrating various information systems. Besides system integration of single entrprises, cooperating networks in the product chain require external integration. This requires an adjustment of the semantic and pragmatic concepts, which are applied by the involving enterprises. It will be argued that the construction of models for the product chain can be conducted by integration of selected components from enterprise information architectures. The planning and implementation of these architectures is likely to cut across existing departemental boundaries and orgzanizational biases may raise political issues and concerns. Information architecture, despite its widespread usage, has no standard definition. Much confusion surrounds the information architecture concept. To my opinion practical guidelines are necessary for the involved business for going through the organizational and IT labyrinth. Architecture planning is better not undertaken unless it can be done right, using staff whose credibility and prestige are high within the participating businesses. The purpose of this paper is:

- to clarify the context within which various relevant architectures are developed and interact
- to examine important IT trends that may have consequences for the way we exchange information in the product chain
- to illustrate essential components that support the construction of chain models based on information architectures of separate enterprises in the chain

Therefore an in-depth analysis of the fundamental components for the construction of these architectures is given.

Metamodels for complex systems

The modelling of complex information systems, like interorganizational systems, requires that a large number of issues to be dealt with. Various frameworks to model infor-

	what	how	where	who	when	why
product chain						
enterprise						
system model						
information technology						

Figure 1. Applied framework

mation systems have been proposed. Among them are those of CRIS , CIM/OSA and Zachman and Sowa. *Fig. 1* shows the framework adapted for this study.

In these frameworks a different number of dimensions and a different subdivision of these dimensions in perspectives or aspects is proposed. The CRIS approach and CIM-OSA use as one of their dimensions the life-cycle of information systems. For projects where this system development phases are not considered, or when applying an evolutionary develoment method instead of the waterfall cycle, this dimension is not recognizable for the projectmembers.

More useful is a dimension representing a number of abstraction levels each related to the perspective of a major interest group. The second dimension illustrates the system aspects that can be distinghuished: data, function, network, people, time and motivation. Therefore the framework of Sowa Zachman is adapted, fig. 1 gives an overview of the relevant aspects represented in the columns, the perspectives of interest groups as distinghuished in this study are shown in the rows of this table. The data aspect deals with what information is required. Function refers to how the processes in the businesses are done. We will give repesentations of the dynamics in the time column (when). The network describes where the relevant locations are. Authority and responsiblities assigned to agents are represented in the who column. Purpose and objective are formulated in the motivation column, answering the why question. The basic model for each column is actually a generic metamodel. Each row represents the models for the related interest group. Their perspectives will mostly emphasize different constraints. Constraints are additive. In practice a constraint in a lower row might be inconsistent with a model in the next higher row. In practice the interest groups who stand for the model must speak about these constraints and decide what must me changed to ensure consistency with models of contiguous rows. The adapted framework is suitable for constructing information architectures and may be uses as a checklist in composing project scenarios.

Well-known modelling techniques are applied in the metamodelling approach, where the resulting components of these techniques are adjusted, balanced and checked. The

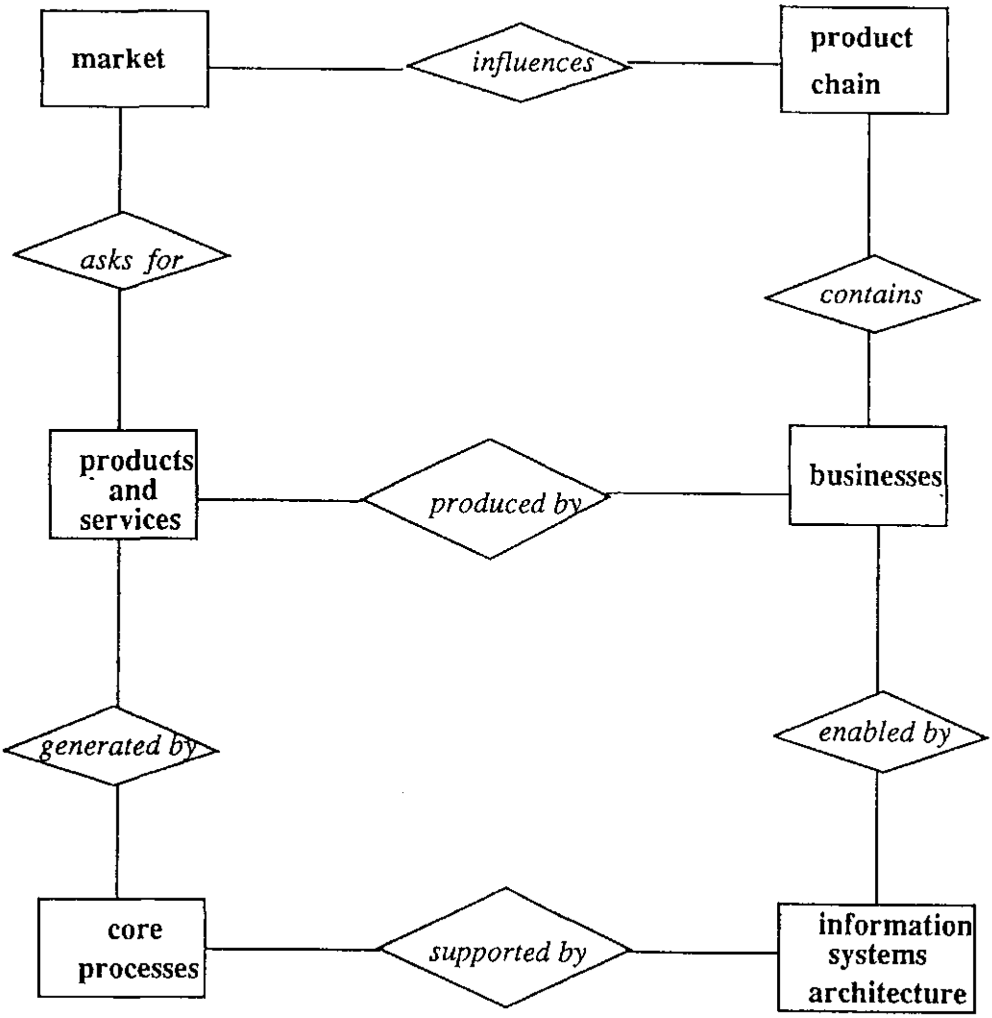

Figure 2. Meta datamodel of the product chain

basic model for each column is mentioned a generic metamodel. It is generic because it is the same for each cell in the colomn The meta-datamodel of *fig. 2* shows what important entities in the product chain are highlighted in this study. A meta-activity model will present how architectures in enterprises may be constructed in a way that they are tuned with relevant concepts of the product chain. In this approach we will reuse components of reference-models.

Reference-models

During the second part of the former decade several reference-informationmodels for the agricultural sectors as dairy, pigs, poultry and horticulture were developed in The Netherlands. Such a model, is a frame of reference for every one involved in building agricultural management information systems. The construction of the models was a joined effort of the branch organizations and agricultural researchers.

Partial models, which are reference models for a specified line-of-business, may be composed. These models may focus on one aspect of this framework, e.g. data in the approach which is advocated in. A special kind of information model is a reference-information model. Common information requirements and decision processes in a particular line are identified. Information systems planning studies which we conducted by using these reference-models showed that the duration of the studies can be shortened. In a meta-activity model illustrates how the planning studies can be accelerated using reference informationmodels.

Especially for small and medium business the use of reference models appear to advantages. It is often (economic) impossible to carry out a informationplanning study or to develop tailor-made information system for a small business. The use of reference models stimulates standardization of information technology, for instance supporting the electronic data interchange (EDI). The models for information planning studies are usually represented by means of natural language descriptions, charts, matrices and various other diagrams.

The use of reference models on the level of a line-of-business can be instrumental in the coordination and stimulation of a well-balanced introduction of information-technology.

We extend the framework from fig. 1 with a 3rd dimension: genericity. This level is concerned with partially instantiated models applicable to a specific category of enterprises.

Enabling information technology

The lowest row of fig. 1 refers to the information technology that enables enterprises to increase their efficiency and effectiveness of the core processes and to be more competitive with their products and services on the market. In order to be a valuable instrumentarium for the product chain some basic requirements on information technology may be defined:

- the decisions of the management, analyzing bottle-necks and opportunities, must be illustrated and supported by tools and simulation;
- reuse of specifications and software should accelerate the design of interorganizational information systems;
- large volumes of data about e.g. the market should be distributed in a fast and reliable way.

The role of standards

The amount of coordination is increasing as the interconnections within the production chain become more sophisticated and their dependencies grow. This raises the need for an understanding of standards. No single policy vision coordinates infrastructure development today. Nor could any centralized decision process posibly guide such a complex engineering today. Standards arise from either official acitivity or by the force of practice. For instance the Open Systems Interconnection (OSI) standards are official, or de jure standards, while DOS is a de facto standard for operations systems on Personal computers. A de jure standard might be more rigorously defined as a publicly available document voluntarily agreed upon as a result of public consultation. Cooperation may be described in terms of succisevely deeper levels of underlying processes. Many coordination processes require that some decision has been made. Group decision require members of the group to comminicate in some form, and this communication requires that some messages have to be transported in a standard language. In this setting standardization plays the dual role as constraint and as coordinator.

Object orientation
Object-oriented system development claims to improve software design for reliability and maintenance. Further claims are that the development process is made more efficient by reuse. In an approach shows how reference-information models can be transformed to object oriented systems. The major steps of the object oriented part originates the methodology OMT (Object Modeling Technique). In specifying objects we distinguish static and dynamic aspects. Static concepts concern the attributes of the objects and the relationships between objects. Object orientation attempts to satisfy the needs of the end-users as well as those of the developers of software products. This is accomplished via real-world modeling capabilites as shown in exampes of applying these techniques to the fruit growing enterprises .

Object orientation provides better paradigms and tools by constructing reusable components and easily extensible libraries of specifications and software modules. As a consequence we don't have to recode everything from scratch when software for comparable functions within the product chain is constructed.

Prototyping
A prototype is the partial implementation of a system built expressely to learn more about a problem or a solution to a problem. The creation of a prototype has been a standard practice in many engineering and manufacturing industries for decades. The benefit of building a prototype instead of the actual object is that the risk of manufacturing and development is reduced. Promising technology in this area are CASE (Computer Aided Software Engineering) tools. Case technologies have demonstrated their potential for conceptual modelling and as vehicle of communication. There are two distinct types of software prototypes described in the literature: throwaway and evolutionary. A throwaway prototype is built as quickly as possible and the implementation is focused on the requirements that are poorly understood. After the prototype is complete, the specifications are extended with what was learned. Throwaway prototypes work very well in isolation to verify relatively small parts of a complex system. In contrast to a throwaway prototype, an evolutionary prototype is built in a quality manner. Confirmed requirements are implemented into baseline software products. In short time, a collection of useful changes and enhancements are taken to configuration management. The development team will incorporate the new features in a quality fashion into the evolutionary prototype, creating a new baseline.

Client server architectures
Modern distributed information systems are today based on client server architectures. A client server computational model implies a relationship between two processes in which one makes requests to the other. This organization allows a decomposition of function-

ality in complex interorganizational systems. Parallel databases can cope with large volumes of data and parallel hardware offers more processing power to ensure a good performance. This is a good alternative to conventional mainframe technology, small and unexpensive components can be used to build high performance systems.

The data highway
There is little disagreement about the benefits of a data highway. Extending the present infrastructure of fiber-optic strand, radio waves and satellites should ultimately result in better and faster links from enterprises, universities and homes to the communication backbone. Applications facilitated by the highway, such as videoconferencing, document sharing gives consumers a wide choice of services. It's in the details that opinions start to diverge, and these difference could have a major effect on how the information infrastructure will be further elaborated. Because contributing parties (telphone companies, cable distributors, computer manufacturers, publishers) may have different technologies and views, the forecasting of the ultimate form and function of the data highway requires examining these conflicting perspectives. Therefore we run the risk that it becomes increasingly difficult to manage the vast inventory of information resources without a clear, global understanding of their existence, location and role as well as the dynamic relation among them.

Reviewing IT
The methods, techniques and tools provided by todays information technology, should be maintained carefully. The mapping of the required technology products, methods and techniques is defined as the IT companionship. In the review of IT trends we may use the following quality factors:

- Verifiability is the ease of preparing acceptance procedures and procedures for detecting mistakes
- Robustness is the ability of specifications and software to function even in different locations and conditions
- Extendibility is the ease with which specifications and software may be adapted to changes.
- Reusability is the ability of specifications or software to be reused, in whole or in part for new environments.
- Correctness is the ability of software to perform the tasks as defined by the specifications

If the product chain demands more processing power and storage capacity for handling information, information technology offers products, methods and techniques that enable enterprises to innovate their processes and products:

- The decisions support for the management is stimulated by prototyping tools and alternatives can be verified by simulation. Prototyping may reveal issues positioned in the who and why cell of the technology row of fig. 1. Next to it, prototyping can illustrate relevant data for the agents.
- Reuse of specifications and software is enhanced by object oriented technology, which offers robust and extensible deliverables. The data, function and time columns of the framework are covered by object oriented technology.

- The distribution of large data volumes is possible using client-sever architectures and networks, replying to where issues.

Towards aligned architectures

The development of modern computer-based information systems started with file-oriented systems. The resulting computer programs suffered from redundancy, inconsistency and were not flexibel. In order to overcome these shortcomings a three-level schema architecture is advocated by standardization committees: they contain internal models, conceptutal models and external models. As a consequence of the data independence concept we realized that data rather than the proces structure in the applications were principal to model.

Architectures suggest synthesis, putting many relevant aspects into a whole to meet an artistic or functional need. It suggest a global view or scheme, representing the component parts fit together.

Definitions of information architectures

According our view architectures play a vital role in information management within enterprises and within the enterprises of a product chain. The following definitions are stated:

- Zachman gives the following general definition of an architecture: 'An architecture is a logical construct for defining and controlling the interfaces and the integration of all of the components of a system'.
- The Diebold Group filled in some more detail, with special reference to information architectures: 'An information architecture is high level map of the information requirements of an organization that shows how information requirements relate to business processes and how the information categories and functions must be defined, implemented and interconnected with appropriate facilities and technology to support decision makers'
- Brancheau and Schuster: 'an information architecture is a personnel and technology independent profile of the major information categories used within an enterprise. It provides a way to relate business functions and data classes and document their relationships.'
- Teng: 'a high-model of a set of databases configured to support the organization's value adding business processes. The model may be portrayed in graphical, tabular, or narrative form and is independen of technology and current organization structure'.

To be aware of the importance of informaton architectures consider the analogy with the transportation area. To make effective use of automobiles, roads needs to be built. After a period during which automobile use expanded dramatically, it became obvious that great bottle-necks would arise if each local jurisdiction were left to build only the roads which were neede by the residents.

Planning architectures is a decision-making proces, by which management gives direction to the development of a strategy for information services. This concerns the formulation of a strategy, creation of an architecture plan and an information projects plan. The framework of fig. 1 is used as a springboard for the planning of architectures. Planning work within which information systems, organizational units can be placed in the context, with interrelationships clearly understood. Moreover, interactions among the activities of business architecture, systems architecture and IT architecture takes place as feedback-loops and feed forward loops. An IS plan should no longer be separated from the business plan and vica versa. The organization is concerned with organizational and skill related issues that are necessary for the enterprise to be in balance with the information technology it uses and with the organization structure implemented.

Alignment with IT architecture
The technical architecture us an insulating layer separating business requirements for IS (systems architecture) from the set of products and components that cooperate in providing computing support to the information needs. Moreover the technical structure includes a definition for an environment and infrastructure that are necessary for the integration and cooperation of different applications. Finally the organizational structure emphasizes the mutual dependencies between an organization and IT and the emergent properties derived from the interaction between them.

The use of benchmarks
As the benefits of planned information systems are often difficult to quantify because there may be a lot of intangible factors there is a need for other instruments. Benchmarking has proven to be an adequate technique that can contribute to the improvement of decision processes . Benchmarking is a process which measures the performance of some key elements of a business, in order to compare these measured results. Some lessons learned from conducted benchmarks are:

- commitment of topmanagement is essential
- attention has to be paid to training and understanding of the involved projectmembers
- communication and documentation should be well prepared

As fig. 3 illustrates, we distinghuish three kinds of benchmarks:

- product benchmarks: characteristics of IT products are determined resulting mostly in a short list for selection of a product.
- competitive benchmarks: some key ratio's are determined and compared with other organization.
- internal benchmarks: enterprise functions within one organization are measured and compared.

Linking information architectures in the product chain
The components introduced in this paragraph are restricted to which they do contribute to the modelling of relevant aspects of the product chain. A product chain represents how businesses are linked to each other by the supply of goods and services.

For the construction and integration of a model representing the relevant aspect on the chain level, we may ask ourselves if it is a suitable approach to add and reshuffle the functions and data classes of the involved separate businesses. The major disadvantages of this approaches, which is illustrated in *fig. 4*, may be:

- integration of data schemas gives semantic problems

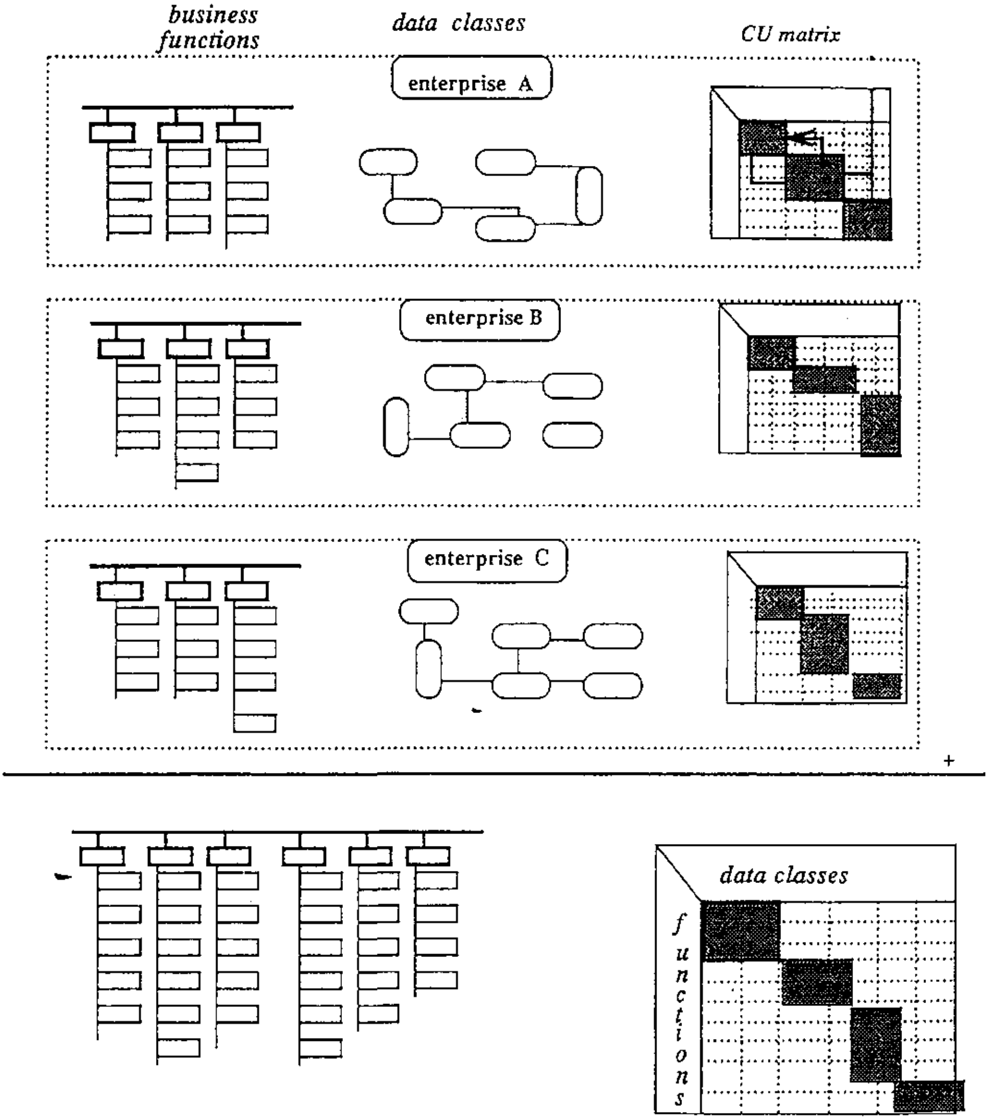

Figure 4. Is construction of a information model for the product chain an aadition sum with some reshuffeling?

- participating businesses can not easily recognize their contributions to the product chain within the resulting model colossus
- maintencance of the resulting whole chain model will be a problem, partly as a consequence of the functional decomposition.

Construction of chain models by events

The aim of the research is to develop a chain information model that explicitly integrates relevant components of the different aspects as they are represented by the columns of fig. 1. Dynamic relationships among enterprises in the product chain may be explicitly specified through events. For the process aspect, events can be made explicit by associating minimally two events with each process: a start-event that is associated with the triggering of the proces and a completion event that signals the termination of the proces. While an elementary process is conducted local to an entity and just gives a possible way to handle the entity, an event characterizes two forms of dynamic interaction between two or several entities of enterprises. Firstly, by grouping the set of processes to be triggered when a particular situation occurs, an event expresses synchronization.

Secondly, as processes may induce state changes of entities that in turn generte events, the sequencing of events makes clear the cascade of entities transformations due to the initial signal.

In bringing together the data- and procescomponents of the information systems architecture the event component plays therefore a central role.

An example. The event 'order delivery' for a client may trigger:

- the proces 'request payment' conducted by the financial department
- the proces 'taking out' done by the people at the storehouse

The second proces (taking out) induces an internal event 'out of stock', when the present quantity is lower than the replenishment level. Related to the mentioned processes are updates of data about Account, Product stock and Supply orders.

The advantages of the event concept are as follows:

- static and dynamic phenomena are selected for the construction of a chain model
- object encapsulation is realized by including the events and processes to the entity definition.
- if optimization of chain processes is requested, e.g. improving the terms of delivery, we get a good overview of relevant data and processes.

Consequences of this latest argument will be elaborated in the next section.

Definitions of business reengineering

To create adequate management of product chains enterprises have to think about how to rework their business. An interesting concept with regard to design or redesign of processes is the concept of business reengineering . Business reengineering seeks to redesign work processes to enhance productivity and competitiveness. One major instrument that can be used in business reengineering is Information Technology .

Some other definitions of business proces redesign:

- Davenport and Short: 'the analysis and design of work flows and processes within and between organizations'
- Hammer: 'reengineering is the fundamental analysis and radical redesign of business process to achieve dramatic improvements in critical measures of performance'
- Alter: 'business reengineering is a methodological process that uses Inforamtion technology to radically overhaul business process and thereby attain major business goals'

- Venkatraman: 'business proces redesign involving the reconfiguration of the business using IT as a central lever. Instead of treating the existing business processes as a constraint in the design of an IT infrastructure the business process itself is redesigned to maximally exploit the available IT capabilities'

With regard to product chains reengineering involves the whole chain of companies from the production of raw materials up to the end-products for the consumer. Some interesting developments in the production area are forms of cooperation like co-designership and co-makership, value contracts between more then two chain participants, giving mutual insight in inventory levels by supplying and consuming companies, etc.

Conclusions

There is currently a growing awareness that architectures can be a very effective instrumentation for information management, it provides:

- a flexible platform for tuning the infrastructure in the product chain
- a roadmap for planning IT applications
- a basis for redesign of enterprises, taking into account issues in the product chain
- an effective way to decide and controll investments, using benchmarks.

An information architecture provides a proactive basis for the developement of interorganizational information systems, as opposed to the reactive backlog approach, enterprises should prioritize the construction of these architectures.

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