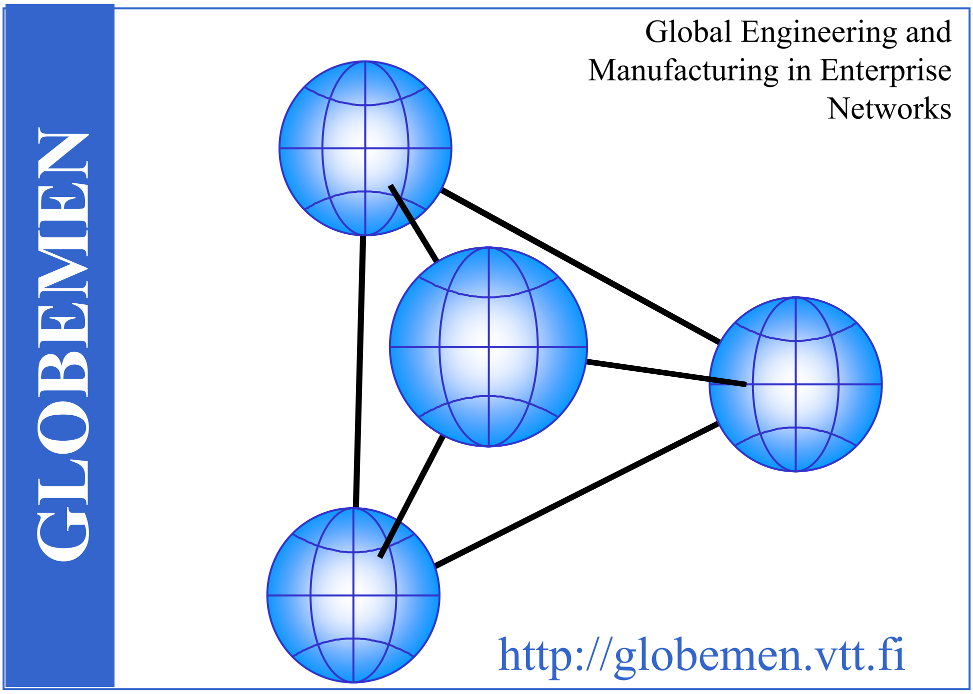
ESPOO 2003
VTT SYMPOSIUM 224



Global Engineering and Manufacturing in Enterprise Networks

GLOBEMEN

VTT SYMPOSIUM 224

Keywords:
manufacturing, engineering, networks, virtual enterprises, integration, collaboration, virtual organisations

Global Engineering and Manufacturing in Enterprise Networks

GLOBEMEN

Helsinki, 9.–10.12.2002

Edited by

Iris Karvonen, VTT Industrial Systems, Finland
Roel van den Berg, Baan Development B.V., Netherlands
Peter Bernus, Griffith University, Australia
Yoshiro Fukuda, Hosei University, Japan
Matti Hannus, VTT Building Technology, Finland
Ingo Hartel, Swiss Federal Institute of Technology Zurich, Switzerland
Johan Vesterager, Technical University of Denmark, Denmark

Organised by

VTT Technical Research Centre of Finland
YIT Corporation, Finland

ISBN 951–38–5739–5 (soft back ed.)
ISSN 0357–9387 (soft back ed.)

ISBN 951–38–6275–5 (URL:http://www.inf.vtt.fi/pdf/)
ISSN 1455–0873 (URL: http://www.inf.vtt.fi/pdf/)

Copyright © VTT Technical Research Centre of Finland 2003

JULKAISIJA – UTGIVARE – PUBLISHER

VTT, Vuorimiehentie 5, PL 2000, 02044 VTT
puh. vaihde (09) 4561, faksi 456 4374

VTT, Bergsmansvägen 5, PB 2000, 02044 VTT
tel. växel (09) 4561, fax 456 4374

VTT Technical Research Centre of Finland
Vuorimiehentie 5, P.O.Box 2000, FIN–02044 VTT, Finland
phone internat. + 358 9 4561, fax + 358 9 456 4374

VTT Tuotteet ja tuotanto, Tekniikantie 12, PL 1301, 02044 VTT
puh. vaihde (09) 4561, faksi (09) 456 6752

VTT Industriella System, Teknikvägen 12, PB 1301, 02044 VTT
tel. växel (09) 4561, fax (09) 456 6752

VTT Industrial Systems, Tekniikantie 12, P.O.Box 1301, FIN–02044 VTT, Finland
phone internat. + 358 9 4561, fax + 358 9 456 6752

Text preparing Arja Grahn

Technical editing Leena Ukskoski

Otamedia Oy, Espoo 2003

Preface

Dr. R. H. (Bob) Brown, Australia (email: rhbrown@eck.net.au)

In the late 1980's Professor Yoshikawa of Tokyo University recognised that no single organisation, or even a country, could learn enough to form the basis for future advances in the increasingly complex Global Village in which we now live. He proposed a scheme for sharing experiences in intelligent engineering. That scheme has now been adopted internationally and is known as the Intelligent Manufacturing Systems (IMS) program.

Following a series of meetings, Australia, Canada, the European Free Trade Association (EFTA) countries, the European Union (EU) and the USA conducted a feasibility study from 1992 until 1994. A full-scale IMS initiative commenced in 1995. The program now involves Australia, Canada, EU and Norway, Japan, Switzerland, USA and South Korea. Other regions have expressed interest and discussions have commenced to consider a revised program following the current term – 2004.

The IMS initiative provides a support structure for conducting R&D projects within specific arrangements for the protection of intellectual property rights. Results of collaborative IMS projects are shared through a process of controlled information diffusion that protects and equitably allocates any intellectual property.

The program is led by industry and addresses business practices and technologies of direct relevance to all phases of innovation and manufacturing life-cycle: from conception, design, production development, manufacture, distribution and recycling. The technical themes embrace total product life cycle, strategic planning and design, manufacturing processes, global enterprise integration, human organisation and social issues.

It has been found that consortium members joining an IMS project are initially wary of the agreement requirements, but once a consortium is operating and achieving useful results, an environment of trust and mutual respect develops. That trust and collaborative spirit, crossing cultural barriers, is a significant feature of the IMS program.

Several of the organisations participating in the GLOBEMEN project recognised the benefits of collaborating under the IMS program and they formed a project "Globeman21" in 1992, at the feasibility stage of IMS. This was reformulated and operated in 1995 and achieved some important findings till its planned conclusion in 1999. In January 2000 GLOBEMEN commenced as a new project with less partners than Globeman21 and a sharper focus on inter-enterprise information exchange and control.

Contents

Part II. Sales & Services

Part III. Inter-enterprise Coordination

Part IV. Distributed Engineering

Part V. Performance Assessment

Introduction

Martin Ollus
VTT Industrial Systems, Finland (email: martin.ollus@vtt.fi)

Abstract

The IMS project GLOBEMEN deals with networked engineering and manufacturing, including the pre- and aftersales phases. Engineering and manufacturing in enterprise networks are embedded in a large number of novel concepts and theories about a variety of issues. These are covered in the development tasks performed in the GLOBEMEN project.

The wide variety of issues affects attempts to communicate about progress in the area. Introductions to production in virtual enterprises easily go astray due to the complexities of the interdisciplinary field addressed. As an instrument for communication to the non-specialist public, the IMS GLOBEMEN project produces a web-based scenario as a part of its dissemination activities. The scenario is aimed at giving a practical overview of the specific challenges in the field and of the contributions of the project. Based upon a generic Virtual Enterprise Reference Architecture (called VERA), the partners in the project have developed a set of protypes to be implemented in their own business processes. The results will be illustrated in one integrated scenario.

1. Introduction

Under the Intelligent Manufacturing Systems (IMS) programme, the GLOBEMEN (Global Engineering and Manufacturing in Enterprise Networks) project aims to support the integration of business and engineering processes executed by a virtual enterprise (VE) in a global and multicultural environment [1]. The main focus is on inter-enterprise integration and collaboration in one-of-a-kind production, which usually consists of large deliveries, for example process and power plants, infrastructure projects, production lines, tele-communication systems, aerospace products, ships and offshore platforms. The virtual enterprises producing such products work under short-term business relationships and are characterised by high capital costs, multidiscipline inputs and complexity. GLOBEMEN aims at producing results that will lead to products and new business practices that will enable partners with different information and communication technology (ICT) and different business processes to collaborate efficiently.

The GLOBEMEN project consists of partners from Australia, Europe and Japan. They all bring to the project core competencies in a variety of fields related to thetasks and challenges mentioned earlier. There are partners with strong experience of delivery and operation of one-of-a-kind products as well as partners with good reputation in the area of systems and infrastructures in the consortium. The research competencies cover a large area from enterprise and business modelling to product data exchange and ICT support for networking activities.

To achieve the results, the project develops an architectural framework harmonising the requirements for ICT support. The framework will be supported by guidelines on setting up and operating VEs. The industrial end user partners will demonstrate the business benefits of the harmonised ICT architecture in their own processes.

Three main business processes are addressed, i.e. sales and service, inter-enterprise (project) management, and distributed engineering. The processes are chosen to give a wide coverage of the different phases of the life cycle of the products. The results of the project will be applied as prototype solutions in the business processes of the industrial companies involved. These represent a wide variety of industrial sectors such as construction, power plants, shipbuilding, chemical plants, food and feed processing plants and telecommunication networks.

The participating end users will benefit from the framework through more efficient processes. Since the developed results will be integrated, parts of their business processes, a wider dissemination and general demonstration of the results require special attention. For this purpose, the consortium has developed a demonstration scenario that will combine all the developed solutions into a coherent frame and that can be used to explain their content and relationships.

The aim of this book is to present the results of the GLOBEMEN project to the public outside the consortium. All the partners are involved in the presentation of the results, which are grouped into five parts. Part I deals with the reference architecture, the main goal of the project. The VERAM reference architecture and methodology and its parts are presented and illustrated. In Part II, applications in the sales and service area are described whereas Part III covers inter-enterprise co-ordination. Distributed engineering is discussed in the papers of Part IV, whereas Part V contains an assessment of the performance and benefits of the project.

A web-based demonstration has been developed in parallel with this book to support dissemination of the results and to transfer the experience between the partners and to the outer communities. This will help support reuse of the results of the project. This demonstration will shortly be discussed in this introductory paper.

2. Approach in GLOBEMEN

The development of a framework to support integration is based on a combination of bottom-up and top-down approaches illustrated in Figure 1.

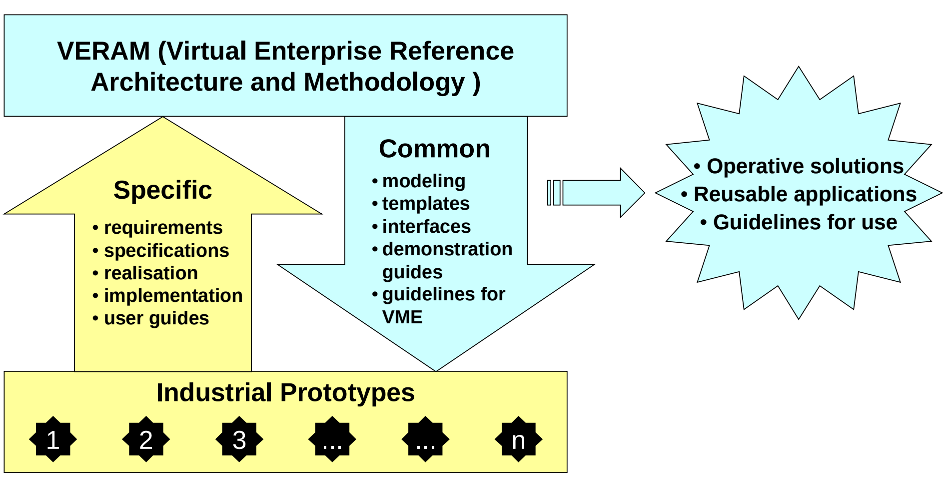


Figure 1. Combined bottom-up and top-down approach to develop an architectural framework for virtual manufacturing enterprises (VME).

The industrial partners develop their solutions based on their own company-specific business processes and information systems. However, the requirements, specifications and solutions are all made following the same guidelines aiming at supporting integration and interoperability. Generic guidelines are also developed to support reuse of the solutions. The top-down approach is based on a set of models included in the VERAM framework created as a part of the GLOBEMEN project, cf. [2].

3. Demonstration scenario

The main proof of the relevance of the results will be the use of the prototypes in the companies for which they have been developed. The prototypes are demonstrated within the companies as running software using related process data. Because of the local connections and because of possible use of confidential data, the results cannot be widely distributed in this way. The prototypes are described in the other papers of this volume.

The consortium has developed demonstration scenarios to allow a wide dissemination and to demonstrate the achievements for a wide public. There are two scenarios that can be accessed over the web. One is focussed on mass production systems and the other on one-of-a-kind production.

In the demonstration scenario the prototypes are connected to each other using fictive cases, production of pet robots and an oilrig. The scenarios are described as a story with a set of scenes. The stories serve as neutral frameworks in which partial and industry specific demonstrations from GLOBEMEN are embedded.

4. Conclusions

In an inter-regional consortium, such as the IMS projects, the dissemination and exchange of results within the consortium is a challenging task, because the opportunities for meetings and common discussions are not as good as in a purely regional consortium. These proceedings describe the results of the projects and the content has also been presented in an internal conference to all partners. In addition, the demonstration scenarios will help all partners to easily understand each other's achievements despite e.g. geographical distances and cultural differences. They also force the partners to present their results understandably, since they have to be applied in a completely new environment compared to the original development. Thus, the demonstration scenarios support the transfer and reuse of the results within the consortium.

The proceedings and the demonstrations are also aimed for becoming an important vehicle for external dissemination. The demonstration scenarios will hopefully help give an understanding of the achievements in the specific prototypes and of the general architectural framework for promotion of integration and interoperability. The structure of the demonstration allows access to the supporting background documents and presentation concerning the theory and methodology behind the development. Hopefully, the dissemination of results will also stimulate the generation of new ideas and approaches to solve the integration and interoperability problems, which seem to be some of the most challenging issues in the formation and operation of virtual enterprises and networks. The development of approaches to manage collaboration between the partners in VEs seems to emerge as an important part of this area. The VERAM approach could be a good basis for further work in the field.

References

GLOBEMEN. Global Engineering and Manufacturing in Enterprise Networks. Research project Jan 2000 – Dec 2002. IMS 99004, IST-1999-60002. http://globemen.vtt.fi.

1. Zwegers, A., Hannus, M. & Tølle, M. Integration issues in virtual enterprises supported by an architectural framework. In: International IMS Project Forum 2001, a common platform for cross-fertilization among IMS projects and promotion of the IMS program, ed. by Bernardo Ferroni, Claudio R. Boer & Charles M. Anderson. ISBN 88-900298-3-8.

2. Vesterager, J., Pedersen, J. D. & Tølle, M. Virtual Enterprise Reference Architecture and Methodology, a modified for publication extract of deliverable 1.3 “Final Report on Models” of IMS 95001/ESPRIT 26509 Globeman21 (Global Manufacturing in the 21st Century). 120 p.

3. Vesterager, J., Bernus, P., Pedersen, J. D. & Tølle, M. The what and why of a Virtual Enterprise Reference Architecture. In: E-work and E-commerce, Novel solutions and practices for a global networked economy, ed. by B. Stanford-Smith & E. Chiozza. IOS Press, 2001. Pp. 846–852.

4. GERAM. Generalised Enterprise Reference Architecture and Methodology. IFAC/IFIP Task Force on Architectures for Enterprise Integration. (1999). (Available to download from http://www.cit.gu.edu.au/ ~bernus/ taskforce/ geram/versions/geram1-6-3/v1.6.3.html).

5. Hartel, I., Burger, G., Billinger, S. & Kamio, Y. Virtual organization of after-sales service in the one-of-a-kind industry. In: Collaborative Business Ecosystems and Virtual Enterprises, ed. by Luis M. Camarinha-Matos. Kluwer Academic Publishers, Boston (USA), 2002. Pp. 405–420.

Part I

Reference Architecture

VERAM:
Virtual Enterprise Reference Architecture and Methodology

Arian Zwegers
Baan Development B.V., Netherlands (email: azwegers@baan.com)
Martin Tølle
Technical University of Denmark, Denmark (email: mat@ipl.dtu.dk)
Johan Vesterager
Technical University of Denmark, Denmark (email: jve@ipl.dtu.dk)

Abstract

Nowadays, enterprises cooperate more extensively with other enterprises during the entire product life cycle. Temporary alliances between various enterprises emerge such as those in Virtual Enterprises. However, many enterprises experience difficulties in the formation and operation of virtual enterprises, for instance concerning integration issues. This chapter lays down an architectural framework, called VERAM, which aims to support the set up and operation of virtual enterprises. The framework aims to offer handles that contribute to solving the problems that enterprises face when they want to cooperate in a Virtual Enterprise. Supported by the framework, individual enterprises might operate and set up a virtual enterprise from a dynamic, inter-enterprise network. Furthermore, this chapter shows how other chapters of this book fit into the VERAM architectural framework.

1. Introduction

One of the trends in the global market is the fact that enterprises cooperate more extensively with other enterprises during the entire product life cycle. This is related to business drivers, such as the need for cost reduction, flexibility, focus on core competencies, and so on. The result is anything from a rather stable alliance between partners as in a supply chain to a more transitory cooperation as in a Virtual Enterprise (VE) [1].

The objective of this paper is to lay down a foundation for future applications to support the set up and operation of VEs. It is a result of research performed on the definition of an architectural framework for virtual enterprise engineering, as part of IMS project GLOBEMEN [2]. The project focuses on one-of-a-kind-production (OKP) and aims to organise knowledge about the formation and operation of virtual enterprises. The framework that organises all this knowledge is called VERAM – Virtual Enterprise Reference Architecture and Methodology and is a VE specialisation of GERAM (ISO15704: 2000) [3].

This chapter is organised as follows. The next section explains the need for an architectural framework for VE engineering. In section 3, the VERAM architectural framework is presented. Each of the components in the framework is subsequently presented in more detail. If applicable, references are made to other chapters of this book that fill in the VERAM components. A discussion concludes this chapter.

2. Rationale

Several problems frequently occur during the set up, operation, and reconfiguration of virtual enterprises. Different levels of integration have to be considered. A number of viewpoints must be taken into account; not only the technical view, but also – for instance – the economic, organisational, and legal points of view have to be taken into consideration. Generally, virtual enterprises are quite complex, and their set up and operation is often quite expensive and risky. The information systems, business processes, and procedures of existing companies – i.e. the members of the virtual enterprise – have to be considered in the VE design process, so that the members can interact in a proper way. The activities performed during each phase of the VE life cycle are essentially derived from ad hoc procedures, so that the quality of the resultant VE will depend considerably upon the experience of the persons and companies involved. The problem is accentuated due to a low level of formalism with which those activities are usually carried out. This often leads to solutions that do not adequately address business requirements, lack of traceability of design decisions, low repeatability of successful results, and so on.

The purpose of the architectural framework is to structure a body of knowledge that supports future work in the area of global engineering and manufacturing in enterprise networks. The framework aims to offer handles that contribute to solving the problems mentioned above, and with which individual enterprises might operate and set up a virtual enterprise from a dynamic, inter-enterprise network. The aim is to organise knowledge about the formation and operation of virtual enterprises. A large part of the procedures, tools, and methods used is in fact similar and common every time a VE is set up or operated. This part could be formalised and re-used instead of figuring out every time what tools or methods to use, and developing some parts again from scratch. In addition to a more time and cost-effective operation of the VE, it is expected that the set up of the VE from an enterprise network would become faster and more efficient. Therefore, an architectural framework is needed that organises all this knowledge.

The above implies that the architectural framework contains tools, methods, applications, etcetera, on a *generalised level*, i.e. these tools, methods, and applications are not focused on one specific virtual enterprise or instance of a network. Rather, it focuses on generic knowledge, which is applicable in many, specific situations. Other companies outside the GLOBEMEN consortium might use these tools, models, and methods as well.

3. VERAM

3.1 Introduction

A Virtual Enterprise Reference Architecture and Methodology (VERAM) has been created in GLOBEMEN (see Figure 1). The architectural framework positions elements that support modelling, formation/set up, management and ICT support of VEs, such as reference models, and supporting tools and infrastructures. Interrelations among these elements are indicated. This framework is inspired by the GERAM framework [3], and focuses on virtual enterprise formation and operation. First versions of VERAM were previously published in [4, 5].

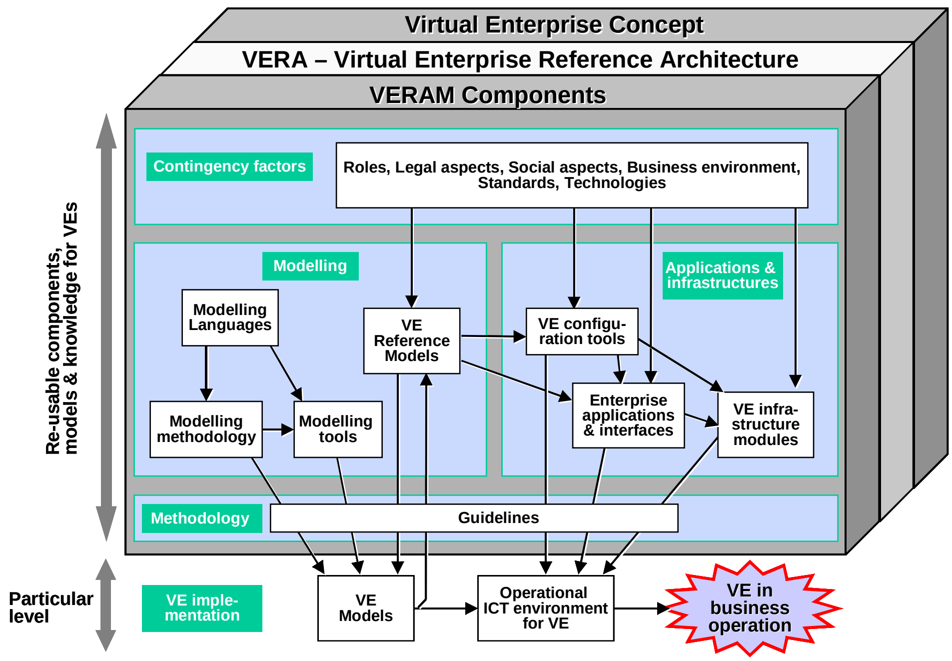


Figure 1. VERAM – Virtual Enterprise Reference Architecture and Methodology.

Figure 1 shows that VERAM consists of three layers. A layer builds on its underlying layer, which at its turn builds on its underlying layer as well. Consequently, a layer explicitly uses the concepts of its underlying layer, and implicitly uses the concepts of all layers underneath its underlying layer. The rest of this chapter describes the three VERAM layers.

3.2 Virtual Enterprise concepts

The bottom layer shows the Virtual Enterprise concepts (see Figure 2). It introduces the concepts of the Virtual Enterprise (VE) and the Enterprise Network. The latter is a cooperative alliance of enterprises established to jointly exploit business opportunities through setting up virtual enterprises. The main purpose of a network is to prepare the life cycle of VEs and the products created by the VEs as well as to manage the life cycle of VEs. It establishes mutual agreements among its members on issues such as common standards, procedures, intellectual property rights, and ICT, so that these time-consuming preparations can be significantly shortened when a customer request arises, and a VE is put in place. The network should be seen as a potential from which different VEs can be established in order to satisfy diverse customer demands. The network will seek out and await customer demands, and when a specific customer demand is identified the business potential is realized by forming a VE. When the customers demand has been fulfilled, the virtual enterprise dissolves. Accordingly, compared to a virtual enterprise, a network can be perceived as a relatively long-term cooperation since it typically sets up multiple VEs. Conversely, the VEs have a more temporary nature.

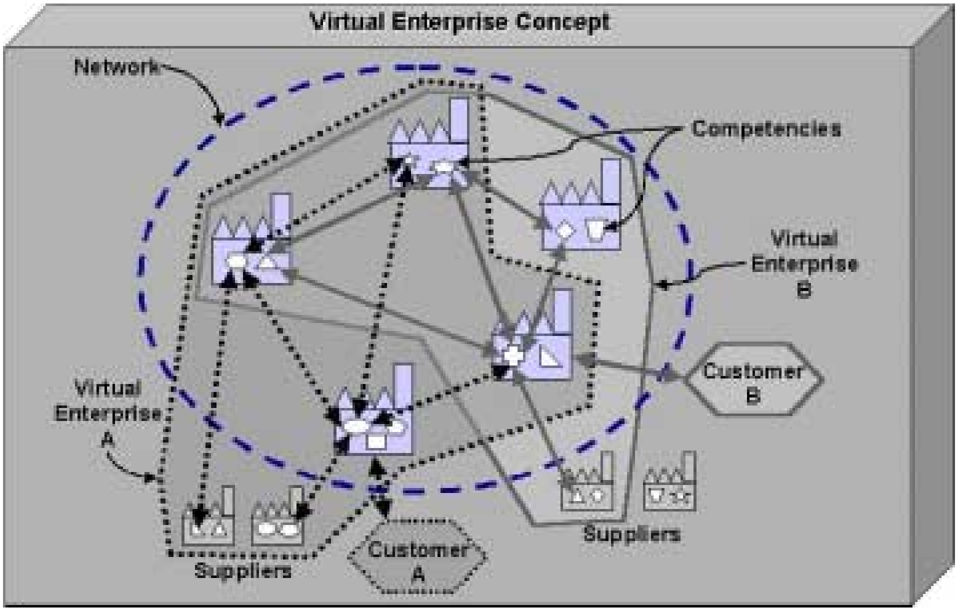


Figure 2. Enterprise Network and Virtual Enterprises.

A Virtual Enterprise can be defined as a *"Customer solutions delivery system created by a temporary and reconfigurable ICT enabled aggregation of core competencies"* [2, 6]. Formation of the VE materializes through configuration of the core competencies and capabilities available in the network and possibly through inclusion of additional, required competencies provided by non-network participants, cf. Figure 2. Though being comprised by competencies from various partners, the VE performs as one, unified, and attuned enterprise. Hence its virtual nature. Accordingly, the business processes are not carried out by a single enterprise, but every enterprise is a node in the VE that adds some value to the product chain.

3.3 Virtual Enterprise Reference Architecture

The middle layer consists of the Virtual Enterprise Reference Architecture (VERA), which organises the virtual enterprise related generic concepts recommended for use in virtual enterprise engineering and integration projects (see Figure 3). It captures the essence of the GLOBEMEN view of virtual enterprises described in the bottom layer, and conceptualises it into a generic framework based on the entity life cycle concept and modelling architecture of GERAM [3]. VERA also organises other essential VERAM components, such as Reference Models, configuration tools, applications, and also some of the Contingency factors (standards and technologies).

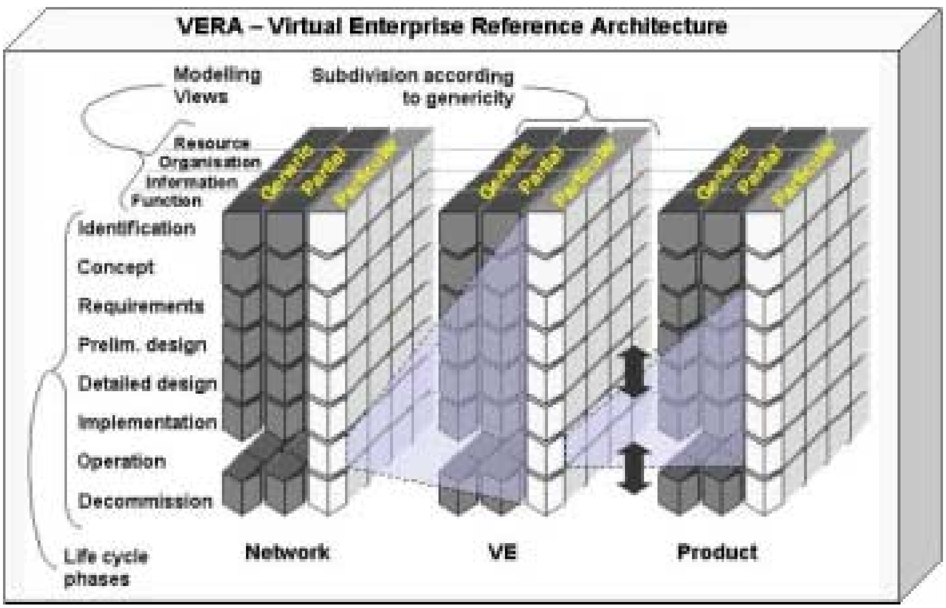


Figure 3. The Virtual Enterprise Reference Architecture.

In short, VERA illustrates the logical, recursive relationships between the network entity, the VE entity, and the product entity. Each of these three entities is represented by a life cycle describing possible phases an entity can be in throughout its life span from identification to decommission. VERA illustrates that the network can create VEs in its operational phase and, correspondingly, that a VE can create products and/or services in its operational phase. A central means for facilitating a fast and efficient set up and operation of VEs and hereunder a fast realisation of the product or service in the VE is through preparation. The generic and partial boxes in Figure 3 have been shaded indicating the location of general (thus reusable) parts such as e.g. reference models (RMs) in VERA. The remaining non-shaded boxes represent the particular entities containing instantiated RMs, commercial off-the-shelf components or self-developed components. Enterprises engaged in VE focused networks should determine which of the non-shaded boxes they would need and most importantly by what means (using available standards, RMs from other sources, and/or develop own RMs) [7]. The life cycle activities of the VE are prepared in the network phases up to and including implementation and set up in the operation phase of the network. The preparation in the network should address not only the set up but also the operation of the VE. This means that the network also should prepare the products or services created by the VE. Likewise the life cycle of the product or service can be further prepared (if needed) and subsequently created in the operation phase of a VE. Please note that a network can establish several VEs, just like a VE can produce several products.

Even though VERA implies a time progression from the identification phase to the decommission phase and from the network entity to the product entity, neither the individual life cycles nor the complete reference architecture express an explicit time dimension. Therefore, it does not describe the actual or planned life history of a virtual enterprise. Examples of life histories can be found in [8] and [9].

What is not shown in VERA is that the network is identified, set up as well as operated by enterprises. Each of the life cycle phases of the network is carried out by one or more enterprises, all of them being in their operational phase. Thus, all phases of the network are executed by ‘real’ enterprises, which are not shown in Figure 3. Likewise, when a network sets up and operates VEs, it is the ‘real’ enterprises participating in the network which set up and operate the VE which eventually creates the delivery to the customer.

For more information about VERA, please refer to [8]. Special cases of the Virtual Enterprise concept in VERA are the concepts of the ‘Quotation Virtual Enterprise’ and the ‘Service Virtual Enterprise’ [10]. Building upon the latter concept is another chapter in this book which describes an organizational and technical approach to how small and medium sized enterprises can improve and extend their future after-sales service business by setting up cooperation networks [11]. Within the scope of cooperations between one-of-a-kind producers, customers, service partners and suppliers, services can be offered in collaboration with local service partners or directly in interaction with the customer using tele-service and e-service applications.

3.4 VERAM components

3.4.1 Introduction

Finally, the top layer consists of the VERAM components that are used during the application of the architectural framework in practice. It consists of those tools, applications, models, and so on, that can be used during the formation and operation of VEs and enterprise networks. Please note that these components can be positioned in VERA as well, but they are shown in the top layer to indicate their mutual interrelations and their application in practice.

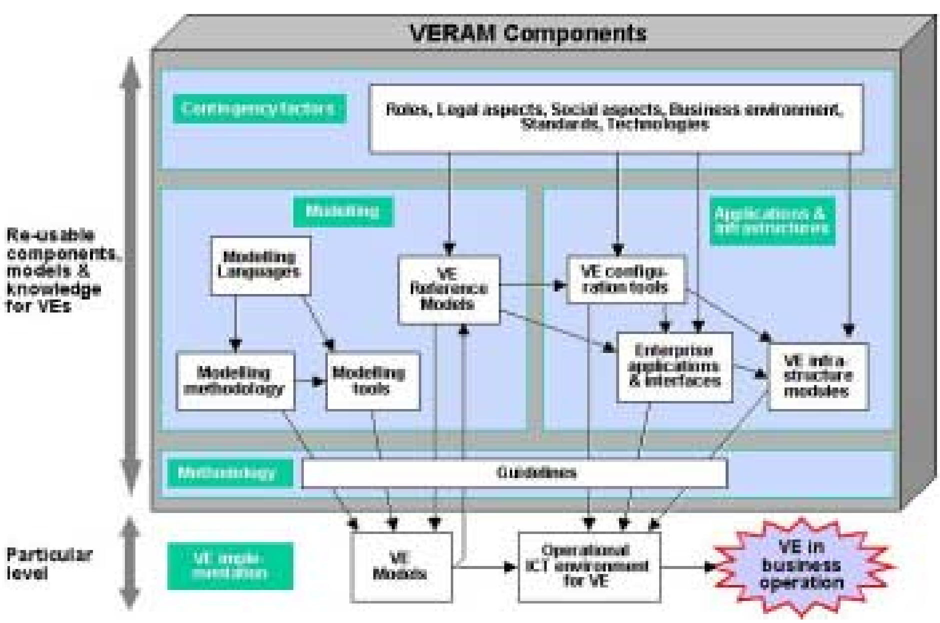


Figure 4. VERAM components.

Perhaps the most important component in the top layer is the guidelines that indicate how the tools, applications, and models should be used in practice. Therefore, VERAM includes a methodology, which describes how an organisation should use the various components of the architectural framework during virtual enterprise engineering (see [9]). The guidelines should describe main procedures and considerations to apply for deciding how to get from the top layer VERAM components to the particular models and operational ICT environment for a specific VE, as a way to get to the actual business operation of the VE.

In the remainder of this section, the top layer VERAM components are described into detail.

3.4.2 Modelling

VERAM's modelling part allows enterprises to analyse, prepare and (re-)design the VE's business processes, partner roles, contracts, and so on. During the formation of a VE, but also during reconfiguration of an existing VE, enterprises may acquire knowledge of current business processes by means of modelling. This knowledge is needed in order to analyse the existing processes and communicate about them. Then, the models may be changed to take required modifications into account.

The definition of sound business processes, upon which the further design or selection of needed ICT tools and applications is based, is one of the keys to business process integration. Cooperation in virtual enterprises requires that a common understanding exists about shared business processes. Modelling languages are needed to make these business processes explicit. Main areas are modelling of data and modelling of processes.

Modelling Languages

(Enterprise) Modelling Languages define the generic modelling constructs for (enterprise) modelling adapted to the needs of people creating and using enterprise models. In particular, enterprise modelling languages provide constructs to describe and model human roles, operational processes and their functional contents [3].

Main classes of modelling languages are:

- Process modelling languages, such as SADT, OMT, Petri nets
- Data modelling languages, such as Entity-Relationship Modelling, Express
- Process and data modelling languages, such as IDEF, UML

Most enterprise modelling languages are generally applicable to inter-enterprise modelling as well but may require a specific modelling style in order to distinguish intra- and inter-enterprise issues.

Modelling Methodology

Modelling Methodologies support the modelling process by means of guidelines, which guide a user in making models. Modelling Methodologies are usually related to a specific Modelling Language and may be 'embedded' in a Modelling Tool.

Modelling Tools

Modelling Tools support the processes of enterprise engineering and integration by supporting modelling languages. Frequently, a kind of engineering methodology is implemented in a modelling tool as well. Modelling tools should provide for analysis, design and use of enterprise models.

Numerous modelling tools are available that support IDEF or UML modelling. In addition, well-known enterprise engineering tools exist, such as ARIS.

VE Reference Models

Reference Models (or Partial Models) capture characteristics that are common to many (virtual) enterprises within or across one or more industrial sectors. Thereby, these models capitalise on previous knowledge by allowing model libraries to be developed and reused in a 'plug-and-play' manner rather than developing the particular (VE) models from scratch. Reference models make the modelling process more efficient.

The scope of these models extends to all possible components of the enterprise such as models of human roles (skills and competencies of humans in enterprise operation and management), and operational processes (functionality and behaviour). Some authors consider models of technology components (service or manufacturing oriented), and infrastructure components (information technology, energy, services, etc.) to be part of reference models as well. However, in VERAM the latter two are positioned in Enterprise Applications and VE Infrastructure Modules respectively.

Reference models may cover the whole or a part of a typical (virtual) enterprise. They may concern various enterprise entities such as products, projects, companies, and may represent these from various points of view such as data models, process models, and organisation models. More information about reference models applicable for VEs can be found in [7].

The GLOBEMEN Reference Model focuses on the processes executed by an enterprise related to:

- participation in / management of an enterprise network,
- formation of a virtual enterprise, and
- operation in a virtual enterprise.

Figure 5 shows that the GLOBEMEN Reference Model consists of various types of models, ranging from $IDEF_0$ process models to UML implementation diagrams.

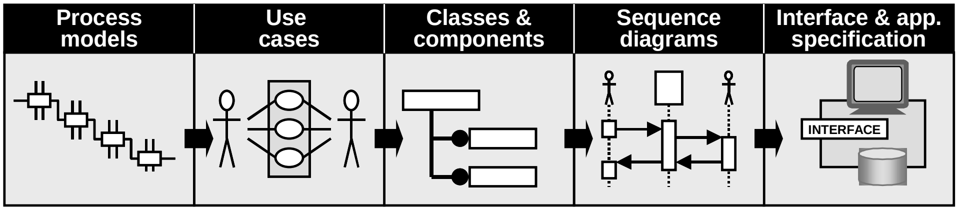


Figure 5. Types of models in the GLOBEMEN Reference Model.

Other chapters in this book that deal with reference models are [12, 13, 14].

Bernus *et al.* propose a new approach based on intelligent agents to improve reference models for the management of virtual enterprises in general, and the GLOBEMEN reference model in particular [12].

In another chapter, Bernus *et al.* show the advantages of using tailorable reference models for virtual enterprise design and implementation [13]. They present a step-by-step methodology for designing virtual enterprises for after sales service. Their methodology includes the identification and concept development of the enterprise network as well as of its virtual enterprises. The management and service delivery processes are designed through customising the Globemen Reference Model.

Also in the after sales domain, Hartel *et al.* present a reference model for collaborative service and an industrial case study [14]. They introduces a model showing how future collaboration in after-sales services in the one-of-a-kind industry might look like. The proposed reference model is intended to provide a guideline to set up an inter-enterprise service enterprise based on the principles of the virtual enterprise.

3.4.3 Contingency Factors

The rationale behind having a set of contingency factors is that – like in many other fields – there are few, if any, simple and universal principles that explain virtual enterprises, and that there are few, if any, solutions that are applicable for all types of virtual enterprises. This does not mean that no valid general descriptions can be made, for instance about how to set up and operate a virtual enterprise. It does mean, however, that the VE concepts, tools, and guidelines must reflect situational or contingency conditions. That is, certain types of situations and environment speak for certain types of configurations and accompanying solutions such as applications and infrastructure.

The contingency factors distinguish between two types:

- **Situational factors**: conditions, which affect the set up of the VE-focused network, i.e. characteristics of the business environment, which is outside the control of the network and VE members.

- **Design parameters**: selected parameters, which describe different set ups for VE-focused networks, e.g. pre-qualification for the network, network management, etc. Thus design parameters are defined as the solution space in which the network can freely be decided.

For instance, the duration of the network could influence the level and type of preparation in the network – a longer duration implies a higher level of preparation. Similarly, the 'power balance' between the partners speaks for different types of design, e.g. a consortium with a dominant main contractor needs different role models and management structure than a more democratic partnership where the partners have a more similar size and power towards each other.

3.4.4 Applications and Infrastructure

The Applications and Infrastructure section contains the components that perform or support the business processes as described in the Modelling section. As such, they provide the (technological) realisation of these business processes. These Applications and Infrastructure Modules concentrate on the execution or support of the formation or operation of virtual enterprises and networks.

VE Configuration Tools

VE Configuration Tools are used to set up virtual enterprises. Different types of configuration tools may be identified such as platform configuration tools, project configuration tools, and contract configuration tools. These tools aim to set up a virtual enterprise quickly, based on proven business models, applications, and platforms. They use VE Reference Models, and define a configuration of Enterprise Applications and VE Infrastructure Modules.

Zwegers *et al.* propose an approach based on 'traditional' project management tools for the definition and management of relations in an enterprise network

[15]. They introduce the concept of eXtended Relationship Management services. These services should be part of an integration infrastructure, and should be used for definition and management of inter-enterprise relationships.

Enterprise Applications

Enterprise Applications are either standard, commercial off-the-shelf systems or bespoke solutions, developed for a particular enterprise. In this context, we focus on the functionality provided by Enterprise Applications to join and/or set up a network, and to form and/or operate a virtual enterprise. Examples are applications for collaborative project management, distributed engineering, subcontracting, internal trade, certain knowledge management functions, and so on.

Enterprise Applications provide (parts of) the functionality that is outlined in the VE Reference Models. Therefore, mappings can be made between Enterprise Applications and VE Reference Models. In other words, the mappings indicate what business processes as defined in VE Reference Models are covered by what (standard, off-the-shelf, home-grown) Enterprise Applications.

Many other chapters in this book present examples of enterprise applications, showing the large diversity of prototypes developed within the GLOBEMEN project. These prototypes are shortly listed below.

Anastasiou and Tsagkas describe the AGORA prototype, which aims to support the management of information related to the pre-sales and marketing processes in an inter-enterprise environment [16]. It builds on the thesis that the efficient operation of a business network is based on the dissemination and exchange of partners' local knowledge and innovation, throughout the whole product life cycle, from marketing and implementation to operation and support.

Välikangas and Puttonen present a knowledge creation environment (KCE) and accompanying procedure [17]. They show the principles that can be applied in collecting, creating and using standardised information in power plant engineering. They conclude that the KCE is a promising concept to establish advanced support for information exchange between different parties in a VE.

The KCE is seen as an enabler of VEs, where the major role is to harmonise data exchange between different parties in a VE.

An internet-based platform for distributed after-sales services building upon the concept of the 'Service Virtual Enterprise' is presented by Kauer *et al.* [11]. The E-Service Support System gives access to various main user groups in a service virtual enterprise (e.g. service centre staff, service technicians, service partners, and customers) via three communication channels (Internet Channel, a Point-to-Point Channel and an Intranet-Channel).

Fukuda *et al.* show an example of a novel type of application, namely a Web-based instruction system using a wearable computer [18]. That system uses web manuals and web applications as powerful tools for instructing complex work, for instance to be used in maintenance and repair activities.

Kamio *et al.* introduce a prototype of a remote maintenance system that was developed for a fertiliser plant in Indonesia [19]. They discuss an accompanying business model of collaborative after-sales services in the one-of-a-kind industry, and the advantages of utilising the proposed hosting services as well.

A method, tools and services to support the design for agile set up or agile renewal of manufacturing systems are shown by Mori [20]. He proposes Renewal Support Services based on a distributed object oriented model. These services provide good factory design support functions to reduce total lead-time of the re-design of shop floors in factories of global inter-enterprise networks.

Kimura *et al.* introduce an example of a manufacturing support system called 'ASSIST' – After-Sales Support Inter-enterprise collaboration System using information Technologies [21]. ASSIST does not only support maintenance services but also consulting services for manufacturing systems consisting of multi-vendor machine tools. In order to do this, the system enables inter-enterprise collaboration between engineering companies and machine tool vendors.

Various Manufacturing Execution System (MES) applications using the OpenMES framework are described by Okano *et al.* [22]. The OpenMES framework is an object-oriented application framework for MES in the assembly and machining industry. This framework is connected to a B2B framework which enables the realisation of – for instance – sharing production data within a supply chain.

Nishioka *et al.* introduce the SUPREME prototype that deals with dynamic supply chains for one-of-a-kind production environments [23]. It covers web-based virtual enterprise design and collaborative planning. The architecture contains an APS module, PSLX interfaces, and web-service client-server modules.

Van den Berg *et al.* launch a prototype for collaborative project management, called C-Project [24]. It allows main contractors to set up, manage, and control a virtual enterprise, and is based on the traditional project management tools described in [15] for the definition and management of relations in an enterprise network.

Finally, the GAIA-DEE (Global Advanced Information Application for Distributed Engineering Environment) prototype is described by Kawashima *et al* [25]. It is a Web-based application platform for integrating dynamic business activities and product life cycle information. GAIA-DEE offers a collaborative engineering solution for globally distributed companies.

VE Infrastructure Modules

VE Infrastructure Modules are used to enhance Enterprise Applications with VE specific functionality. An explicit distinction is made between an Enterprise Application and the enabling technology offered by an infrastructure upon which the Enterprise Application resides. If certain technologies are chosen for the Enterprise Applications to implement certain functions, some additional technology (i.e. its functionality is not defined in VE Reference Models) might be needed to enable a proper functioning of the first technologies. VE Infrastructure Modules thereby enable the execution of VE processes by Enterprise Applications.

Within GLOBEMEN, a seven layer architecture has been defined that covers the VE applications, VE infrastructure modules, and enterprise-specific applications

[26]. In addition, an integration infrastructure has been defined that should be able to support the set up and operation of virtual enterprises [27].

Kazi and Hannus claim that information exchange (upload and download) in a VE setting should be done through links between enterprise systems and stored in a central repository which also supports specific VE services [28]. They identify three different inter-enterprise mechanisms for one-of-a-kind production, viz. file exchange, project servers, and links between enterprise systems.

Kazi *et al.* argue that relying on common standards is seen as a main instrument for information exchange between heterogeneous information sources and applications [29]. In industries such as construction where multiple partners share complementary competencies to deliver a unique product, information integration and exchange is being pioneered through the use of product data technology. Approaches are developed that rely on pre-populating product models with references to relevant best practices, and making the results available through multi-dimensional visual interfaces for use by different categories of end-users.

4. Discussion

The discussion focuses on two parts, namely on how the VERAM framework can be used for the integration of different enterprises into a virtual enterprise, and on the status of VERAM. Regarding the first part, a distinction is made between five levels of integration. Satisfactory integration at a lower level is necessary before integration at a higher level can be achieved. Over the years, the higher levels of the framework have become more relevant.

The lowest level of integration, physical integration, is needed to facilitate co-operating applications and enterprises. Relevant standards at this level of integration are TCP/IP and Ethernet. VERAM does not explicitly address these technology standards.

Application integration is concerned with the usage of ICT to provide interoperation between enterprise resources. Cooperation between humans, machines and software programs has to be established by the supply of information through inter- and intra-system communication. Application integration is split in two parts. Whereas semantic standards support integration at the level of 'meaning', syntactic standards are meant for integration at the level of 'form'. Syntactic standards enable sources and messages to have similar formats. Standards in this area are STEP Part 21, Java RMI, XML, Corba, and DCOM. Semantic application integration should result in a situation where the output of applications is meaningful to other applications. Examples of standards at this level are EDIFACT, STEP Application Protocols, RosettaNet, and BizTalk. Clearly, the Applications and Infrastructures part of VERAM deals with application integration.

Business process integration is related to the fact that integration in virtual enterprises requires a common understanding about shared business processes. Modelling languages are needed to make these business processes explicit. Examples of standards at this level are IDEF, Petri nets, UML, and so on. VERAM's Modelling part is concerned with business process integration. Even if cooperating enterprises speak the same language, they may not understand each other because their business processes may not be aligned. Modelling interactions between members in a virtual enterprise – for example by means of UML sequence diagrams – is a suitable tool to define and analyse aligned business processes. The internal processes do not have to be modelled; just the business processes 'at the interface'. Furthermore, the VE Reference Models are the appropriate means to get consensus among different partners in a VE about the business processes to be adopted, about the various roles of different partners, and so on.

The highest integration level, inter-enterprise coordination, is specific for supply chains and virtual enterprises, in short for all situations in which enterprises cooperate with other enterprises and coordination is needed beyond their boundaries. For this, dedicated guidelines for inter-enterprise coordination are needed, e.g. for partner selection, certification or inter-enterprise best practice definition, and so on. The guidelines within VERAM address these issues.

Regarding the status of VERAM at the end of the GLOBEMEN project, it is clear that some parts are more mature than others. The foundations, the bottom and middle layers, are relatively stable and mature, but the top layer might be elaborated upon as new insight becomes available. This is an ongoing process which should be continued beyond the GLOBEMEN project. The availability of reference models, suitable applications and infrastructures, and perhaps above all guidelines and methodologies are crucial to execute upon visions such as 'collaborative business'.

The VOSTER project continues the work started on VERAM [30]. Its four technical work packages address respectively concepts, modelling, technologies and standards, and infrastructures for Virtual Organisations. Although VOSTER does not explicitly consider an architectural framework, its activities are based on (earlier versions of) VERAM. VERAM will find an adequate successor for GLOBEMEN in VOSTER.

References

1. Berg, R. van den, Hannus, M., Pedersen, J. D., Tølle, M. & Zwegers, A. 2000. Evaluation of state of the art technologies. Globemen EU (IST-1999-60002) deliverable D411.

2. Global Engineering and Manufacturing in Enterprise Networks. IMS 99004, IST-1999-60002, 2000–2002. URL: http://globemen.vtt.fi

3. GERAM – IFAC/IFIP Task Force on Architectures for Enterprise Integration, "GERAM: Generalised Enterprise Reference Architecture and Methodology, ISO15704: 2000". (available on: http://www.cit.gu.edu.au/~bernus)

4. Zwegers, A., Hannus, M. & Tølle, M. 2001. Integration issues in virtual enterprises supported by an architectural framework. Proceeding of the IMS Forum. Bernardo Ferroni, Claudio R. Boër & Charles M. Anderson (eds.). Pp. 246–254.

5. Zwegers, A., Hannus, M., Tølle, M., Gijsen, J. & Berg, R. J. van den 2001. An architectural framework for virtual enterprise engineering. E-work and E-commerce – Novel solutions and practices for a global networked economy. B. Stanford-Smith & E. Chiozza (eds.). IOS Press. Pp. 1117–1123.

6. Vesterager, J., Larsen, L. B. & Gobbi, C. 1999. Architecture and methodology for creating virtual enterprises – results from Globeman21. Presented at the IMS Globeman21 Open Day, March 9th 1999. TIME24, Tokyo, Japan.

7. Tølle, M., Bernus, P. & Vesterager, J. 2002. Reference Models for Virtual Enterprises. Collaborative Business Ecosystems and Virtual Enterprises. Luis M. Camarinha-Matos (ed.). Kluwer Academic Publishers, Boston, USA. Pp. 3–10.

8. Vesterager, J., Tølle, M. & Bernus, P. 2002. Virtual Enterprise Reference Architecture. This book, pp. 39–51.

9. Tølle, M. & Vesterager, J. 2002. VEM: Virtual Enterprise Methodology. This book, pp. 53–70.

10. Jansson, K., Karvonen, I., Ollus, M., Hartel, I., Burger, G. & Kamio, Y. 2002. Virtual Organisations in the Sales and Service Life-cycle Phase of an One-of-a-kind Product. This book, pp. 125–134.

11. Kauer, M., Burger, G. & Hartel, I. 2002. An Internet-based Platform for Distributed After-sales Services in the One-of-a-kind Production. This book, pp. 179–194.

12. Bernus, P., Baltrusch, R., Tølle, M. & Vesterager, J. 2002. Better Models for Agile Virtual Enterprises – the Enterprise and its Constituents as Hybrid Agents. This book, pp. 91–109.

13. Bernus, P., Noran, O. & Riedlinger, J. 2002. Using the Globemen Reference Model for Virtual Enterprise Design in After Sales Service. This book, pp. 71–90.

14. Hartel, I., Burger, G., Kamio, Y. & Zhou, M. 2002. A Reference Model for Collaborative Service. This book, pp. 135–149.

15. Zwegers, A., Wubben, H., Hartel, I. & Berg, R. van den. 2002. Managing Relations in Networks of Enterprises. This book, pp. 111–123.

16. Anastasiou, M. & Tsagkas, E. 2002. Management of Information in Collaborative Sales. This book, pp. 207–218.

17. Välikangas, P. & Puttonen, J. 2002. Knowledge Creation and Virtual Enterprises in Power Plant Construction. This book, pp. 245–259.

18. Fukuda, Y., Kurahashi, T. & Kamio, Y. 2002. Web Based Instruction System Using Wearable Computer. This book, pp. 169–178.

19. Kamio, Y., Kasai, F., Kimura, T., Fukuda, Y., Hartel, I. & Zhou, M. 2002. Providing Remote Plant Maintenance Support through a Service Virtual Enterprise. This book, pp. 195–205.

20. Mori, K. 2002. Renewal Support Services for Manufacturing Systems. This book, pp. 219–232.

21. Kimura, T., Kasai, F. & Kamio, Y. 2002. Development of an After-sales Support System for Multi-vendor Manufacturing System Using Inter-enterprise Collaboration. This book, pp. 233–243.

22. Okano, A., Kawamura, T., Asaka, S. & Koyama, S. 2002. An Object-oriented Application Framework for Construction of Manufacturing Execution System. This book, pp. 261–274.

23. Nishioka, Y., Kasai, F. & Kamio, Y. 2002. A Planning and Scheduling Integration Platform for Operational Virtual Enterprises. This book, pp. 277–285.

24. Berg, R. J. van den, Wubben, H. & Zwegers, A. 2002. Towards a Software Solution for Inter-enterprise Delivery Management. This book, pp. 287–297.

25. Kawashima, K., Kasahara, K. & Nishioka, Y. 2002. Collaborative Engineering in Inter-enterprise Networks. The prototype system GAIA-DEE. This book, pp. 337–351.

26. Kazi, S., Hannus, M. & Ollus, M. 2002. Layered architecture for inter-enterprise collaboration. Proceedings of E-business and E-work – Challenges and Achievements in E-business and E-work. Brian Stanford-Smith, Enrica Chiozza & Mireille Edin (eds.). IOS Press, Amsterdam. Pp. 1373–1379.

27. Busschbach, E. van, Pieterse, B. & Zwegers, A. 2002. Support of Virtual Enterprises by an Integration Infrastructure. Collaborative Business Ecosystems and Virtual Enterprises. Luis M. Camarinha-Matos (ed.). Kluwer Academic Publishers, Boston, USA. Pp. 311–326.

28. Kazi, S. & Hannus, M. 2002. Interaction Mechanisms and Functional Needs for One-of-a-kind Production in Inter-enterprise Settings. This book, pp. 301–312.

29. Kazi, S., Nummelin, O., Pirinen, V., Huhtala, M. & Huittinen, E. 2002. Management of Best Practices in Construction through Interfacing with Product Models. This book, pp. 363–377.

30. Virtual Organisations Cluster. IST-2001-32031, 2001–2004.
URL: http://voster.vtt.fi

VERA:
Virtual Enterprise Reference Architecture

Johan Vesterager
Technical University of Denmark, Denmark (email: jve@ipl.dtu.dk)
Martin Tølle
Technical University of Denmark, Denmark (email: mat@ipl.dtu.dk)
Peter Bernus
Griffith University, Australia (email: bernus@cit.gu.edu.au)

Abstract

Globalisation, outsourcing and customisation are main challenges of today not least for one-of-a-kind producers. A crucial competitive factor will be the ability rapidly to form customer focused virtual enterprises comprised of competencies from different partners by taking full advantage of ICT. To prepare for this is a complex task, in fact all business, management and planning views, and related subject areas and activities, may be involved. In order to deal with this complexity in a systematic way and secure global understanding GLOBEMEN has developed a Virtual Enterprise Reference Architecture based on GERAM. This paper describes its main contents and presents examples of its use and potentials.

1. Introduction

A crucial part of GLOBEMEN is the development of virtual enterprise (VE) architecture, guidelines, and reference models. In order to organise this work and secure a common global understanding, a Virtual Enterprise Reference Architecture and Methodology (VERAM, [1], [2]) has been developed by use of the international standard GERAM (Generalised Enterprise Reference Architecture and Methodology) [3]. Part of VERAM is VERA (Virtual Enterprise Reference Architecture) that is based on the GERA component of GERAM. This paper presents VERA and explains the potential uses of VERA. The next section introduces the contents of VERA explaining its main components. Section 3 presents examples of the use of VERA by considering the "what" of planning and the related "when" and "how", and finishes with more examples of VERA as a tool for organising the VE domain of knowledge. Section 4 draws up the conclusion.

2. The contents of Virtual Enterprise Reference Architecture (VERA)

The Virtual Enterprise Reference Architecture (VERA) is based on the modelling framework and associated concepts of GERAM named GERA [3]. GERA contains the three modelling dimensions: entity life cycle, genericity and view, see Figure 1. The life cycle phases of an entity are shown at the left, and the GERA modelling framework with all mentioned dimensions is depicted at the right. The dimension of genericity comprises the generic, partial, and particular levels. The particular level denotes the specific entity in question, whereas the partial level covers what is common to a group, or a type of entities. Correspondingly, the generic level includes what is general for the whole universe of discourse of the matter in question. The dimension of view[1] (denoting *how* you view) includes the four views: function, information, organisation and resource. Note the phase name abbreviations "I", "C" etc. in the boxes to the left. These will be used in the rest of the article.

If displaying VERA by use of only the life cycle dimension, VERA is composed of three recursive entities as shown in Figure 2 to the left: a network entity, a virtual enterprise entity, and a product entity.

---

[1] This view in GERAM is also named "Entity Model Contents View". GERAM introduces other views as, e.g. "Entity Purpose View", and contains several other general engineering concepts, which for reasons of space are not explicitly used in this paper.

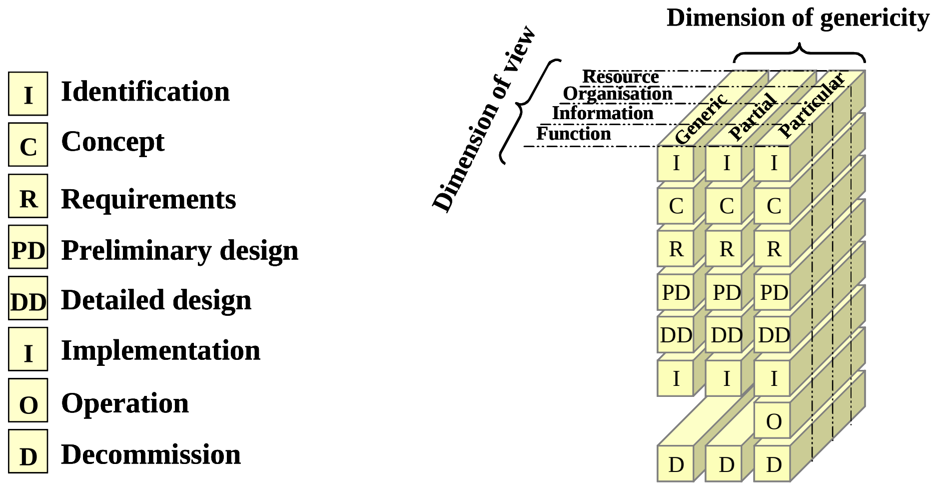


Figure 1. Entity life cycle phases (left), and GERA with all dimensions (right).

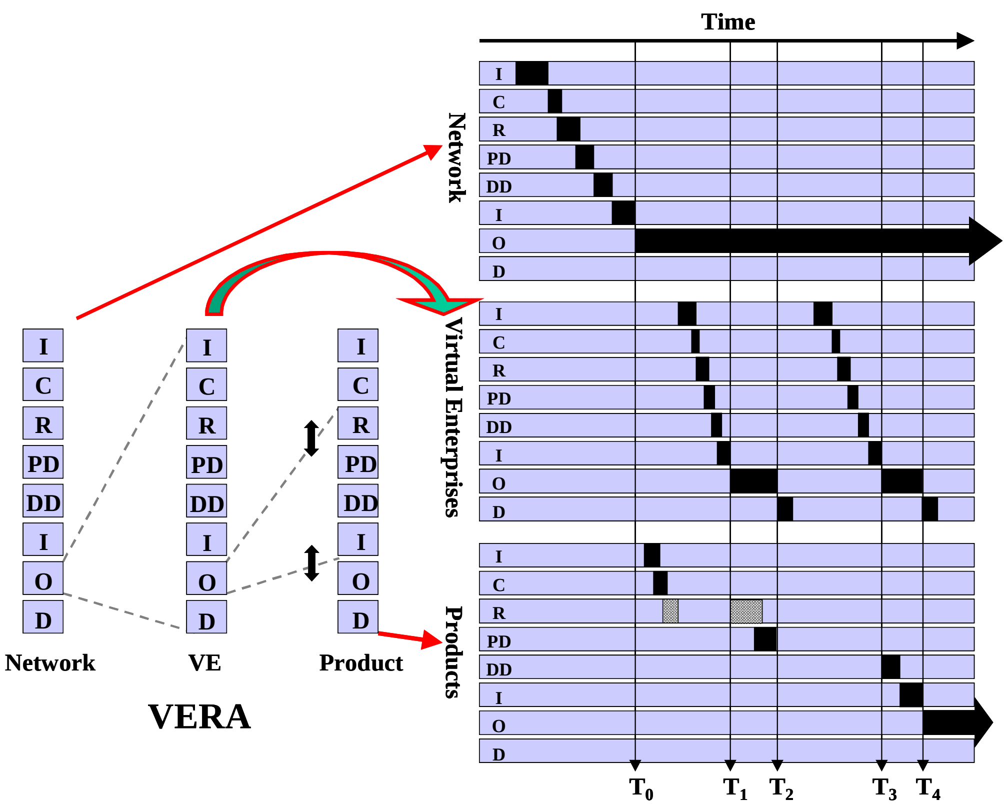


Figure 2. VERA (left) and example of life history (right).

VERA states that a group of companies form a network by assigning competencies to the network in order to be able to form VEs. In the network operational phase customer-focused VEs are formed, which produce the deliverables in question[2]. A deliverable corresponds to some product life cycle activities (called 'phases'). The phases in question will often vary from one VE to the other and correspondingly from customer to customer. Therefore two double-arrows are shown on the lines between the VE entity and product entity. Note that the enterprises forming the network are not included in the figure of VERA in this paper. This is done in order to simplify and only focus on basic structure of VERA. Also we should be aware of the fact, that the product might be an entity that produces another entity, e.g., a chemical plant that produces a chemical compound.

All in all a VE is defined as: *a customer solutions delivery system created as a temporary, re-configurable, and ICT enabled aggregation of core competencies.*

By adding the time dimension to VERA it is possible to sketch an example of a so-called *life history* of a network – see Figure 2 to the right. In this part of the figure the three VERA entities are drawn above each other in order to make the presentation possible. Note the conformity with traditional Gantt-charts, and in this way a first introduction of planning issues.

At time T_0 the network has been set up and goes into operation. Shortly after a customer identifies the need for a product (i.e., carries out the product life cycle phases "Identification", "Concept", and part of the "Requirements") and subsequently asks the network for full requirements specifications and a quotation. At time T_1 the network has set up a quotation VE, which commences operation and creates the needed product specifications for the quotation, here corresponding to a completion of the product life cycle phases "Requirements" and a carrying out of "Preliminary design". At time T_2 the quotation work is finished, and the VE is decommissioned. Subsequently, the customer accepts the

[2] Non-network members might be included in the formed VEs as, for instance, standard component producers. Relationships between network members can vary from ownership as one extreme to a "Yellow Page"-relationship as the other extreme. In practice the degree of mutual engagement will define the network – an issue not dealt with in this paper. See references for a further discussion.

quotation and the network sets up a production VE. At time T_3 the production VE goes into operation and produces the product, which corresponds to the product life cycle phases “Detail design” and “Implementation”. At T_4 the product is finished and delivered, and the product goes into operations (traditionally operated by the customer) whereas the production VE is decommissioned. During product operation service VEs could be established to maintain or repair the product.

3. Use of VERA

Good management can be boiled down to asking the right questions at the right time and determining the answers in the right way by use of the right methods. Crucial for doing this is to be able to define and frame: *what* to consider, and *when* to consider (in this case: when in the life history – compare the right side of Figure 2). These questions relate to *how* to decide on *what* and *when*. We will deal with these questions below.

3.1 Issues of planning for virtual enterprises – VERA and what to consider

Figure 3 depicts VERA including all three dimension of the GERAM modelling framework. Three numbered boxes with arrows have been included as examples to discuss. Box number 1 is in the product requirements phase and points into the partial and generic level. Products are very different from industry to industry. Examples of issues to consider here could be: do usable reference models for the product in question exist? Is it possible and does it pay for the network to develop its own general requirement models in order to obtain reuse and repeatability? These questions typically should be raised when setting up a VE-focused network. For a specific VE the product related question could be (if no reference models are instituted yet): is it possible to reuse parts or modules of previous solutions? As part of an experience collection in the decommission phase of a specific VE the question could be: should already established product reference models be further developed for future use? If so, it would result in a network modification. A use of the view dimension could narrow down the fields of investigation. This could be a consideration of requirements as regards product information exchange (information view), or product operator requirements (resource view) besides functional task or design requirements.

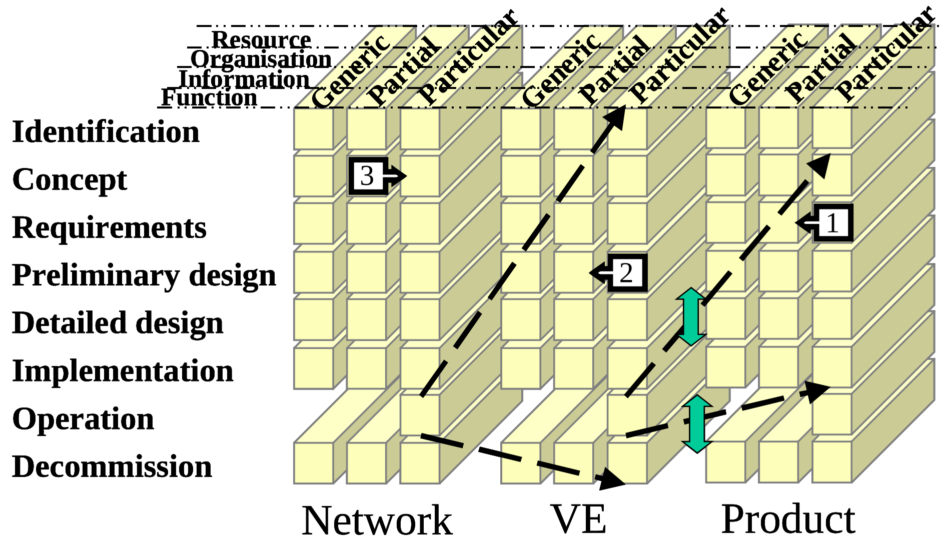


Figure 3. VERA depicted with all modelling dimensions.

For box number 2 the questions could be: which available VE configuration tool or VE infrastructure modules to use in the set-up of a VE or VEs? If all VEs to be produced by the network are considered, the question is asked in the network requirements phase, and final choices are made in the network design phases. The issues corresponding to box 2 also could concern legal/contractual issues, risk models, enterprise applications etc., that is, all issues of relevance for an overall preliminary design of a VE as a project organisation with geographically dispersed partners. Again the view dimension can help narrow down the issues in question as described above.

Box number 3 in the concept phase at the partial level of the network entity contains reference models of visions, missions, strategies, operational concepts, etc., for different types of networks meant to be used as inspiration when setting up a particular network. The issue of reference models for virtual enterprises are further treated in [4] by use of more elements of GERAM.

Two different types of VEs have already been mentioned. The product life cycle phases can be used to distinguish between different VEs as shown in Figure 4. This terminology will be used in the following sections well aware that terminologies differ from industry to industry.

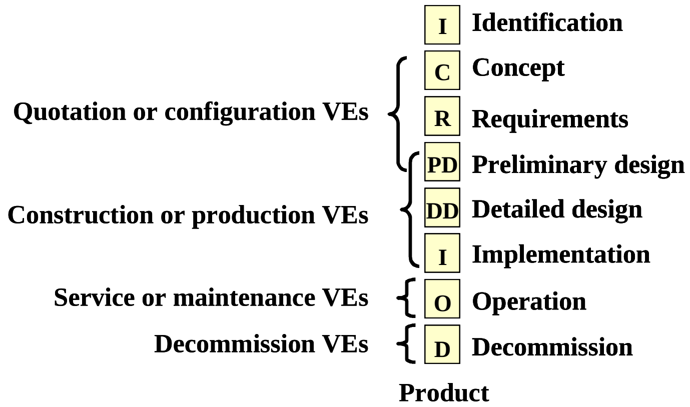


Figure 4. Classification of different VE's by reference to product life cycle phases.

3.2 Issues of planning for virtual enterprises – the 'when' and 'how'

"When to consider" an issue (issue – the "what" just discussed) of planning is not independent from the question of "how to decide". The crucial subject behind the "how" is ideally the desire to achieve integration by use of all relevant knowledge. It amounts to saying that the planner must be omniscient which of course is an impossible requirement, not least for a topic as complex as "planning for virtual enterprises". However, a sound systematic procedure to follow for deploying the "how" can help make sure that not only all relevant issues are dealt with at the right time, but also all important knowledge perspectives are incorporated as basis for decisions. In this respect GERAM helps on a general level because it proposes a carefully prepared structure and contents. This can be illustrated by examples – knowing quite well that not all components of GERAM have been used in deploying VERA in this short paper; therefore the full potential of VERA must be left to the reader to discover.

A change in the representation of a network's life history is appropriate in order to allow the presentation of an example. To the left in Figure 5 is shown the life history example from Figure 2 that contained one network entity, two VE entities, and one product entity. In the upper right corner this life history example is condensed into 4 lines as shown. This can be generalised as shown in the diagram in the lower right corner of Figure 5. This means that the life cycles numbered 1 to 4 (encircled) correspond to the life history example above and to the left. In the following this diagram will be used almost as a pictogram to depict a planned (i.e., a projected) life history of a VE-focused network.

Figure 6 in the centre shows this pictogram. The figure is used to describe some basics of a procedure for how to carry out the network concept phase.

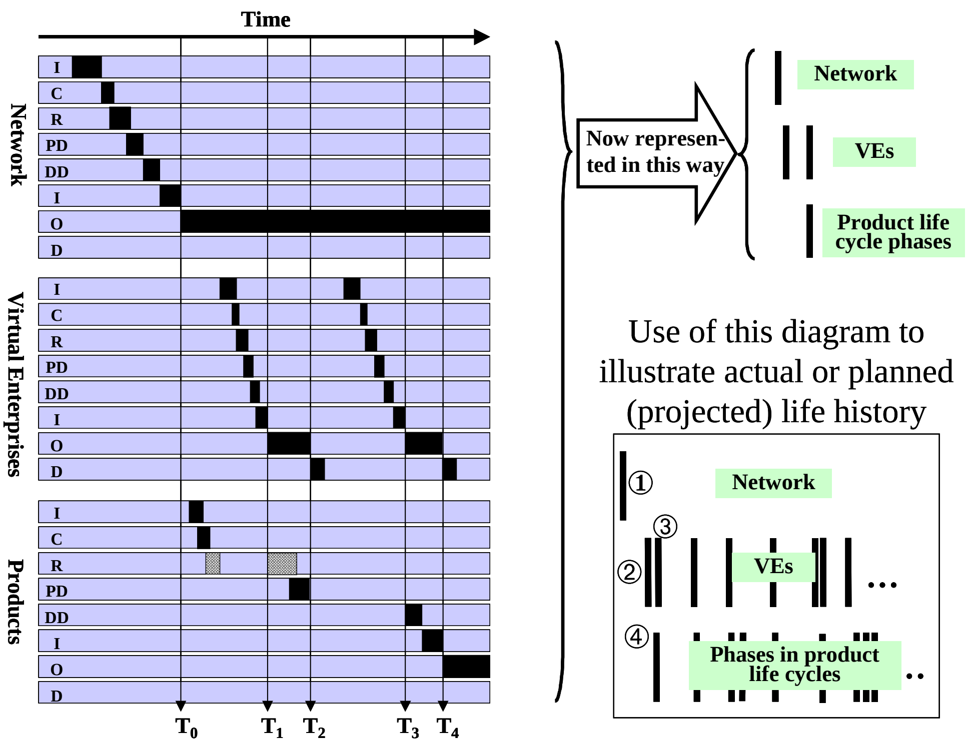


Figure 5. Change in life history representation.

The network concept phase constitutes a strategic planning activity that has to define the mission, basic operational concepts, policies etc. for a network. Strategic planning is usually an iterative activity, among other things comparing different possible development paths to ideal situations. In order to define an ideal "to-be"-situation, analyses often will take outset in market surveys and define potential competitive deliverables. A critical question is here: how much can be planned in advance, and to what degree is it possible to find or define commonalities between deliverables in order to secure reuse or repetitiveness in different ways – for instance by developing product models, service modules, or define common product platforms. These questions reflect the degree of preparedness for the network to aim at, and can constitute decisive elements of network operational concepts – among other things strongly influencing delivery times and quality. With the three dimensions of GERA in mind (i.e., life cycle phases, views, and genericity) a systematic analysis of expected deliverables (in the figure depicted as a hatching of some product life cycle phase activities) will help decide on these issues. For very important issues, it might be appropriate in the network concept phase to consider details of deliveries – compare the description of box 1 in Figure 3. In this example, as shown in Figure 6, three main types of deliverables have been identified: configuration, construction and maintenance deliverables. The figure also hints at a frequency of the different deliveries to be estimated and decided.

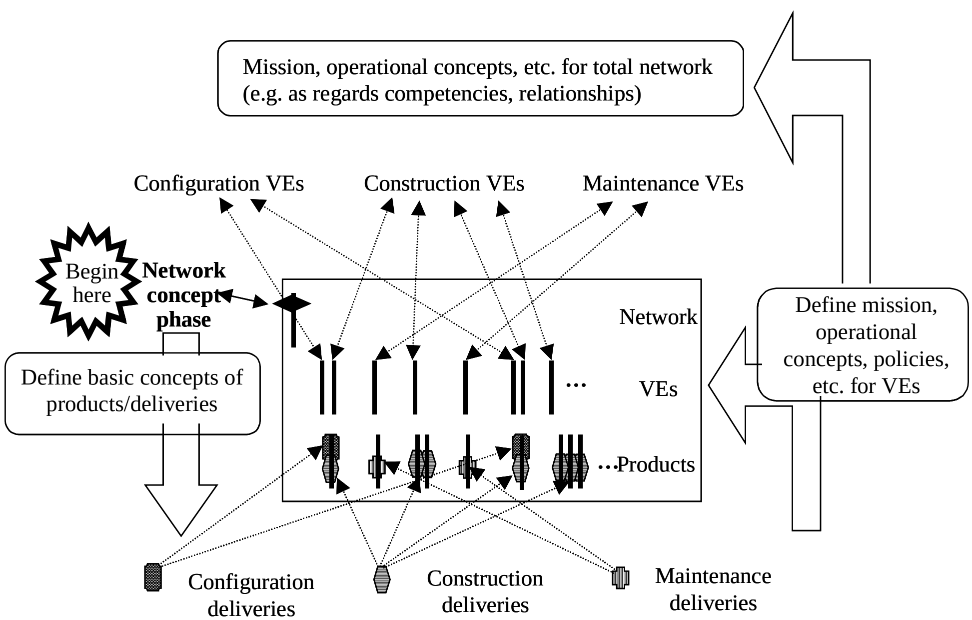


Figure 6. Example of network concept phase procedure.

If we assume that the deliverables have to be produced by geographically dispersed VEs, the next step is to define concepts and strategies for the corresponding VEs. Again, as for the deliverables, more detailed analyses might be needed and a use of the three GERA dimensions can help to focus the analysis on the right topics. These could be: crucial technologies for VE formation (the resource view), crucial tasks for VEs (functional view), reference models for VEs (the partial level of the VE entity in VERA) as contract models (information view) or project models (function, information, organisation and maybe resource view) – compare box 2 in Figure 3. Again, it is important to define commonalities between the different VEs. Most of these questions relate to the extent of knowledge of already existing network partners or potential new partners. Many of the analyses and decisions might have to be performed together with network partners – or at least with different partner types in mind if future specific partners are not known.

All things considered these analyses result in a definition of network missions, operational concepts, etc., as a totality. Reference models for VE focused networks, as indicated by box 3 in Figure 3, not only could help define the final network concept, but also could be of help through the whole planning process as guiding principles. See [5] for more information on procedure and methodology.

3.3 VERA as an organising tool – more examples

Different industries are very different as regards to products, workflow, operational procedures, etc., and even for the same industry different traditions and concepts are used in different companies and countries. This is an important barrier to the exploitation of the potentials offered by ICT-supported cross-continental and cross-cultural project organisations, such as virtual enterprises. An agreed-upon architecture, such as VERA, in this context will not only help to frame what is discussed or negotiated, but also to organise the already existing body of knowledge as reference models including standards [4].

In the forerunner of GLOBEMEN, the Globeman21 project (Global Manufacturing in the 21st Century, [6]), VERA[3] was used to compare and analyse all industrial pilot projects [7]. It proved possible in this way to compare seemingly very different projects and as a consequence enable a general experience collection.

The dynamics of virtual enterprises have been emphasised by many writers in the field why reconfiguration has been proposed as an important phase in life cycle models of virtual enterprises. In [8] it is shown how reconfiguration, by use of VERA, proves to be either a part of the operational phase of a virtual enterprise as an already built-in flexibility, or proves to be a backflow into preceding phases of the virtual enterprise life cycle. In the last case VERA allows for an easy classification of different types of reconfiguration depending of how many life cycle phases are involved. Figure 7 illustrates the case.

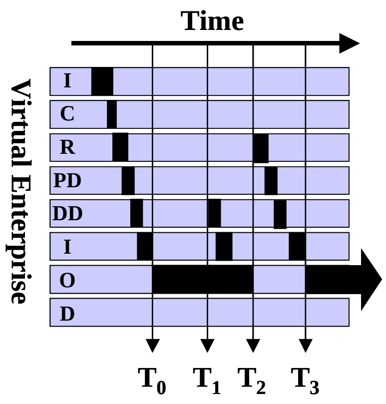


Figure 7. Examples of VE reconfigurations.

At T_0 a VE has been formed and goes into operation. At T_1 a reconfiguration need is discovered. In this case it implies only a minor redesign of the VE (a backflow into "Detail Design" and a corresponding "Implementation" of the design changes). Notice, that the VE does not need to stop its operation during the reconfiguration. The other shown example occurs at time T2, whereupon a more extensive change is required, resulting in a backflow into the "Requirements" phase and a simultaneous suspension of the VE operation. In

[3] In Globeman21 VERA was named VE Framework Model. In GLOBEMEN it was renamed in the process of creating VERAM.

this way VERA allows for us to develop a typology of reconfiguration. A consideration of reconfiguration might be an important aspect of the “what” and “when” questions already discussed. Paraphrased, what types and what degrees of flexibility should be prepared for when setting up a VE focused network or a specific VE?

4. Conclusion

Enterprises, not least in one-of-a-kind industries, face major challenges regarding a full exploitation of existing and future ICT potentials. Major keywords for the challenge are globalisation, outsourcing and customisation. The vision is a rapid formation of customer-focused and -tailored virtual enterprises together with partners from different continents and cultures. This demands a new global understanding, enabling a safe cross-company communication and negotiation in the preparation for and the order-triggered set-up of virtual enterprises. The Virtual Enterprise Reference Architecture (VERA) and the matching Methodology developed by GLOBEMEN show promise not only as a management tool to structure and guide in preparing for the challenge, but also as an organising tool to sort out and order already existing knowledge as, for example, reference models. This again will enable a cross-company and cross-industry sharing of experiences gained.

References

Note: references to non-GLOBEMEN literature can be found in listed publications.

1. Zwegers, A., Hannus, M., Tølle, M., Gijsen, J. & Berg, R. J. van den (2001). An architectural framework for virtual enterprise engineering, E-work and E-commerce, Novel solutions and practices for a global networked economy (ed. by B. Stanford-Smith & E. Chiozza). IOS Press. Pp. 1117–1123.

2. Zwegers, A., Hannus, M. & Tølle, M. (2001). Integration issues in virtual enterprises supported by an architectural framework, International IMS Project Forum 2001. A common platform for cross-fertilization among IMS projects and promotion of the IMS program (ed. by Bernardo Ferroni, Claudio R. Boer & Charles M. Anderson). ISBN 88-900298-3-8.

3. GERAM (1999). IFAC/IFIP Task Force on Architectures for Enterprise Integration. GERAM (Generalised Enterprise Reference Architecture and Methodology). ISOIS15704:2000 (available on: http://www.cit.gu.edu.au/~bernus).

4. Tølle, M., Bernus, P. & Vesterager, J. (2002). Reference Models for Virtual Enterprises. Collaborative business ecosystems and Virtual Enterprises (ed. by Luis M. Camarinha-Matos). Kluwer. Pp. 3–10.

5. Tølle, Martin, Vesterager, Johan & Pedersen, Jens Dahl (2000). A Methodology for Virtual Enterprise Management – Results from IMS 95001/ESPRIT 26509 GLOBEMAN21 project. Proceedings of the 6th International Conference on Concurrent Enterprising (ICE 2000). Toulouse, June 28–30. Pp. 119–127.

6. Globeman21 (Global Manufacturing in the 21st Century), IMS project no. 95001. In EU: ESPRIT project no. 26509. Project finished November 1999.

7. Pedersen, Jens Dahl, Vesterager, Johan & Tølle, Martin (2000). Application of a GERAM based Virtual Enterprise Framework – Results from IMS 95001/ESPRIT 26509. Proceedings of the 6th International Conference on Concurrent Enterprising (ICE 2000). Toulouse, June 28–30 2000. Pp. 139–142.

8. Vesterager, J., Bernus, P., Pedersen, J. D. & Tølle, M. (2001). The what and why of a Virtual Enterprise Reference Architecture, E-work and E-commerce, Novel solutions and practices for a global networked economy (ed. by B. Stanford-Smith & E. Chiozza). IOS Press. Pp. 846–852.

VEM:
Virtual Enterprise Methodology

Martin Tølle
Technical University of Denmark, Denmark (email: mat@ipl.dtu.dk)
Johan Vesterager
Technical University of Denmark, Denmark (email: jve@ipl.dtu.dk)

Abstract

This chapter presents a virtual enterprise methodology (VEM) that outlines activities to consider when setting up and managing virtual enterprises (VEs). As a methodology the VEM helps companies to ask the right questions when preparing for and setting up an enterprise network, which works as a breeding ground for setting up VEs. The VEM applies the Virtual Enterprise Reference Architecture (VERA) as an underlying structure. Both VEM and VERA are developed as a part of the GLOBEMEN project.

1. Introduction

Enterprises co-operate more extensively with other enterprises in all product life cycle phases. This is driven by various reasons such as cost reduction, flexibility, and focus on core competencies. The result is anything from rather stable alliances between partners in fixed supply chains to a more transitory co-operation as in a virtual enterprise (VE).

This chapter presents elements of a virtual enterprise methodology (VEM) developed as part of the IMS GLOBEMEN project. The VEM presents key activities to consider when setting up enterprise network and VEs respectively. Thereby, the VEM is intended to help companies to ask the right questions when preparing for and setting up enterprise networks and their accompanying VEs.

The next section introduces the concept of virtual enterprises. Section 3, presents the Virtual Enterprise Reference Architecture (VERA) as a central and structuring element of Virtual Enterprise Reference Architecture and Methodology (VERAM). Both VERA and VERAM are created in GLOBEMEN based upon GERAM [1]. The following section gives an example of a life history of an enterprise network. Section 5 introduces part of the VEM. A discussion concludes this chapter.

2. Introducing the GMN VE concept

This chapter applies the VE understanding of the GLOBEMEN project, which regards a network of enterprises as the breeding ground for preparation and formation of VEs, cf. Figure 1. As a part of forming the enterprise network, the network partners will establish a degree of *preparedness* for forming particular VEs. VEs are formed based on the competencies available in the network in order to meet customer demands. Additional competencies from sub-suppliers or local contractors may be included in VEs as well [2], see Figure 1. When the customer's demand has been satisfied, the experiences gained in the VE are transferred back to the network, the VE is decommissioned, and the network awaits or seeks other possibilities in the market.

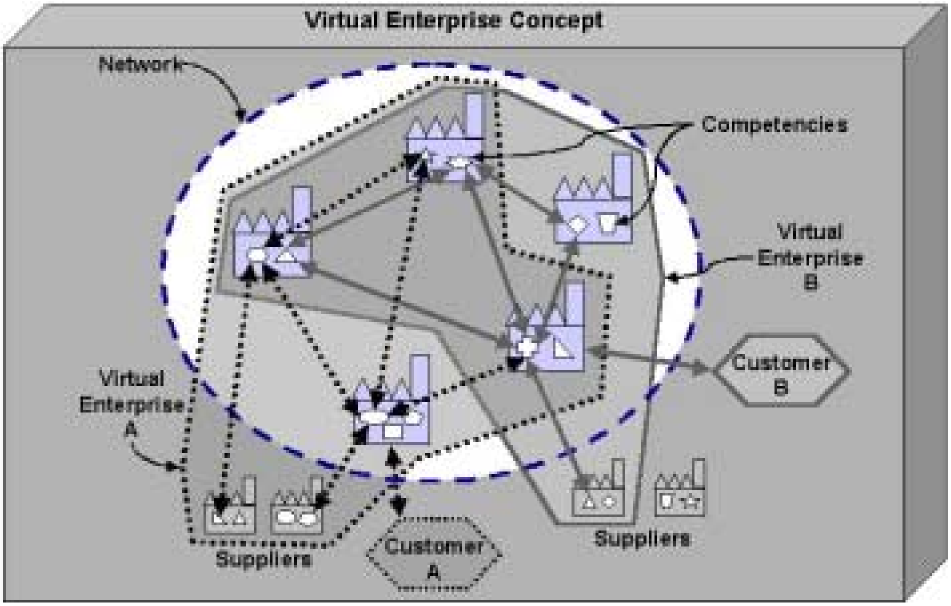


Figure 1. VE concept appiled in Globemen.

2.1 Preparedness – Reference Models and Methodology

A central and important aspect to setting up VEs in a continuous, fast and dynamic way is the concept of *preparedness*. The potential competitive advantage of a VE – being able to configure world class competencies together into a system of service delivery or production – is often jeopardised by the time it takes to set up a VE, especially if the VE is composed of partners unknown to one another before the formation of the VE [3].

When setting up an enterprise network one of the key things to consider is the level and type of preparation in the network and among the network partners. *Reference Models* (RMs) work as important means for this preparation. A reference model (RM) is a model that captures characteristics/concepts common to several entities (e.g. networks or VEs) [3]. The purpose of RMs is to *"capitalise on previous knowledge by allowing model libraries to be developed and reused in a 'plug-and-play' manner rather than developing the models from scratch"* [1]. Hence, RMs *"make the modelling process more efficient"* [ibid.]. RMs are used to convert the VE formation task into a re-use/ configuration task resulting in quick, low-cost, and secure VE creation.

Many different RMs exists today. Tølle, Bernus and Vesterager [3] have mapped 8 different RMs applicable for VEs. What is lacking however, is a sort of *methodology* for when to select which models and not least how to handle the management task of creating an enterprise network capable of setting up an effective VEs efficiently, i.e. within a reasonable timeframe and capable of delivering a competitive solution to the customer. This chapter aims at providing a methodology for the latter.

3. VERAM

As a part of Globemen a Virtual Enterprise Reference Architecture and Methodology (VERAM) has been created based upon GERAM [1]. The purpose of VERAM is to structure a body of knowledge that supports future work in the area of global engineering and manufacturing in enterprise networks. A part of this knowledge is in fact similar and common every time a VE is set up or operated, and could be standardised and re-used [4]. VERAM positions elements that support modelling, formation/set up, management and ICT support of VEs, such as reference models, and supporting tools and infrastructures. Interrelations among these elements are indicated in Figure 2. For more information about VERAM, please refer to [5].

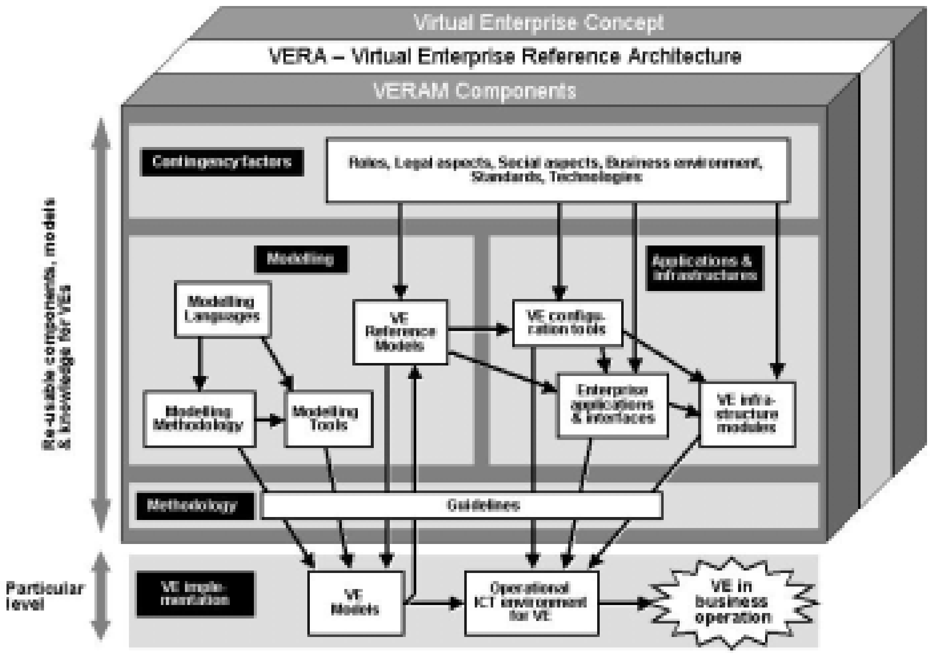


Figure 2. VERAM – Virtual Enterprise Reference Architecture and Methodology.

3.1 VERA

One of the central parts of VERAM is the middle layer, the Virtual Enterprise Reference Architecture (VERA) likewise based upon GERAM [1]. As shown in Figure 3 VERA captures the VE concept described above. VERA consists of three recursive entities, viz. a network, VE and product. The figure shows that the network in its operational phase creates VEs and a VE carries out some products life cycle activities (‘phases’), indicated by double arrows.

Each of the three entities are represented by use of the three dimensions of the GERA modelling framework: the life cycle dimension, the genericity dimension, and the view dimension [1]. The white part of VERA in Figure 3 represents the *particular* part, i.e. the part that is related to the specific network, VE and product respectively. Whereas, the dark shaded boxes represent the generic (and thus reusable) parts. Thus, RMs (as the ones mapped in [3]) are located in the shaded part of VERA and, when used, they are instantiated into a particular case e.g. when setting up a VE.

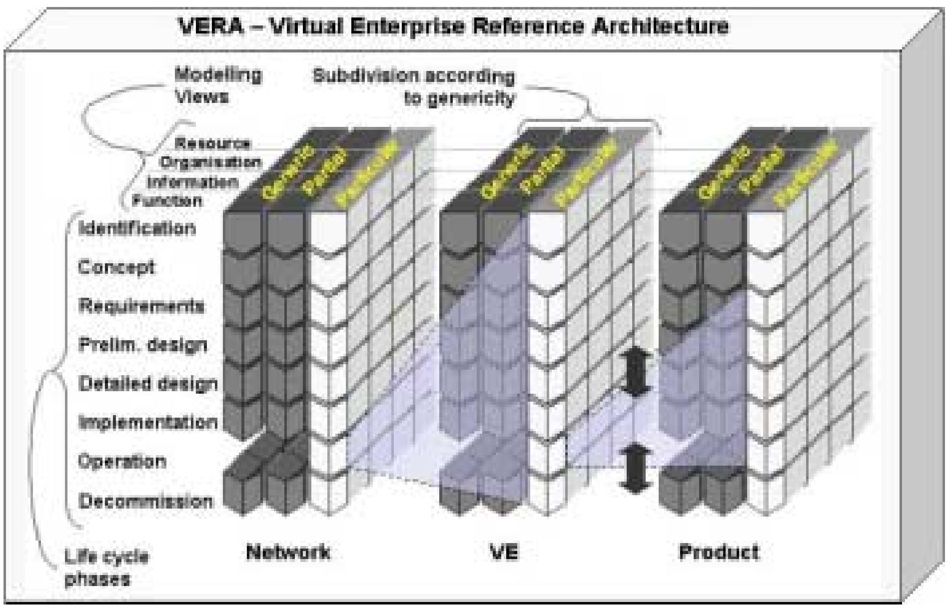


Figure 3. VERA – Virtual Enterprise Reference Architecture.

Another view applied in VERA is the explicit inclusion of the so-called purpose view of GERAM, which distinguishes between the *customer product and service activities* and the *management and control activities* representing the mission fulfilment and the mission control aspects respectively, see [1]. This distinction is made starting from the requirements phase to the decommission phase of an entity, cf. Figure 3. More elaborate descriptions of VERA can be found in [2], [6], [7] & [8]. In this chapter VERA will be used as an underlying structure for the VEM.

4. Life history example

Before describing the VEM, a life history of an enterprise network will be given to exemplify how this can evolve over time. It should be noted that this is only one of many possible life histories (i.e. unfolding over time). The following life history example illustrates how VERA can be used. The example integrates the activities of the three VERA entities together into one life history description. Other life history examples can be found in [8] and in [9]. In the latter Ollus et al [9] describe a so-called demonstration scenario outlining different scenes of an enterprise network and illustrates how the prototypes developed by the industrial partners in Globemen can support different activities related to setting up the network and its subsequent set up of a Quotation VE, Production VE and Service VE, cf. [9].

In brief, this life history example starts with the identification of a network. This is followed by the preparation and engineering of the network. At some point in time during the operation phase of the network, a customer contacts the network with a request for quotation. Based on the customer's need the network sets up a Quotation VE that carries out the first phases of the product's life cycle in order to deliver a quotation to the customer. The customer accepts the quotation and the network sets up a Production VE, which completes the product design, and finally produces (implements) the product. In Figure 4 the overall picture of the life history is illustrated. It should be noted that, compared to Figure 3, the three entity life cycles are arranged above each other, and that a time dimension has been added going from left to right.

The triangles on the figure symbolise RMs such as e.g. models, tools and procedures created by the network or VEs, that support activities in the operation phase of either the network (e.g. contract models) or VEs (e.g. product models). The numbers 1 to 16 relate to the description in the following list:

1 At time $\mathbf{T_0}$ an *initiator* related to the *initiating company* identifies that the company could benefit from establishing a more formalised enterprise network.

2 After a preliminary feasibility study the *initiator* presents the idea of a more formalised enterprise network to his/her superior. This 'internal recognition' process includes convincing the CEO of the company and getting

commitment to carry on with the project. In the process of reaching this recognition one or more internal meetings and workshops can be held, resulting in a formulation of the network concept. Following the ‘internal recognition’, the *initiating company* contacts potential network partners and informs them about the network idea. Furthermore, the *initiating company* prepares a network kick-off meeting.

3 At the kick-off meeting(s) the opportunities of establishing a more formalised enterprise network are discussed. The partners agree on the concept of the network (including the description of overall purpose, types of VEs, types of products, and markets to address). Furthermore, a list of preparation projects is specified. This includes the definition of overall requirements for each project, such as clarification of overall business rules of the network, overall contractual/IPR issues, the type of tools, procedures, etc. to be used. At the end of the kick-off meeting a set of preparation project groups have been defined.

3a Additionally, the partners establish a *network preparation management team*, which manages the further preparation and setting up of the network, i.e. subsequent activity #3a. This *network preparation management team* is in operation at time $\mathbf{T_1}$. On the figure this is shown as the management and control system of the network.

4 Each of the groups carry out their preparation projects, i.e. carry through the requirements to implementation phases of their specific network projects. These could be projects concerning IT infrastructure, tools (e.g. product configurators), business process models (e.g. order fulfilment process models), legal/contractual issues, organisational issues, knowledge management, quality management, environmental management, standardisation issues, and so on. Figure 4 illustrates that some of the preparation projects primarily deal with either customer service and product activities or management and control activities, and others deal with both purpose views. The preparation projects create RMs (models, tools, procedures, contract models, etc.) to be applied in the operation phase of either the network or VEs, cf. the triangles on Figure 4.

5 As soon as the different project groups in #4 have concluded their work, the network goes into operation at time $\mathbf{T_2}$ and awaits customer requests. At that time the focus of the management group defined at #3 shifts from managing the preparation of the network to managing its actual operation.

6 Independent of the operation of the network a customer identifies a need for a product.

7 At time $\mathbf{T_3}$ the customer contacts the network and initial negotiations are made between the network and the customer. The network sets up a Quotation VE. This includes selecting partners (network partners and maybe

temporary, non-network partners) and defining a management structure (selection of *Contract Manager,* contribution of each partner, etc.).

8 The management groups of the Quotation VE can set up one or more project groups each focusing on different aspects of the preparation and creation of the VE. This corresponds to the above-mentioned types of project groups in #4, although the VE projects will typically be more VE specific. Again, topics for project groups could be IT infrastructure, tools, business processes, legal/contractual issues, organisation, etc. It should be noted that the type and extent of preparation projects related to the set up of a VE can vary widely depending on the preparation level already achieved during the network preparation and set up. For a network with a very high preparation level the VE set up might only involve an instantiation of different, already predefined, models – e.g. contract models, risk sharing models, business process models, etc.

9 The VE goes into operation at the time the project groups in #8 have concluded their work. In the operation phase (at time $\mathbf{T_4}$) of the Quotation VE the VE-partners transform the customer's need into a product concept, clarify important requirements and corresponding relevant design aspects.

10 This forms the basis for a completed quotation at time $\mathbf{T_5}$. It should be noted that this is only an example; the contents of a quotation could differ from industry to industry.

11 The Quotation VE has completed its tasks and is decommissioned.

11a As part of this activity the experience with the Quotation VE is collected. This triggers a need for modifying some of the existing RMs and creating new ones.

12 The customer accepts the quotation at time $\mathbf{T_6}$, and the network sets up a Production VE. This corresponds to setting up the Quotation VE, cf. #6.

13 Corresponding to the groups mentioned in #8, the VE management can set up one or more project groups focusing on particular Production VE aspects, e.g. specification and installation of new production equipment.

14 At time $\mathbf{T_7}$ the Production VE goes into operation and finalises the design of the product as well as manufactures (i.e., implements) the product.

15 The product is delivered to the customer for operation at time $\mathbf{T_8}$ and the Production VE is decommissioned, which again could lead to the modification of existing RMs (not shown in the figure). At this time a Service VE (not shown in the figure) could be established for service of the product in its operation phase. Analogously, a Decommission VE (not shown on the figure) could be established when the product is to be decommissioned.

16 At time $\mathbf{T_9}$ the network is finally decommissioned.

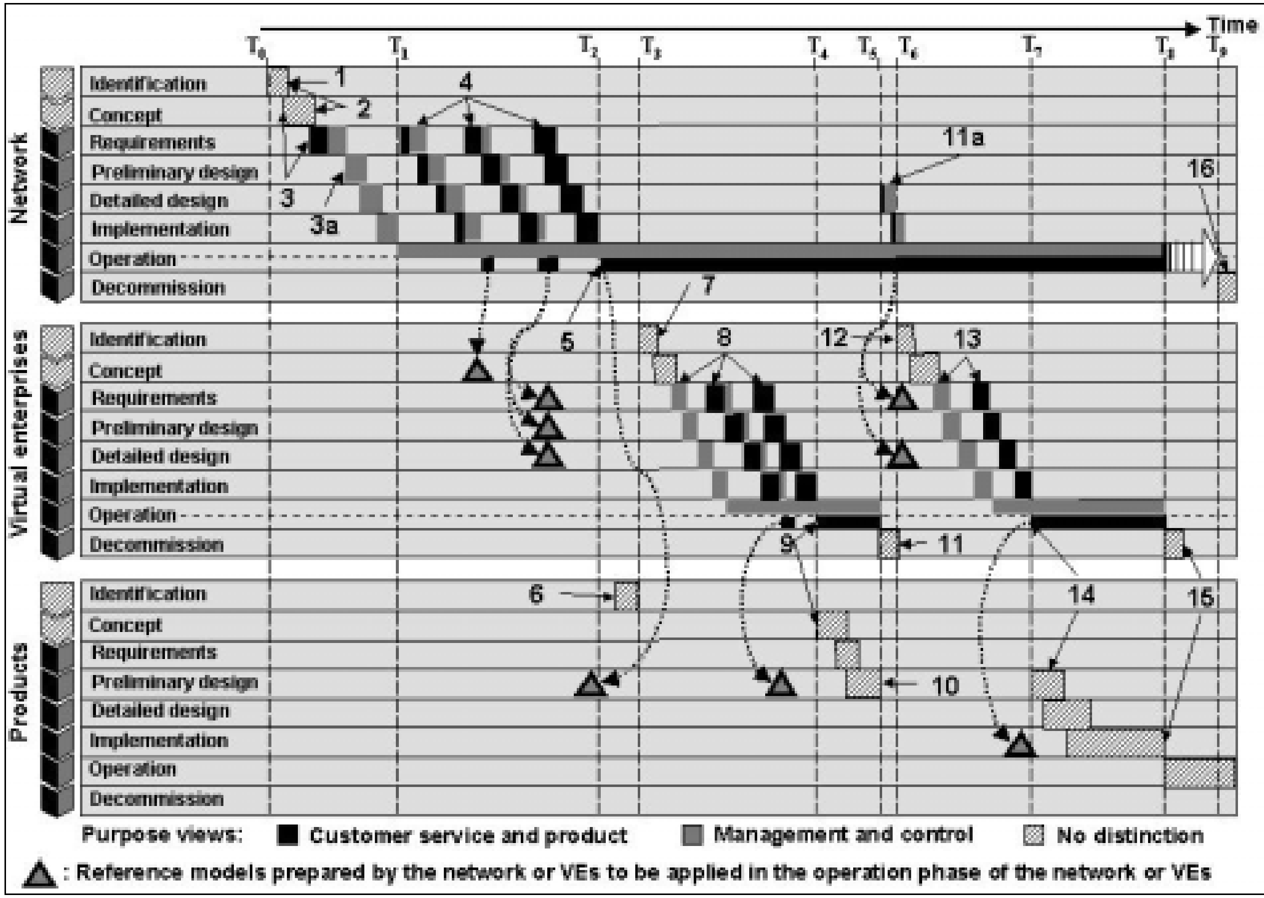


Figure 4. Life history of a network setting up VEs producing quoation and product.

5. VE Methodology (VEM)

The life history in the previous chapter is – as already mentioned – only one example out of several possible ways in which activities can unfold over time. This chapter will describe key activities in a VE methodology (VEM). Compared to the life history the descriptions of the following activities contain no reference to time. Thus, the user of the methodology has to determine which are the activities that are relevant in their specific situation and has to add a timeline to the activities determining in which sequence they should be executed. Inspiration can be found in the life history presented in the previous chapter, but as mentioned the activities can be unfolded in many other ways.

The first part of the methodology is addressing the life cycle of the enterprise network outlining activities to be considered when setting up and managing enterprise networks. The second part is addressing the set up and management of VEs.

It should be noted that the guidelines are relevant for all enterprises and not only for enterprises not yet operating with partners in a kind of enterprise network. Enterprises already operating with partners in, e.g. a strategic alliance can still benefit from going through the outlined activities. The starting point of the enterprise (i.e. “as is”) that applies the methodology can be one of many. Two overall types of use of the outlined guidelines can be envisioned:

a) ***General use (Step-by-step)***:
   Using the list step-by-step from top to bottom can support an enterprise for mastering how to set up a more formalised enterprise network. This could either be an enterprise already operating in a sort of network environment but where a need for further preparation and clarification is needed in order to be able to set up effective VEs efficiently, i.e. in a competitive manner with regards to e.g. time, cost and quality. Alternatively, it could be an enterprise that is exploring its competencies in a new way e.g. by applying existing competencies in new types of solutions where new and unknown competencies and thereby new partners are needed.

b) ***Selected use (pick relevant activities***):
   As an alternative to using the whole list step-by-step, selected activities can also be used to support within a certain sub-part. This could be the case if a more formal enterprise network has already been established. In this case the list in general can work as a kind of checklist and serve as inspiration for how the network could be configured or prepared in a different matter. If a need for reconfiguration is identified then the list could be used in more detail to support one or more of the described activities.

5.1 Set up and management of enterprise networks

Figure 5 depicts key activities related to setting up and managing an enterprise network. In the following each of the activities will be described in Table 1.

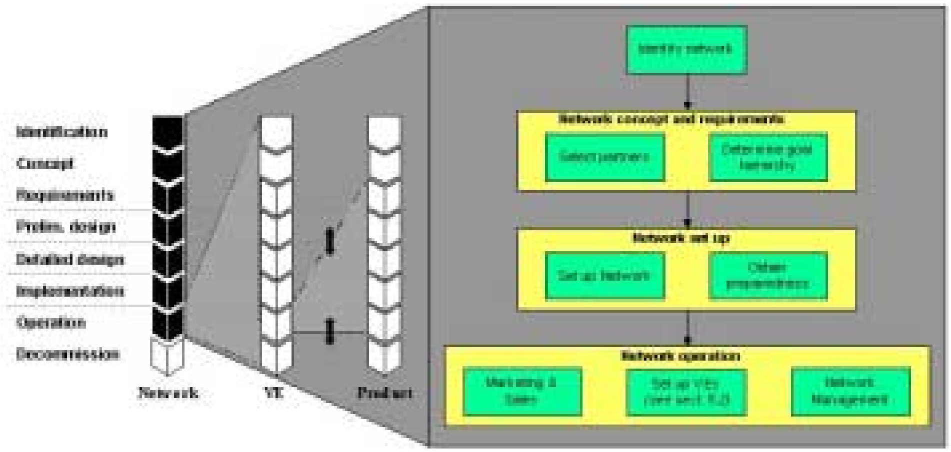


Figure 5. Key network activities, derived from [10].

It should be noted that in addition to this description [2] contains further details regarding the identification, concept and requirements phases of enterprise networks.

Table 1. Enterprise network set up and management activities.

Activity	Description
Identify network	The aim of this activity is to identify the overall purpose of the network including its raison d'être, the network type, and its boundaries in relation to the internal as well as the external environment. The main outcomes are to identify key drivers, motivations for the enterprise network and to get a clarification of the overall purpose of the network including which type(s) of market(s) it shall address and with which type(s) of product(s).
Select partners	A central element when preparing for and setting up an enterprise network is to identify and select the partners that should participate in fulfilling the vision of the enterprise network. The selection of partners depends not only on the expected future situation, but also on the existing partnerships of the enterprise driving the network set up, i.e. partners already trusted. To participate in a VE, companies should basically possess two types of competencies, i.e. *Functional competence* and *Alliance competence*, cf. [11]. That is, partners should not only posses sufficient competencies to do the needed task but also posses the ability to enter into and participate in VEs, e.g. manifested by an ability to manage and implement alliances and ability to display alliance spirit and behaviour [11].
Determine goal hierarchy	To avoid potential conflict among network partners some efforts should be taken regarding establishing and ensuring that the partners have a shared goal hierarchy, i.e. its mission, vision, strategies and objectives. If it turns out that network partners are pursuing different or, worst case, conflicting goals then the success of the enterprise network could be jeopardised.
Set up network	A key challenge when operating in an enterprise network is to be able to set up competitive VEs within a short timeframe. One of the key means in doing this is to prepare the network partners, enabling a configuration of the customer focused VEs faster and more efficiently. Many different elements of a network can be prepared (see examples in #4 in above life history), and the type and level of preparation for a specific network depends of the type and frequencies of the tasks that the network expects to carry out. Once the aimed "to be" situation is determined

	sufficient actions have to be taken to evolve each of the partner enterprise from their existing “as is” situation.
Obtain preparedness	When the network has determined what type and level of preparedness it want to pursue, and the models have been identified and/or prepared, the decisions/models have to be implemented in the network and in every partner respectively. This includes e.g. getting the system up and running in an integrated manner with the partners’ legacy systems and training of personnel.
Marketing & sales	During the operation of the enterprise network marketing and sales activities have to be carried out. This includes e.g. looking out for new customers; respond to customer request; contract negotiations with customer; marketing activities, e.g. a more proactively seeking customers.
Set of VEs	The most important task of a network is to set up VEs answering customer needs. This is elaborated more in the following section, cf. Figure 6 and Table 2.
Network management	Management of enterprise networks includes all types of management tasks and levels known from traditional management of conventional enterprises. This includes, e.g. direct and indirect monitoring, and operational, tactical and strategic level decisions. *Direct monitoring* includes operational level decisions monitoring progress and taking appropriate actions to manage that the goals are achieved, e.g. setting up VEs able to respond effectively to a customer need, solve possible disputes among partners. *Indirect monitoring* looks at the appropriateness of e.g. the network’s level and type of preparedness and initiate appropriate actions if a need for reconfiguration is needed. Reconfiguration of networks/VEs is elaborated further in [7] & [8].

5.2 Engineering and operation of VEs

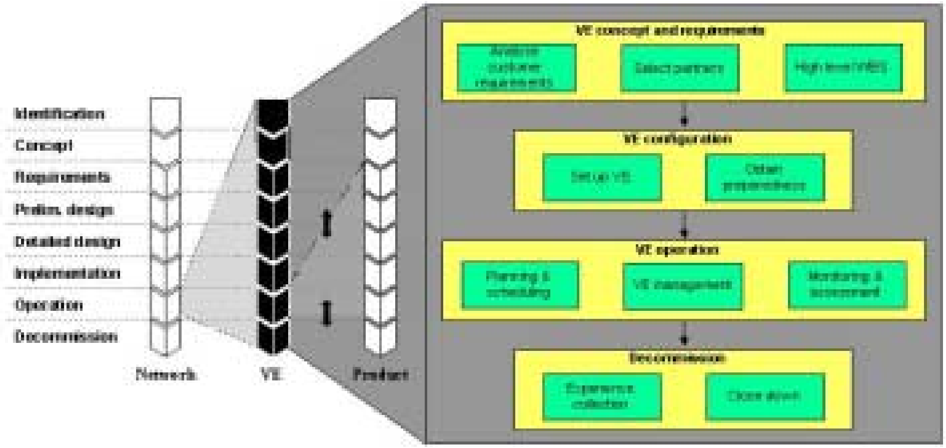


Figure 6. Key activities related to VEs, derived from [10].

Table 2. Virtual enterprise set up and management activities.

Activity	Description
Analyse customer requirements	When a network partner is confronted with a customer need, the first activity is to assess if the network should pursue to fulfil the request, i.e. clarify if the request is within the scope of the enterprise network.
Select partners	Selection of partners to participate in specific VEs includes assessing if the partner possesses sufficient capabilities, i.e. have knowledge and experience to fulfil the type of work as well as have needed capacity at the requested time. Most of the considerations about partner selection in the network may also be valid when selecting VE partners, cf. Table 1. Of course, the more extensively the partners have been assessed in the network the less assessment needs to be done as a part of the VE and vice versa.
High level WBS	Parallel with the selection of partners for the VE a Work Breakdown Structure (WBS) should be created. The WBS captures the decomposition of the VE's product into deliverables and the accompanying partner selection, i.e. which partners is responsible for which deliverable.

Set up VE	Set up of a VE highly depends on the type and level of work preparation already determined as a part of the network set up, cf. Table 1. The more the network has foreseen and prepared the configuration of different VEs, the less has to be created during the VE set up and the more it can become an instantiation of previously prepared models. The set up includes e.g.: ➢ Set up VE infrastructure, e.g. a multi tier (partner) project structure, define access rights and interfaces with partners legacy systems ➢ Determine VE rules, templates to be used, RMs to instantiate in the specific situation, other tools, etc. ➢ Contractual issues, e.g. contract reference models to use ➢ VE organisation, e.g. standard roles or ad hoc, depending on the specific project
Obtain preparedness	This activity is similar to the corresponding activity of the network, cf. Table 1. Again, the more that is already done during the network set up the less is left to do during the set up of the VE.
Planning & scheduling	Once the VE starts operating more detailed planning is needed. Each of the partners have to make more detailed plans of what they will do, schedule the VE's tasks in accordance with their other activities and decide if they will sub-contract some of the parts to their own sub-suppliers if needed and not already decided. Further details of this can be found in [10].
VE management	Similarly to the network management the management of a VE includes direct as well as indirect monitoring, cf. Table 1.
Monitoring & assessment	Monitoring of projects is, together with progress reporting, an important project management activity to ensure that the project is completed within time and budget. VEs partners should continuously assess the genericity (in the sense of reusability) of the tasks performed and assess if the current type and level of work preparation in the VE and enterprise network is sufficient or needs to be modified or updated. This includes e.g.:

	➢ Assess if the RMs/technologies/standards/procedures/rules of the network and VEs are sufficient or if new ones are emerging/needed? ➢ Assess if the task performed within a VE is of a certain genericity that could make it appropriate to prepare it at the network level for future similar projects.
Experience collection	Once the product has been handed over to the customer and all paperwork and payments are taken care of it is time to decommission the VE. However, before closing it down the partners should give some time to capture their experiences learned in the project. Consideration includes: What have we learned; How would we do it different in the future; Fill in 'log-book' available for VE partners; Fill in 'log-book' available for all network partners (probably subset of VE log); Is there a need for updating and/changing the type and level of preparations in the enterprise network?
Close down	The project is closed down and the partners go back to the enterprise network and await new customer needs.

6. Conclusion

The Virtual Enterprise Reference Architecture (VERA) presented in this chapter provides a generic structure, which permits a systematic approach to the complex and multidimensional tasks involved in preparing VEs. To support the realisation of VEs there is a need for a comprehensive methodology for VE engineering and management.

The Virtual Enterprise Methodology (VEM) applies VERA as an underlying structure. Both VERA and the VEM are created as a part of the IMS Globemen project. The part of the methodology presented in this chapter focus on setting up and managing enterprise networks and virtual enterprises (VEs) respectively. The methodology is intended to support enterprises that are faced with the challenge of operating more in accordance with the VE concept presented in this chapter, i.e. in a more dynamic and agile matter. The VEM can help these enterprises to “ask the right questions at the right time”, and as such facilitates the planning and preparation of VEs.

Applying a GERAM (ISO15704: 2000) based architecture as VERA as an underlying structure for the VEM reduces the risks of misunderstandings and permits dissemination to a broader audience. Furthermore, a shared reference architecture as VERA makes it possible to focus on a subset of the VE challenge while still securing integration of work carried out by different partners. Thus, VERA allows the unification of research and practice within the VE area.

The VEM addresses activities of relevance when setting up and managing enterprise networks and VEs. The VEM integrates existing methods and procedures into a VE context, i.e. most of the management activities are well known methods and procedures; what is new is that they are put into the VE context.

The VEM presented in this chapter can work as an important means to widespread realisation of more agile virtual enterprise type of organisations.

References

1. GERAM – IFAC/IFIP Task Force on Architectures for Enterprise Integration, GERAM: Generalised Enterprise Reference Architecture and Methodology, ISO15704:2000.
   (available on: http://www.cit.gu.edu.au/~bernus)

2. Tølle, M., Vesterager, J. & Pedersen, J. D. (2000). A Methodology for Virtual Enterprise Management – Results from IMS 95001/Esprit 26509 Globeman21 project, Proceedings of the 6th International Conference on Concurrent Enterprising, Toulouse, 28–30 June 2000. Pp. 119–127.

3. Tølle, M., Bernus, P. & Vesterager, J. (2002). Reference Models for Virtual Enterprises. In: Collaborative business ecosystems and Virtual Enterprises. Ed. by Luis M. Camarinha-Matos. Kluwer. Pp. 3–10.

4. Zwegers, A., Hannus, M. & Tølle, M. (2001). Integration issues in virtual enterprises supported by an architectural framework. In: International IMS Project Forum 2001, A common platform for cross-fertilization among IMS projects and promotion of the IMS program. Ed. by Bernardo Ferroni, Claudio R. Boer & Charles M. Anderson. ISBN 88-900298-3-8.

5. Zwegers, A., Tølle, M. & Vesterager, J. (2002). VERAM: Virtual Enterprise Reference Architecture and Methodology, GMNBook, GLOBEMEN final plenary, December 2002.

6. Vesterager, J., Bernus P., Larsen L. B., Pedersen J. D. & Tølle M. (2001). Use of GERAM as Basis for a Virtual Enterprise Framework Model. In: Global Engineering, Manufacturing and Enterprise Networks. Ed. by J. P. T. Mo and L. Nemes. Kluwer. Pp. 75-82.

7. Vesterager, J., Bernus, P., Pedersen, J. D. & Tølle, M. (2001). The what and why of a Virtual Enterprise Reference Architecture. In: E-work and E-commerce, Novel solutions and practices for a global networked economy. Ed. by B. Stanford-Smith & E. Chiozza. IOS Press. Pp. 846–852.

8. Vesterager, J., Tølle, M. & Bernus, P. (2002). VERA: Virtual Enterprise Reference Architecture, GMNBook, GLOBEMEN final plenary, December 2002.

9. Ollus, M., Hartel, I., Tølle, M., Wubben, H. & Hannus, M. (2002). Using scenarios for dissemination, Experiences from the IMS GLOBEMEN project. Proceedings of eBeW2002 conference, Prague, 16–18 October 2002.

10. Tølle, M. & Vesterager, J. (2002). Guidelines for Inter-Enterprise Management (IEM), Globemen Deliverable D23.

11. Pedersen, J. D. & Berg, R. J. van den (2001). Supporting partner selection for Virtual Enterprises. In: Global Engineering, Manufacturing and Enterprise Networks. Ed. by J. Mo & L. Nemes. Kluwer. Pp. 95–102.

Using the Globemen Reference Model for Virtual Enterprise Design in After Sales Service

Peter Bernus and Ovidiu Noran
Griffith University
Joachim Riedlinger
ETH Zurich

Abstract

This article presents present a step-by-step methodology for designing virtual enterprises for after sales service. The methodology includes the identification and concept development of the enterprise network as well as of its virtual enterprises. The management and service delivery processes are designed through customising the Globemen Reference Model.

The authors demonstrate the advantage of using tailorable reference models for virtual enterprise design and implementation. The methodology is developed to respond to the industry need for fast reaction to changing market requirements.

1. Introduction

Several Enterprise Engineering Methodologies have been developed in the past. Some are generic, such as the Purdue Guide for Master Planning [1] or GIM (Grai Integrated Methodology) [2]), while some are more specialised, such as the Globemen[1] Reference Model for creating Company Networks and Virtual Enterprises (VEs).

---

[1] Globemen: Global Engineering and Manufacturing in Enterprise Networks [3].

The authors have found that while these methodologies are very useful (i.e. they list the necessary activities that management needs to perform in order to achieve the above objective), partner companies have difficulty following these methodologies, mainly because of the level of genericity on which these methodologies are formulated.

Figure 1 shows the life cycle of an enterprise engineering project as it may have been created by the initiating partner of an enterprise network. This was done in order to initially set up a service network organisation and subsequently create VEs for the delivery of after sales service of large engineering installations (such as e.g. chemical factories). As the figure shows, as this project operates, it is required to develop master plans both for the Network and for the VEs in question.

The difficulty of this arrangement is that the roles of the involved entities (partners, project, network, VEs, potential / actual suppliers) are not fixed meaning that alternative assignments of roles may also be possible.

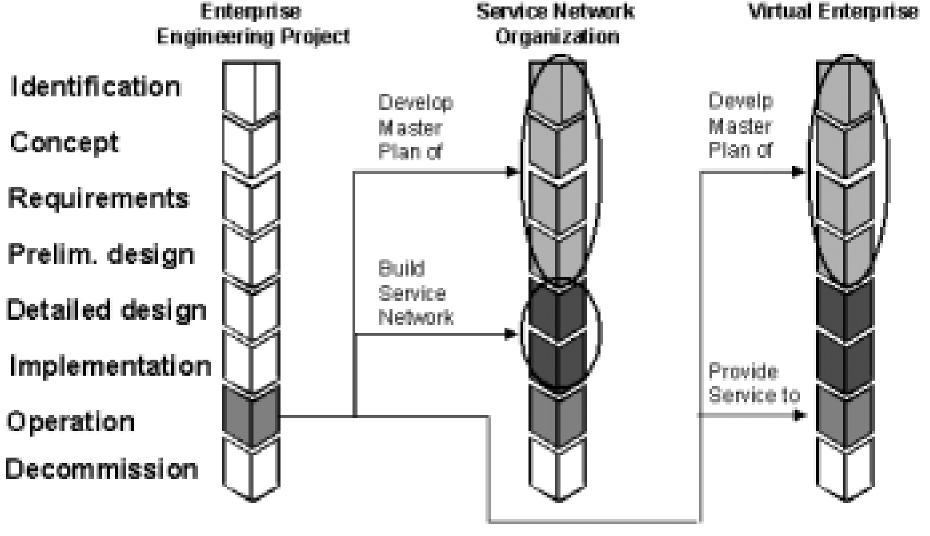


Figure 1. The Life cycle of an enterprise engineering project and related entities (Note: the actual tasks of the project may differ between the two alternatives; also, many other alternative choices exist).

For example, the initiating partner may decide that the master planning of individual VEs is to be carried out by the Network. Thus, a fairly autonomous Network would be created, with both the authority and the ability to create Service Virtual Enterprises (SVEs). This arrangement may be well suited for a given initiating partner, but at the same time it may be contradictory to the intentions of a given initiating partner.

Therefore, a generic enterprise engineering methodology must be tailored and specialised to reflect the specific requirements that the project must satisfy.

Thus, a generic enterprise engineering methodology may be looked at as a Reference Model for enterprise engineering projects, which then can be adapted and specialised so as to satisfy the intentions of the initiating partner.

In addition to the above tailoring task, participants in the Globemen project seem to find it difficult to systematically produce deliverables that the industry partners can readily use. It would therefore be useful to design a step-by-step method (or project plan) that the industry partners can execute in order to ultimately create the desired Network organisation and pilot it (by operating the Network to create a working Service VE). Naturally, it is expected that the experiences of such piloting would result in changes being made to both the Network and the Service VE created by it.

The authors have undertaken the task of designing a tailoring method that can use as an input a generic methodology (or selected parts of several methodologies), and turn it into a step-by-step project plan that satisfies the needs of the initiating partner. This tailoring method may be called a 'meta-methodology' (i.e., a methodology to produce a methodology) in the sense that it produces a particular methodology on the basis of a generic methodology. (It could be argued that this method is actually a special project planning method, which is also a correct view, given that the result takes the form of a project plan.)

The work presented here is a pilot project in itself, because by performing this tailoring task the first time, the authors hope to learn about the generic requirements that such a methodology must satisfy. As further similar tailoring exercises are performed in the future, the authors intend to build a 'knowledge base of tailoring'. The longer term objective would then be to build this tailoring expertise into an advisory system, so that future tailoring tasks could be assisted by an expert system, rather then being completely done by hand by a project manager.

The rest of this article will therefore explain a possible way to create a particular project plan for Network and VE creation and will in addition point out decision points that future tailoring tasks would have to consider.

2. Relationship between generic and particular methodologies

Generic enterprise engineering methodologies describe the evolution of an enterprise entity in isolation. Thus, the activities involved in identifying the enterprise entity, developing the concept, the user requirements and the requirements specification, the master plan (or architectural design), etc. are described on the example of one entity. In practice, the Identification phase activity develops a ‘Business Model’ that identifies more than one entity. Each of these entities needs to be modified or designed depending on their current status and their involvement in the new Business Model. While generic methodologies acknowledge this fact (in compatibility with the GERAM reference architecture ([4], [5]) and in particular the GERA concept of entity recursion), more concrete methods are needed for practical application of this concept.

Figure 2 shows the relationships among relevant enterprise entities as identified by the initiating partner for an enterprise network for after sales service. (At the time of writing the initiating partner has not completely decided on the relationships as represented in Fig. 2. Hence, this figure shows an assumed final decision noting that this may change for the actual Globemen partner.)

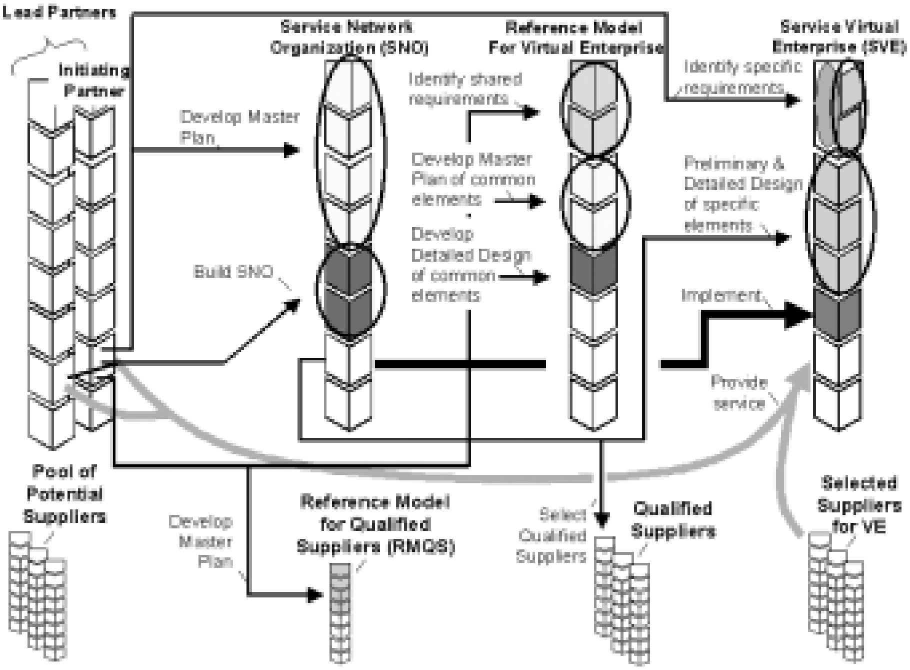


Figure 2. The Business Model for a particular Network and the Service Virtual Enterprises created by this Network (Note: the Enterprise Engineering Project of Fig. 1 is not shown, since it is a project run entirely by the Initiating Partner).

There are several lessons to be learned from Fig. 2, all of them related to strategic intentions and strategic decisions of the initiating partner. Thus the reason why it is possible to produce a step-by-step method for this particular case is that the initiating partner *operationalises* its strategy once its strategic intentions are clarified and agreed on internally. This step-by-step method (as developed by the Globemen team) should be either accepted or modified as necessary by the initiating partner, for it to operate according to its intention. In future similar cases the initiating partner may either design the step-by-step process alone, or use external consulting help to do so. In either case the process must be discussed, understood and accepted by all of the lead partners[2] . For the sake of simplicity, Fig. 2 shows the step-by-step process having been designed by the initiating partner and it is assumed that all lead partners have agreed. The

[2] NB The initiating partner and the selected strategic partners together may be called *lead partners.*

overall agreement of all involved lead partners is not trivial to achieve in practice because each enterprise has its own policies, culture and objectives and hence it may not be ready to follow all detail of the process defined by the initiating partner. Agreeing on the desired outcomes of this step-by-step method will help create a common understanding between all involved lead partners and to overcome the main obstacle – finding and using a common accepted approach (modus operandi) in this business partnership.

As can be seen form Fig. 2, substantial emphasis is laid on the creation and update of Reference Models for both the Virtual Enterprise and for Qualified Suppliers of the VE. These Reference Models (created by the Initiating partner and maintained by the Lead partners, including the initiating partner) should capture valuable Service VE creation and Supplier qualification expertise for preservation and reuse.

3. Designing the New Business Model

3.1 Identifying business opportunity and developing the Business Model for the Network and Service VEs

a) The Network is created because the initiating partner has identified a business opportunity to use Networks and Virtual Service Enterprises. This opportunity may be due to several strategic objectives, such as the desire to (1) improve the quality of after sales service; (2) improve the business model through which the initiating partner's resources for after sales service are deployed; (3) improve the cost-effectiveness of after sales service through better use of resources (such as systems and knowledge, including those of subcontractors, etc). *Therefore the business model* (i.e. the identification of involved enterprise entities, and the relationships between them) *needs to be first designed by the initiating partner.* The initiating partner needs to assess this business model from various points of view, such as the effects on business (Does the initiating partner keep or lose strategic advantage? Do the intended participants gain or lose from the implementation of this Business Model? Does the nature of the gain for the partners make it possible, or likely, that partners in this business model might in the long run develop into competitors through participating in the new Business Model)? Is the implementation of this Business Model likely to achieve the strategic objectives (1,2,3,… above)? Is the Business Model culturally adequate[3]?).

While the Business Model may appear to be sound (e.g., answering 80% of the above questions affirmatively), there may be some matters where protection against adverse effects is necessary. Thus, the initiating partner would have to identify a list of intended *contractual obligations* for any future potential partners, which would safeguard against potential negative effects[4]. While this is by no means the complete list of contractual obligations that will have to be agreed on in the future, it is important to have a list of obligations, of which the non-observation might 'make or brake' future relationships.

In addition, the assessment of the Business Model may conclude that the model will indeed support the initiating partner's strategic objectives. However, model assessment usually involves *assumptions* about the business behaviour of potential future partners. Such assumptions, while possibly valid under normal business conditions, might become unsound in case of disturbances, and therefore should be codified as intended contractual obligations.

b) The initial design of the Business Model may have identified strategic partners who therefore need to be included in the subsequent refinement of this Business Model. In this case, the refinement of the Business Model needs to be carried out by a negotiating team of the lead partners and the resulting Business Model needs to be accepted by the involved companies. Note that in the case of the specific Globemen project it has been assumed that there is only one such strategic participant in the Network (the Initiating Partner) – as reflected in Fig. 2.

As the lead partners enter the process, the rest of this step-by-step method would have to be re-visited and potentially modified, so that all lead partners agree on the *modus operandi* of implementing the new Business Model. However, it is

---

[3] i.e. the identified participants are likely to be able to fit into the model. If the partners are not yet identified – e.g. they are only called 'local supplier' without further identification – then is there a selection of such partners whose maturity is at the level which justifies the belief in the feasibility of the Business Model?

[4] i.e. such outcomes and business behaviours which should be excluded.

likely that the lead partners will be willing to accept the method, given also that the model has been operationalised only to some extent[5]. After all, due to the informal and creative nature of these tasks, it would be futile (and potentially harmful or impeding) trying to force a step-by-step procedure on such tasks.

While the above activities are initially done by the lead partners (e.g. through the appointment of an ad-hoc *Negotiating Team*), it is likely that in the long run the Business Model will need refinement and/or adjustment. Additional tasks may also be involved, e.g. in developing more detailed designs and plans for the Network and Service VEs. Therefore, each lead partner will need to appoint a *Supervisory Board*, and these Boards together could form a *Network Supervisory Board*. (The *Charter* of the Network Supervisory board could be drafted by the Negotiating Team and approved by the lead partners in turn.) From the point of view of a lead partner (internally) the members of the Supervisory Board represent the individual company's interests, but it is the Network Supervisory Board that has the authority to direct further joint work. It is therefore necessary to introduce these *new management roles* in each lead partner's organisation.

c) The Business Model presented in Fig. 2 *assumes* certain roles of the participating enterprise entities. Therefore, in reality the step-by-step process may proceed using a slightly different Business Model, resulting from steps a) and b). Nevertheless, for the purpose of this presentation we make the assumptions incorporated in Fig. 2. In this Business Model the initiating partner has identified the types of Service VEs, which the Network should be able to create. The Service VE types are identified by describing the kinds of services that such VEs are expected to deliver. For each individual Service VE, the lead partner(s) will jointly identify the need for that Service VE, as well as the tasks (purpose) of that VE. In the future, the lead partner(s) (through the Supervisory Board) would periodically re-consider this decision, in order to allow the Network's capability to expand. This review may occur at the initiative of either partner, or at the initiative of the Network (since by that time the Network would be operational).

---

[5] i.e., many tasks are identified without trying to further decompose them into elementary steps.

3.2 Master Planning the Service VE types (Reference Model for Service VEs)

The Service VEs deliver their services through the co-ordinated activity of future selected suppliers (typically lead partners also act as suppliers to these VEs).

Service VEs are in fact specialised VEs, therefore the glue that binds the suppliers together is a well defined business process and information exchange interfaces between parts of this process. It follows that the specification of processes that suppliers must implement when taking part in the Service VE needs to be done as part of the VE design rather then as part of a design of separate supplier processes.

How is it possible to develop a Master Plan for the *types* of VEs, rather then for a particular Service VE? Service VEs should be able to provide a range of services, which are selected for every VE from a defined set of service processes. Therefore the lead partners should develop a *range* of business process models, one for each typical service process. Furthermore, the information interfaces should also be defined.

A typical business process model could be expressed in IDEF0[6], and those parts of the process that are procedural could be expressed in IDEF3[7], or CIMOSA[8] (e.g. using the FirstStep[9] tool).

The advantage of being able to use the above tools is that in addition to the activities, the process resources (actually resource types), together with costing and time information, can be added to the process model, which allows the behaviour of the designed process to be analysed using simulation. The simulation can be repeated with different statistical cost and time distributions,

---

[6] ICAM (US Air Force's Integrated Computer Aided Manufacturing) DEFinition Function Modelling Language [6].

[7] A member of the IDEF family of languages developed in the ICAM project, enriching the IDEF0 language with sequencing / time dimension (using Units of Behaviour) and state transitions (using Object State Transition Networks).

[8] Computer Integrated Manufacturing Open System Architecture [7], featuring proprietary modelling constructs described in metamodels [8].

[9] A CIMOSA-compliant enterprise engineering tool [9].

and thus the sensitivity of the service process to variations in cost and time can also be evaluated for the purpose of e.g. risk analysis and contingency planning.

The reference model would also include, as mentioned above, the allocation of resource types to process activities. This includes the allocation of human resource types (describing the necessary skills and capabilities that such human resources need to have), as well as the allocation of application programs and databases.

Unfortunately, at the time of this writing the FirstStep tool does not have a powerful enough information modelling capability; therefore the interfaces identified in the process model should still be specified using a separate data modelling language (such as IDEF1X[10], Entity Relationship Model[11], UML[12] Class diagrams, or EXPRESS[13] – each having enough expressive power for this task).

In many instances, the interface definition is already known because the application programs and databases to be used already exist. In this case only a reference to the specification of such information needs to be included in the model developed here.

Note that while the process model is adequate for identifying the applications as Information and Communication Technology (ICT) resources, the design of the ICT infrastructure is *not* determined by the process model.

Infrastructure design could therefore be performed as a *separate sub-project*, with the functional and other (such as speed, security, volume, transaction speed, etc) requirements that follow from the knowledge of necessary applications and from the identified human roles (user interface requirements, quality of presentation, speed, audio and video transmission and storage).

---

[10] A member of the IDEF family of languages, used to model data. (similar to the Entity Relationship data model).

[11] as originally described in [10] and subsequently extended.

[12] The Unified Modelling Language [11].

[13] A formal language used to describe information models [12].

The master plan for the intended types of VEs codifies the service process and its elements (called Service Operations in the figure). However, the management of this service VEs also needs to be designed. It is proposed to start the development of this model of management and control with a GRAI-Grid[14], because the GRAI grid gives good guidance for the designer regarding the completeness of the model of VE management in terms of management of resources, of the service product, and the planning, scheduling and co-ordination of the service process on all necessary horizons. Such example model was developed earlier in the project (Olegario, 2000).

The lead partners must decide what level of autonomy a Service VE should have, and what management decisions need to be made on the level of the Network (or failing that, by the lead partners).

An argument for increasing the autonomy of the Service VEs is that it is the Service VE that is in direct connection with the customer for whom the service is provided. While the counter argument seems to be that important decisions (meaning decisions that affect the reputation and trust relationship of the partners) should be made by the lead partners it must be kept in mind that the Service VE is a *virtual* enterprise, therefore although the Service VE has its own system of management, sensitive management roles would be filled by management resources of lead partners.

It is therefore correct to design an autonomous management system for VEs; it is only that the allocation of these tasks to partners and/or suppliers should be considered carefully. This allocation of responsibility to partners' resources that defines the *organisation* of each VE. On the level of Master planning of VE types, this allocation does not have to be made; rather, only policies need to be developed, which govern the allocation of responsibilities as will be necessary at the time of creating any particular Service VE.

---

[14] A GRAI Reference Model of the decisional aspect of an enterprise [13].

3.3 Master planning of the Network

While the design of the network is a separate task, it is not independent of the design of VE types. Furthermore, the Network itself does not provide any services to the customer, and may not even provide any customer related services to the VEs: the Network is a ‘management entity’.Thus to design the tasks of the Network, one does not have to create a process model of the ’operations’, because there are no operations. The design of the Network’s tasks is a design of a management system, which interfaces through decision frameworks to the management of lead partners, of suppliers (which may be prospective, qualified, or selected), and operational VEs.

In the Business Model presented in this article it is assumed that while the lead partners design a Master Plan (reference model) for Service VE types, the Network will have the capability to perform the detailed design and the implementation of particular VEs, as well as exercise control over these particular VEs.

In the course of creating particular VEs, the lead partners would identify the need for a particular VE, and based on this specification would transfer the task of designing and implementing such VEs to the Network.

The Network would, as preparation for such tasks, perform the assessment (against supplier qualification criteria) and the selection of *qualified suppliers* (future potential suppliers), and negotiate with such qualified suppliers for them to become *selected suppliers* for particular Service VEs.

Furthermore, the Network would undertake the task of *monitoring* the performance of suppliers in any VE that is already operating and either take corrective action, or (e.g. if lacking adequate authority and/or resources for the task) escalate the problem to the lead partners’ management (through the Network Supervisory Board).

As follows from the above discussion, the interface between the lead partners and the Network would have to be defined in terms of the objectives- and the authorities of the Network. In fact, from an organisational point of view, the Network Supervisory Board would belong to the Network, thus being the highest autonomous Network authority and consisting of members of the lead partners' Supervisory Boards.

In cases where the Network's authority is exhausted, the lead partners need to negotiate outside of the Network regarding the realignment of the Network's objectives, or about the authorities granted to the Network Supervisory Board.

Figure 3 therefore includes (represents) management tasks that need to be implemented within the management structure of lead partners.

Longer horizon decisions (yearly or half yearly management tasks) of the Network are likely to be non-procedural. Therefore, these could be described as task lists, or in more detail as enriched IDEF0 diagrams (e.g. annotated with policies, authorities, constraints). These explanations will be used as job descriptions for individuals or committees allocated to the given management role.

For shorter term management tasks (operating on weekly, monthly or quarterly horizons) most activities would likely contain procedural elements. Thus, for these tasks a procedure could be defined using e.g. IDEF3 or CIMOSA/FirstStep. Nevertheless, activities in these procedures would often still be non-procedural, hence their control would have to be exercised through policies and task descriptions (in the same way as longer horizon management tasks were defined above).

Since both the Network and Service VEs are dynamic entities, it is proposed that these models of management should not be created on paper only and then implemented, but rather these models should be made available on-line (e.g. on the Network's Intranet) to all human resources in the respective management systems, and maintained[15] throughout the life history of the Network. The design authority of the Network may simply be the Network Supervisory Board, or a

[15] Since the TO-BE state applies to dynamic entities (especially for long periods), the model of this desired state may need regular updating. The GRAI Evolutionary Method (GEM) [14] for example proposes the use of several intermediate, shorter term (e.g. equal to the horizon) NEXT STEP states. On reaching each of these states, the TO-BE state should be updated.

group reporting to it. Given that amendments in the Network management should match the lead partner's intentions, any such changes may have to be approved at the level of lead partners, rather than by the Network Supervisory Board.

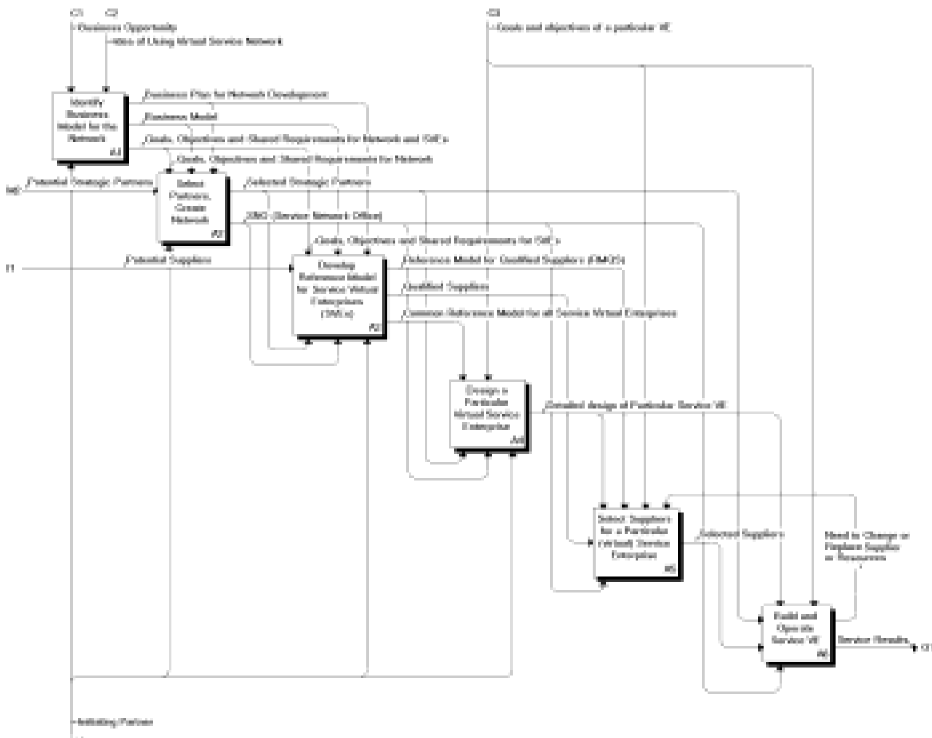


Figure 3. Activity model to set up a Service Network and a Service Virtual Enterprise.

3.4 Developing the Qualification Criteria for Suppliers in form of a Reference Model for Qualified Suppliers

At the stage of this writing, the Business Model *assumes* that qualification criteria for future suppliers on Service VEs are developed by the initiating partner. However, these criteria need to be mutually approved by the lead partners in order to take effect.

In addition, the criteria might change with time, and the initiating partner's respective Supervisory board may have to initiate changes in these criteria in the future. Therefore the lead partners need performance indicators that they can use to monitor the effectiveness of suppliers.

While the Network itself would continuously monitor the performance of suppliers, aggregate information (evaluated at regular intervals) would have to be provided to lead partners. 'Special event reports' should also be provisioned for fast response to significant events, requiring reaction which can not wait for a scheduled aggregate report.

Most of the qualification criteria will have been developed through the Master Planning of Service VE types: the overriding criterion is that qualified suppliers should be able to perform tasks in the suite of processes to be performed by planned VE types.

Thus, a supplier's qualification is tied to having the *demonstrated capability* and resources to participate in the service processes of planned VE types. Also, qualified suppliers must have management processes in place (including the ability to provide the necessary performance indicators), so as to be able to work together with Network Management.

Thus, a supplier may gradually acquire qualification – e.g. the supplier may be qualified for a part of a set of processes, while from the point of view of other service processes qualification might be achieved at a later date.

3.5 Designing and Implementing Systems for use in Service VEs

The identification and requirement specification of prerequisite modules of Information and Communication Technology (ICT) Modules and Modules of Human tasks results from the Master Plan of VE *types.* In the present Business Model, this development is done by the initiating partner[16]. Depending on its

[16] In the situation described, the initiating partner already has many modules that it wishes to use in future VEs.

intentions, the initiating partner may want to keep this design authority (e.g. to protect its competitive advantage) – in which case the initiating partner must have a *Development Team* in place, which is involved in the continuous development of network resources necessary for implementing VEs.

It would equally be conceivable that the relationship between lead partners is such, that keeping the design authority of the above resources does not contribute to competitive advantage, e.g. if the Network is set up as a separate organisation, such as a joint venture co-owned by the lead partners. In the present Business Model it has been assumed that the initiating partner wishes to keep this design authority (an assumption which is still to be confirmed).

Either way, the task is a continuous one: it consists of an initial development, as well as a continuous development in order to allow the Network to expand its capabilities.

3.6 Implementing the Network

The Master Plan of the Network would be potentially simple, since the Network is only a management entity. The implementation of the Network could be done as a separate project, or as a continuation of the Master Planning task – in either case the Network's management information system needs to be developed, and management tasks must be allocated to human resources who would be *delegated* by the lead partners. Should it eventuate that the Network became a separate organisation (such as a joint venture), human resources may either be transferred to the Network's employment, or newly hired.

An important task in the implementation of the Network is *training*. This task may have to be carried out by the initiating partner or it may be outsourced.

Other resources from the lead partners may need to be transferred to the Network (called *Network Office* in the Business Model, assuming that the Network is not a separate legal entity).

The Network needs to start operating as soon as possible in order to build up the list of qualified suppliers, so as to be *ready* for Service VE creation. The qualification process will include discussions and paperwork with potential suppliers, but will focus first and foremost on trials of activities and underlying ICT modules, so as to demonstrate the capabilities of suppliers who wish to qualify.

3.7 Creating Service VEs at the Request of Lead Partners

Once the Network Office is in place and it has built up a set of qualified suppliers, it is ready to create Service VEs (at least a first pilot one). Thus, the effort to create an initial list of qualified suppliers must concentrate on the strategic objectives of lead partners, who would wish to gradually develop the Network's capability and would have intentions regarding both the first pilot and the future Service VE types.

In the present Business Model it is the Network that develops particular business process models for target Service VEs, but this task mainly consists of tailoring the VE Reference Model rather than modelling from the ground up. Thus, it is the Network that engages in the detailed design and implementation of particular VEs. The advantage of this feature of the Business Model is that VE creation becomes a routine task, and as such can be performed swiftly and efficiently at the request of the lead partner(s).

Further operations of the Network may include the testing and verification of each particular VE created, but the details of these tasks are beyond the scope of this article.

4. Conclusion[17]

This article has demonstrated a step-by-step procedure for VE creation, designed on the basis of generic enterprise integration principles and the GERAM / VERAM[18] reference architectures.

The authors therefore argue that Research and Development (R&D) activity that includes partnership between industry and research establishments needs to take the step of developing step-by-step procedures in order for the methodology to be usable for industry partners.

The authors have learned from this case study (and continue to do so, since the project is not yet finished), that it is feasible to create a tailored step-by-step methodology for individual cases. The lessons may be described in the form of a method that, based on business decisions of lead partners, can help an initiating partner to create a tailored methodology. Such methodological know-how can be described and coded in a knowledge base intended for decision support and planning.

References

1. Williams, T. J. (Ed.). 1994. A Guide to Master Planning and Implementation for Enterprise Integration Programs. Purdue Laboratory for Applied Industrial Control: West Lafayette, Indiana.

2. Doumeingts, G. et al. 1992. GIM-GRAI Integrated Methodology – A Methodology for Designing CIM Systems. Version 1.0, Unnumbered Report, LAP/GRAI, University Bordeaux 1: Bordeaux.

---

[17] Ovidiu Noran contributed to this article with details of the meta-methodology and Joachim Riedlinger contributed with guidelines for the Business Model. We acknowledge the contributions of Carl Schodde (Honours student at Griffith University) in the development of the IDEF0 model of the step-by-step methodology. Peter Bernus put it all together.

[18] Virtual Enterprise Reference Architecture and Methodology – a specialisation of the GERAM framework for the purpose of virtual enterprises [15].

3. Globemen Consortium (Global Engineering and Manufacturing in Enterprise Networks), IMS project no. 99004. 1999. EU: IST-1999-60002.

4. ISO/TC184/SC5/WG1. 1999. Annex A: GERAM, in ISO/DIS 15704: Industrial automation systems – Requirements for enterprise-reference architectures and methodologies, ISO-1999, Editor.

5. Bernus, P. & Nemes, L. 1994. A Framework to Define a Generic Enterprise Reference Architecture and Methodology. CSIRO Division of Manufacturing Technology: Melbourne.

6. ICAM, Integrated Computer Aided Manufacturing (ICAM) Architecture Part II, Vol. IV – Functional Modeling Manual (IDEF0). 1981. Air Force Materials Laboratory: Wright-Patterson Air Force Base, Ohio.

7. ESPRIT Consortium AMICE. 1993. CIMOSA – Open System Architecture for CIM. 2nd revised & extended ed. Berlin: Springer-Verlag.

8. Vernadat, F. B. 1998. The CIMOSA Languages, in Handbook of Information Systems, P. Bernus, K. Mertins & G. Schmidt (eds.). Springer-Verlag Berlin: Heidelberg. Pp. 243–263.

9. Levi, M. H. & Klapsis, M. P. 1999. FirstSTEP process modeler – a CIMOSA-compliant modeling tool. Computers in Industry. **40**: pp. 267–277.

10. Chen, P. 1976. The Entity Relationship Model – Towards a Unified View of Data. ACM Transactions on Database Systems. **1**(1).

11. Rumbaugh, J., Jacobson, I. & Booch, G. 1999. The Unified Modelling Language Reference Manual. Reading, MA: Addison-Wesley.

12. ISO/TC184/SC5/WG1, ISO/DIS 15704: Industrial automation systems – Requirements for enterprise-reference architectures and methodologies. 1999.

13. Doumeingts, G. 1984. La Methode GRAI. University of Bordeaux I: Bordeaux, France.

14. Doumeingts, G. 1998. GIM, Grai Integrated Methodology, in Handbook of Life Cycle Engineering – Concepts, Models and Methodologies, A. Molina, A. Kusiaka & J. Sanchez (eds.). Kluwer Academic Publishers: Dordrecht. Pp. 227–288.

15. Zwegers, A., Hannus, M. & Tolle, M. Integration issues in virtual enterprises supported by an architectural framework. In: IMS Forum. 2001: Proceedings of the IMS Forum.

Better Models for Agile Virtual Enterprises – The Enterprise and its Constituents as Hybrid Agents

Peter Bernus and Rob Baltrusch
Griffith University
Martin Tølle and Johan Vesterager
Technical University of Denmark

Abstract

The article proposes a way to improve reference models for the management of virtual enterprises. The pattern of management roles is based on enveloping each decision centre into an agent wrapper, using the same tools and algorithms. Using this approach enterprises (organization, networks, virtual enterprises) will have the emergent agent property – the ability to follow objectives, plan, and take timely corrective action in case the plan breaks down.

The resulting system has a dynamic, agile structure, where each decisional level (strategic, tactical, operational) may organize and re-organize the lower level according to the changes in objectives, or according to improvements in the capabilities or availability of resources.

1. Introduction

In the artificial intelligence (AI) literature, and particularly in Distributed Artificial Intelligence (DAI), agents are usually described as software programs with certain capabilities [1]. These capabilities include goal seeking behaviour [2, 3], the ability to plan [4], autonomous action [5], and reflective reasoning [6, 7] (and often some additional properties as well). In distributed AI these capabilities are extended with co-operative planning and negotiation, which includes trust between the involved agents [9, 10]. The problem is, then, how to specify, design and implement such software agents(or simply agents since this statement precludes the specification of human agents (in the form of a job role for instance). The scope of the improved Globemen Reference Model discussed in this paper is primarily aimed at supporting the management and control functions of the Partner, Network and Virtual Enterprise, since these abstract entities can each be viewed as an agent having agent properties. The notion of the Network being an agent may first seem surprising – the question being whether the Network is referred to as the Network Manager's Office or as the collection of partners in the network, and possibly all suppliers to the Network as well. However, it must be considered that the 'agent' to which we refer in this article is not a physical entity. The 'agent' referred to here is a set of processes linked together in such a way that a competency-based and negotiated allocation of physical entities to these processes allows these physical entities jointly display agent behaviour. In the case of the Network any objective that is in the competency of the Network will be achieved through co-operation by a number of physical entities – incidentally, the same is true of a Virtual Enterprise.

The properties that collectively define an agent can be extended to any system, including a system entirely consisting of humans, or to hybrid systems, consisting of a mixture of human and automated constituents [10].

Agent properties are very attractive for any system to have. For example, if an enterprise is an agent, then it is able to determine its own objectives (perhaps through negotiation), design and follow plans of action according to certain constraints and parameters, as well as it has the ability to negotiate and co-operate with other enterprises to determine and to achieve common objectives. In case the execution of the plan breaks down, the enterprise with agent properties has the ability to change its objectives, change its plans, so as to continue a viable course of action. These properties make the agent 'intelligent'. Thus the question is not how to implement fully automated intelligent agents, but rather, how is it possible to specify, design and organise an entire enterprise, a network of enterprises, or a virtual enterprise, in such a way that each can be considered to be an agent.

Traditional management structures have difficulty achieving agenthood on the enterprise level, because the complexity of co-ordination and planning functions precludes purely human agents to develop solutions to many management problems [10].

It has been established [10] that such emergent management structures will need to satisfy the following fundamental requirements:

Enterprise Integration: In order to support global competitiveness and rapid market responsiveness, an individual or collective manufacturing enterprise will have to be integrated with its related management systems (e.g., purchasing, orders, design, production, planning & scheduling, control, transport, resources, personnel, materials, quality, etc.) and its partners via networks.

Distributed Organization: For effective enterprise integration across distributed organizations, distributed knowledge-based systems will be needed so as to link demand management directly to resource and capacity planning and scheduling.

Heterogeneous Environments: Supporting IT infrastructures will need to accommodate heterogeneous software and hardware in both their manufacturing and information environments.

Interoperability: Heterogeneous information environments may use different programming languages, represent data with different representation languages and models, and operate in different computing platforms. The sub-systems and components in such heterogeneous environments should interoperate in an efficient manner. Translation and other capabilities will be needed to enable such interoperation or interaction.

Open and Dynamic Structure: It must be possible to dynamically integrate new subsystems (software, hardware, or manufacturing devices) into or remove existing subsystems from the system without stopping and reinitializing the working environment. This will require an open and dynamic system architecture.

Cooperation: Enterprises may need to cooperate in a timely manner with their suppliers, partners, and customers in order to meet a set of negotiated objectives.

Agility: Considerable attention must be given to reducing product cycle time to be able to respond to customer desires more quickly. Agile manufacturing is the ability to adapt quickly in a manufacturing environment of continuous and unanticipated change and thus is a key component in manufacturing strategies for global competition. To achieve agility, manufacturing facilities must be able to rapidly reconfigure and interact with heterogeneous systems and partners. Ideally, partners are contracted with "on the fly" only for the time required to complete specific tasks.

Scalability: Scalability means that additional resources can be incorporated into the organisation as required. This capability should be available at any working node in the system and at any level within the nodes. Expansion of resources should be possible without disrupting organisational links previously established.

Fault Tolerance: The system should be fault tolerant both at the system level and at the subsystem level so as to detect and recover from system failures at any level and minimize their impacts on the working environment.

Even if all of the above is theoretically possible, the time and resources available to harmonise objectives and actions is often so limited that human agents alone are not capable of making correct and timely decisions. As a result the management role, or the entire enterprise, starts to display inferior ('not intelligent') behaviour. This harmonisation of objectives between management functions becomes increasingly difficult across organisational and functional boundaries – as is the case in the Network and Virtual Enterprise since there may be greater disparity between management functions.

2. Designing a Modular Reference Model for Virtual Enterprise Management

The improved Globemen Reference Model (based upon [11]), presented here takes this human limitation into account, and defines each management role as a role potentially filled by a *hybrid* agent – i.e. an individual (or a group of individuals) and their supporting automated (software and hardware) tools. This approach reflects the nature of dynamic, collaborative environments since each abstract role has insufficient resources and control to achieve it's objectives alone, and therefore must negotiate and coordinate its activities in order to meet its objectives. For example, if a management role is to be filled by an agent (required to negotiate and co-operate with other management roles) then allocating the task to a group of individuals is likely to deliver inferior solutions. This is because a group (such as a committee) is unlikely to be able to function as an agent alone under the pressures of time and resource limitations. In addition to automated tools, each of the management roles must have certain knowledge at its disposal, and needs to have policies and procedures that collectively ensure the functioning of the group as an agent.

As a consequence, the improved Globemen Reference Model endavours to

a) Encapsulate each management role into an 'agent hull' – defining standard agent negotiation protocols [12] on the interface

b) Determine the requirements, which can be used by enterprise management to design company-specific policies and procedures that are consistent with the requirement that each management role individually (as well as the entire enterprise as a whole) should be capable of displaying agent properties.

c) Identify automated tools and reference models for management roles that improve the ability of the management role to engage in co-operative planning, control and decision making – functionally, in a timely manner, and without functional degradation due to resource limitations.

The model presented here is discussed according to these three objectives, and is proposed as a set of patterns, rather than an integrated solution. The reason for this is that each Business Model (i.e. a set of defined strategic relationships between enterprise entities, as well as each decisional system) is unique, therefore – unless we intend to limit the development of the reference model to a very narrow domain – it is not possible to define a reference model that can be applied in a wide variety of situations by simply refining it through the addition of detail.

In general there are three types (ways to define) of reference models [13, 14].

1. The Reference Model (RM) may be developed as a *generic model*. The use of such form of RM is that particular models can be developed from it through refinement and specialisation. The advantage of such RM is that all particular models based on it share a set of properties, namely those properties that hold true for the RM. This form of RM is in fact the state of the art in industry today: all ERP systems are based on this principle. Thus ERP systems define how management should be like in any enterprise, and the implementation in any particular situation is carried out through parametrising these reference models [14] ERP RMs are developed to a fairly fine granularity (to allow the implementation of modules for fast deployment through parametrisation of the modules).

However, the downside of such RMs is that the variety of allowed particular models is limited. Since there is today no better alternative, enterprises are forced to accept this underlying RM of ERP systems, and make modifications to their own management system. As a result, a) the ERP system does not always fit the intended Business Model [15, 16], and may force a change that is due to the limitations of the RM rather than by some business consideration [17]; b) the ERP system implementation may meet cultural resistance, which makes successful implementation slow, expensive, and may achieve only limited success [18]. Note that we do not intend these comments as criticisms of ERP systems, rather we assess the applicability of this RM type to the problem at hand: the development of a RM for virtual enterprise management.

2. The RM model may be developed as a *paradigmatic solution*. What is meant by this term is that the RM is presented as an individual typical solution. Particular models would in this case be developed on its basis through changing details. This type of RM is even more limited than the generic RMs (so it would be an inappropriate choice for ERP systems, for example), i.e. a paradigmatic RM's applicability is limited to a relatively small *design space.*

In spite of the above limitations, paradigmatic RMs are widely used by consultancies and engineering companies (in all fields of engineering): a set of previous cases of complex systems are documented and kept for future reuse, and subsequent particular cases reuse these either in their entirety (through local changes to the paradigmatic solution) or in part (through cutting out part of the paradigmatic model and replacing it with a brand new part).

The advantage of paradigmatic RMs is that – provided the company using it is faced with a sufficiently similar particular case – both the design and the implementation of a new system has a substantial part that is identical to a previous solution. Thus the need for parametrisation is limited (mainly to operating parameters, rather than design parameters, i.e. the difference between particular systems is only in parameter settings of software systems, where the design of these systems is the same), the time and resource needs of a new system implementation is relatively small, and the risk is substantially reduced.

A reference model for virtual enterprise management developed earlier in the Globemen Consortium [11] is a paradigmatic model. It is developed as a model of a hypothetical case (where the requirements based on which it was developed reflect the views of a set of Globemen partners at the time).

The problem with developing an implementation of this RM is that it is not clear to what extent such implementation can be reused in the future, in other words is it modular enough? Modularity should be preserved both in the models and their implementations (called modules) to allow (re)configuration – either for future particular cases, or to change an existing system of management.

3. The RM model may be developed as a *set of modular components* and rules of how to combine such modules into a system. The modular components themselves have several important characteristics, including a) modules are generic, simple, discrete units enabling highly cohesive, loosely coupled configurations; b) modules have well defined interfaces, inputs and outputs; c) modules transparently produce outputs; d) modules are recursive entities, meaning they can be decomposed into a set of sub modules with the same defining properties above.

Notice that given a set of models and component modules, the design space (the *variety* of systems that can be configured from them) is much larger than covered by generic models through their parametrisation. At the same time, given the granularity of modular model components, there is no obstacle for designing implementations (modules) so that any new system based on this RM type could be designed and implemented through configuration. Special design principles exist to help design modular systems that allow the greatest freedom for combining modules, such as the principle of orthogonalisation [22].

Electronic engineering and construction engineering companies use this type of RM very frequently. Other domains such as software engineering (through the component based software engineering movement) attempt to use it also, but with limited success at this moment – with some exceptions (such as the UNIX operating system, which is a collection of a rich set of modules that can be combined into systems with ease). The reason for limited success in certain areas seems to be a) designing a modular system requires a larger effort than designing a particular system (even if future reconfiguration needs are considered). Thus the cost is not easily absorbed by any particular system design and implementation project b) the skills required to do this (and the underlying principles) are in short supply. This is because configuration of modules can be either optimising or satisficing – that is, the design may be functional but not robust (mainly addressing user requirements) or it may be robust, flexible, maintainable etc (addressing system requirements).

While this type of RM is very attractive, to develop such a modular RM for virtual enterprise management it is necessary to identify a principle (or a set of principles) promising enough to ensure that the resulting RM is of the right granularity. All important design decisions can be made through configuration, and modules have a detailed enough design to be able to implement them as modules. Also, learning from the limited success of modular system design efforts, we must carefully consider the extent of the domain in question, and avoid incorporating modules that are better placed on a different system layer, into an infrastructure that should be separated from the problem domain. This would allow us to limit the RM to modules pertinent to the problem domain and rely on existing transparent services through standard (or industry standard) interfaces.

3. The Agent Principle and its Applicability for Management Reference Models

As explained in the Introduction and in Section 2, our aim is to develop a modular RM that can be the basis for a variety of Business Models so that each enterprise entity should behave as an agent, as well as the complete business process implemented in by Virtual Enterprises in this Business Model should display this property.

Since in a system of management (decisional model) only management *roles* are defined each management role (represented by a Decision Centre) would in an organization be allocated to a manager (decision maker). It is also possible that several decision roles are allocated to one person, while it is possible for a decision role being taken up by a committee. Thus there is no on-e-to-one mapping between decision roles and individuals.

How is it possible to use the principle that enterprises should be designed so as to become agents? Is it the management role that must be an agent (thus an abstract entity), and the system of management must also be an agent, or it is that organizational entities, such as individuals, committees, departments and the complete organization must be agents? Thus we need to make the requirement of agenthood more precise.

Given an organization (such as a company) it is clearly desirable that the organization as a whole should behave as an agent. Thus the organization as a physical should be an agent (and a physical agent at that, since it is real life entity). On the other hand the decision system of the organization as a system of decision functions should also be an agent in the sense that this system of decisions should ensure that the agent property will emerge, once it is implemented in an organization. Of course the decision system is an abstract agent, since the decision system is only a system of decision functions, rather than a real life entity.

What happens when an organizational entity, such as an individual (or a group of individuals who we somehow ensured acts as an agent) is allocated to a decision task? Is it automatically ensured that the decision centre will display agent properties? The answer is simply: no. This is because the decision centre will be an agent only if the individual has the right competencies, support tools, communication channels, and information at disposal that allow the decision function to be performed so as other agents can recognize the decision centre as an agent. For this reason, the application of the *agent pattern* to enterprise management should be done on the functional level first – where the 'agent pattern' is the set of functions that make up an agent's functionality. It is only when this is accomplished that one can consider the allocation of individuals to decision roles.

Naturally for the individual (together with supporting tools or other resources) to be able to fulfill this role, and for the organization to emerge as a physical agent, certain *constraints* must be observed when role allocation is performed. Some constraints on the organizational view (allocation of individuals to decision tasks in this case) are related to competencies. Many decision tasks can only be defined as policy driven activities, rather than procedures, and these policies can only be correctly used if the individual has a certain set of competencies. Some other constraints relate to conflicts in the mapping between decision tasks and individuals: a careless allocation of individuals may create *role conflicts*, whereupon an individual has preferences that prevent it from giving equal consideration to both roles, and consequently the roles are not performed as expected. As a result, in addition to functionally designing the decision system based on the agent pattern, we must also have a set of explicit constraints that govern the construction of the organization

Functionally (on a high level of abstraction) an agent pattern can be represented as in Fig. 1. This agent pattern represents a *negotiating* agent, since the essence of the decision system is that the objective of the enterprise can only be achieved if agents co-ordinate their activities. In a decision framework the ‘Objectives & Authorities Proposed to the Agent’ represent the objectives derived from the enterprise’s objectives, as pertinent to the given agent taking the role of this decision centre. However, as far as consistent with these objectives, other agents may propose other objectives, provided that the authorities derived from enterprise objectives allow this. The acceptance of proposed objectives is not automatic: agent co-ordination is unlike control, because the allocation of objectives is the result of a negotiation.

The Agent (the decision centre under consideration) uses its experience with previous plans to determine if – given its allocated authorities (decision variables and constraints) – the proposed objectives are feasible. Depending on the assessment of the feasibility of proposed objectives the Agent may readily accept the proposed objectives (based on previous experience the objective is feasible), or needs to develop a plan to investigate feasibility.

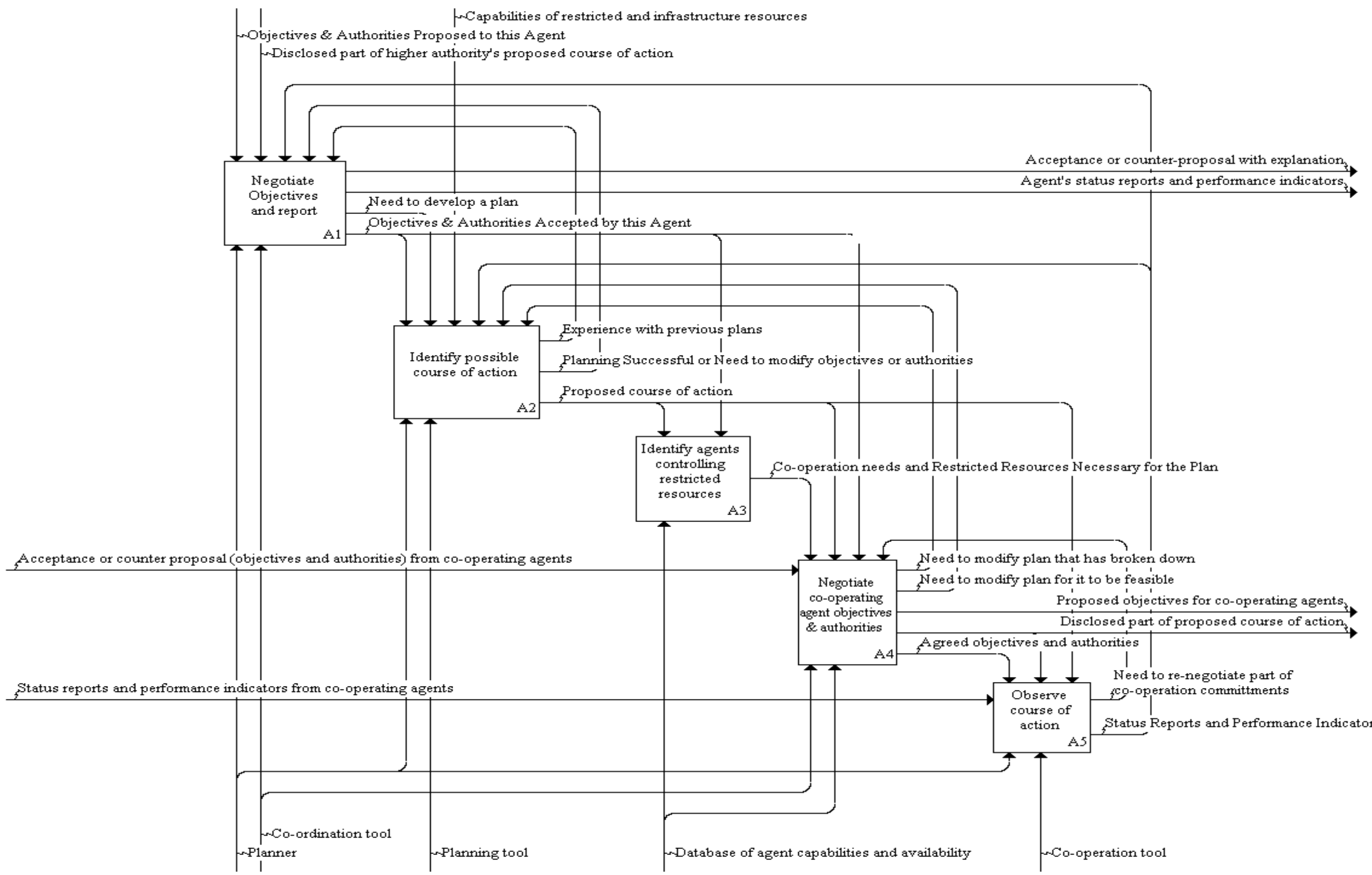


Figure 1. Agent pattern (functional view of negotiating hybrid agent).

During this planning activity the agent may discover that the objective can not be achieved (it is not possible to generate a suitable plan) in which case the Agent may generate and alternative proposal, which either changes the objective, or requests a modification to its presently granted authorities.

Once there exist a set of Objectives and Authorities accepted by the Agent, there is a need to develop a course of action (or plan). The Agent must, using its own knowledge of other agents (potentially in a database of other agents' capabilities and their availability) find suitable other agents for carrying out the plan. If not successful, the plan is not feasible and re-planning is necessary. If successful, the Agent must negotiate with other agents to co-operate in the performance of the plan. In the same way in which this Agent negotiated its objectives and authorities it will negotiate with potential co-operating partners. Once agreement has been reached with all necessary co-operating partners the plan is set into action and the Agent monitors (using performance indicators and status reports) the progression of the plan.

Once again, if the plan is not progressing in a satisfactory manner, or status reports suggest a potential future breakdown, the plan needs to be revised and (some) co-operation agreements must be re-negotiated.

This pattern of agent behaviour is common to all decision centres, and is implemented by a *hybrid agent* – thus the Agent consists of a human and tools needed to be able to implement all the agent functionality.

Also, since this Agent is in fact unable to achieve alone the objective proposed to it, it must aggregate other agents (that possess the necessary resources and capabilities) so that this aggregate community of agents can a) perform actions necessary to achieve the common objective, and b) can modify its co-operative plan if the need arises (e.g. because of the breakdown or resources, or unforeseen events).

As a result, the aggregate community of agents together also displays agent properties, which was the objective of this design. It is important to note that there may be several partly overlapping aggregated communities, since the Network may produce several different Virtual Enterprises at any given time. However, since each Virtual Enterprise has a unique set of goals and objectives and consists of a distinct set of aggregated agent communities, the notion of agent properties still holds.

Notice that each decision centre must follow this pattern, and consequently have the same type of interface for negotiation. (The content of this negotiation of course differs from agent to agent.)

The Database of Agent Capabilities and availability may be looked at as the model that the Agent maintains about other agents. At this level of generality it is impossible to provide details of this database, but for any particular decision centre the database can of course be described.

4. Building a management system from modular decision centre specifications

The agent pattern can be used to describe typical decision centres, such as strategy making, strategic human resource management, strategic technology management, strategic capital management, strategic product development, strategic supply management, tactical production planning, tactical product management (marketing and supply), tactical resource management (human, technology, capital), as well as on the operational control level – customer relationship management, order processing, scheduling, factory control and supervisory control.

We envisage a set of separately specified decision centres, that we are free to combine in a specific system of management.

Figure 2 shows the same pattern as Fig. 1, but those tasks which are common to all decision centres are clustered into two functions (negotiation with higher authority agents and negotiation with all other agents). All the other tasks are typical decision activities, which are specific to the type of task for the decision centre.

Thus to use this model, every decision centre needs to have these two clustered functions, while the activities in-between need to be designed according to the needs of the management task.

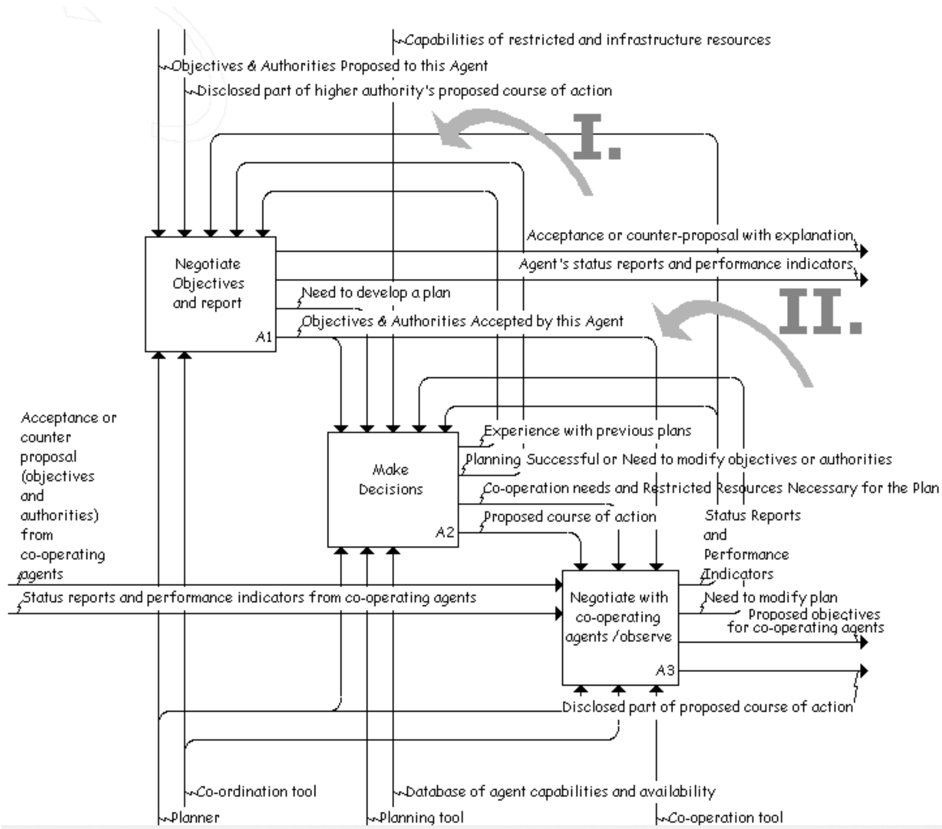


Figure 2. Three clusters of management function in any decision centre: (1) Negotiate aggregate objectives (2) Perform decision making task (3) Negotiate to aggregate capabilities and resources of other agents.

Given that the negotiation tasks are similar for any decision centre, the collaboration and co-operation tools, as well as the reporting channels (status and performance indicators) can be implemented using the same technology, and thus common tools can be developed for this purpose.

As one can see from Fig. 2, we *wrapped* the decision functions into an agent envelope [10], and identified tools to support this wrapping. The two loops (I and II) are needed for the two major negotiating functions: the involvement of the Agent's own decision making in the negotiation with higher authority, and the involvement of the negotiation with co-operating agents in the Agent's decision making, including the need to modify plans if co-operation displays undesired characteristics. In this functional decomposition, we clustered the

Agent’s negotiating functions (1) and (3) in Fig. 2, and the Agent’s own decision making function (2). The figure also shows the mechanisms which support the execution of these negotiation and decision functions (such as (ICT) tools, policies, protocols, human actors). In practice this has important consequences.

(a) The higher level authority does not need to see the details of the organization (i.e., which agent is allocated to which task – whether decision making or service to the customer), because the decision system has the systemic property of behaving as an agent. Thus either the high level objective is achieved through the lower level agents organising themselves, or the higher level agent (operating on a longer time horizon) gets timely feedback about feasible alternatives.

(b) The agent property propagates beyond company walls because the companies themselves behave as agents and their negotiation follows the same pattern. E.g. a Virtual Enterprise, created for the objective defined by a lead partner (or by a Network Organization – whichever may be the case in the given Business Model), emerges from the negotiation of the higher level agent (that defined the objective) and the suppliers that take various roles in the business process. The ‘plan’ or ‘course of action’ of Fig. 1 is in this case is the business process to be performed – such as providing after sales service for a given product or product type, or implementing a supply chain for manufacturing a given product or product type.

(c) The Virtual Enterprise is not a static organization [19, 20, 21], since the agent that negotiates the co-operative commitments of suppliers might change the overall objective (thus modify the ‘plan’, or business process), or through monitoring the performance indicators and status reports of suppliers pertinent to the business process it may conclude that role allocations must be changed (re-negotiated).

Fig. 3 shows the overall picture of this type of organization.

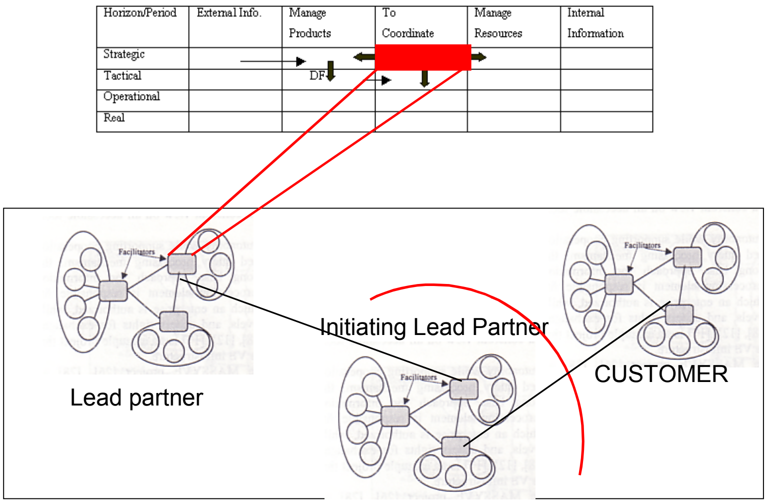


Figure 3. The overall picture of a co-ordinated supply chain- each partner, and each decision role within, is an agent – these agents aggregate into higher level agents.

5. Conclusion

We propose that organizations must strive to achieve agenthood, and even virtual enterprises must have the agent property. To achieve this the management system (or decision system) of involved entities should adopt the agent pattern for implementing management roles.

For this to be achievable, existing management roles need to be *enveloped* by agent wrappers, which ensure a consistent way of decision making within organizations, networks, and virtual enterprises created by them.

The resulting system has a dynamic, agile structure, where each level (strategic, tactical, operational) may organize and re-organize the lower level according to the changes in objectives, or according to improvements in the capabilities or availability of resources. The strict control channels of management systems that are designed from the top down are replaced by negotiated co-operative agreements, supported by a systematic application of performance indicators and status reports and monitoring.

Future methodological development must be done to improve and facilitate the timely implementation of Virtual Enterprises modelled after the agent paradigm. This methodological development should encompass both reference models and tool support.

References

1. Wooldridge, M. Agent-based software engineering. IEEE Transactions on Software Engineering, 144(1), February 1997, pp. 26–37.

2. Lesser, V. R., Durfee, E. H. & Corkill, D. D. Trends in cooperative distributed problem solving. IEEE Transaction on Knowledge and Data Engineering, 1(1), pp. 63–83.

3. Durfee, E. H. (1988). Coordination of Distributed Problem Solvers. Boston: Kluwer.

4. Allen, J. F., Hendler, J. & Tate, A. (Eds.). (1990). Readings in Planning. San Mateo: Morgan Kaufmann Publishers.

5. Franklin, S. & Graesser, A. (1997). Is it an agent, or just a program. In: J. P. Muller, M. Wooldridge & N. R. Jennings (Eds.). Intelligent Agents III (LNAI Volume 1193). Berlin: Springer-Verlag. Pp. 21–36.

6. Bratman, M. E. (1987). Intentions, Plans, and Practical Reason. Cambridge: Harvard University Press, MA.

7. Bratman, M. E., Israel, D. J. & Pollack, M. E. (1988). Plans and resource-bounded practical reasoning. Computational Intelligence, 4, pp. 349–355.

8. Castelfranchi, C. & Falcone, R. (1998). Principles of trust for MAS: Cognitive anatomy, social importance, and quantification. In: Proceedings of the Third International Conference on Multi-Agent Systems. Paris. Pp. 72–79.

9. Wooldridge, M. & Jennings, N. R. (1994). Formalizing the cooperative problem solving process. In: Proceedings of the Thirteenth International Workshop on Distributed Artificial Intelligence. Lake Quinhalt, WA. Pp. 403–417.

10. Shen, W. & Norrie, D. H. (1999). Agent-Based Systems for Intelligent Manufacturing: A State-of-the-Art Survey. Knowledge and Information Systems 1(2), pp. 129–156.

11. Olegario, C. (2001). A Partial Enterprise Model for the Management and Control in an Extended Enterprise Scenario. Masters Thesis, School of Computing and Information Technology. Brisbane: Griffith University.

12. FIPA (2000). FIPA communicative act library specification. Doc. XC00037H.

13. IFIP/IFAC Task Force on Enterprise Integration, GERAM: Generalised Enterprise-Reference Architecture and Methodologies. Annex to ISO/DIS15704.

14. Bernus, P., Nemes, L. & Williams, T. J. (Eds.). (1996). Architectures for Enterprise Integration. London: Chapman and Hall.

15. Holland, C., Light, B. & Gibson, N. (1999). A Critical Success Factors Model for Enterprise Resource Planning Implementation. In: Proceedings of The European Conference in Information Systems. Copenhagen. Pp. 273–285.

16. Sumner, M. (1999). Critical Success Factors in Enterprise Wide Information Management Systems Projects. In: Proceedings of the Fifth Americas Conference on Information Systems. Milwaukee, Wisconsin. Pp. 232–234.

17. Brown, C. & Vessey, I. (1999). ERP Implementation Approaches: Toward a Contingency Framework. In: Proceedings of the 1999 International Conference on Information Systems. Charlotte, NC, December 13–15. Pp. 411–416.

18. Boudreau, M. C. & Robey, D. (1999). Organizational Transition to Enterprise Resource Planning Systems: Theoretical Choices for Process Research. In: Proceedings of the International Conference on Information Systems. Pp. 291–299.

19. Rabelo, R. & Camarinha-Matos, L. M. (1996). Towards Agile Scheduling in Extended Enterprise. Proceedings of BASYS'96: Balanced Automation Systems II. London: Chapman & Hall.

20. Camarinha-Matos, L. M. & Afsarmanesh, H. (1999). Tendencies and General Requirements for Virtual Enterprises. IFIP TC5 WG5.3 / PRODNET Working Conference on Infrastructures for Virtual Enterprises (PRO-VE'99). Porto, Portugal, Boston: Kluwer.

21. Camarinha-Matos, L. M. & Afsarmanesh, H. (1999). The Virtual Enterprise Concept. IFIP TC5 WG5.3 / PRODNET Working Conference on Infrastructures for Virtual Enterprises (PRO-VE'99). Portugal, Boston: Kluwer.

22. Bernus, P., Baltrusch, R., Vesterager, J. & Tølle, M. Fast Tracking ICT Infrastructure Requirements and Design, Based on Enterprise Reference Architecture and Matching Reference Models. In: Proc Int. Conf. PROVE02. Boston: Kluwer. Pp. 293–302.

Managing Relations in Networks of Enterprises

Arian Zwegers
Baan Development B.V., Netherlands (email: azwegers@baan.com)
Herbert Wubben
7B1, Netherlands (email: hwubben@7b1.com)
Ingo Hartel
Swiss Federal Institute of Technology Zurich, Switzerland
(Ingo.Hartel@ethz.ch)
Roel van den Berg
Baan Development B.V., Netherlands (email: rvdberg@baan.nl)

Abstract

Enterprises cooperate more extensively with other enterprises in various forms. To enable the cooperation of multiple organizations in supply chains or virtual enterprises, configuration and set-up tools need to define the relations between partnering enterprises. In the one-of-a-kind industry, enterprises collaborate within a Virtual Enterprise (VE). For the definition of relationships among partners in a VE, standard project management 'tools' can be used. The relationships among partners in a VE are defined by eXtended Relationship Management (XRM) services. These services need to support a network view, viral effects, many-to-many relations, and 'configuration' of the integration infrastructure.

1. Introduction

One of the trends in the global market is the increasing cooperation among enterprises during the entire product life cycle. This is related to business drivers, such as the need for cost reduction, flexibility, focus on core competencies, and so on. The result is anything from a rather stable alliance between partners as in a supply chain to a more transitory cooperation as in a virtual enterprise.[1]

To enable the cooperation of multiple organizations in supply chains or virtual enterprises, the relations between these partners need to be defined. Configuration and set-up tools are needed to define inter-enterprise relationships, in addition to applications for monitoring, management, and optimisation of inter-enterprise business processes. Before processes within a supply chain or virtual enterprise can be executed, the relations between the various partners have to be defined by means of services for the set-up of these cooperation forms. These so-called eXtended Relationship Management (XRM) services can be used to configure a whole supply chain or virtual enterprise [2, 3][2]. Changing configurations of partners in a virtual enterprise necessitate dynamic configurations of both inter-enterprise business processes and the integrations with partners' enterprise applications. Both should be easily modified. XRM tools aim to provide this easy and effective reconfiguration of cooperating partners.

The objective of this paper is to define how relationship management services should support the set-up and reconfiguration of a virtual enterprise out of an enterprise network. The focus is on the definition and decomposition of an inter-enterprise project in order to obtain a more accurate picture of the distribution of work. Only then, it will be clear with what partners enterprises share specifications, on what basis they report progress, when they can start certain parts of the work, and so on. Irrespective of collaborative (project management) applications, the basis of collaboration is found in such a "cooperation structure".

---

[1] This chapter is largely based on [1].

[2] Please note that this paper adopts a slightly different interpretation of the term 'XRM' than Forrester in [2]. According to Forrester's definition, XRM applications manage, monitor, and/or optimize inter-enterprise business processes. Here, we restrict ourselves to the services that allow an enterprise to define relations between enterprises. In Forrester's definition, this is only part of XRM applications. This paper states that this functionality is in fact quite interesting for all collaborative applications, and should be made available to these applications as specialized services.

The next section provides some background about ‘collaborative commerce’, virtual enterprises, and collaborative project management. They are respectively the business model, the organizational structure, and one of the most obvious applications in which XRM plays a role. In section 3, the characteristics of XRM services are defined, and its place in an integration infrastructure is outlined. A case of a virtual enterprise in practice is presented in section 4. The paper gives a first glance of how the relations between the partners in that virtual enterprise can be modelled. A discussion closes this paper.

2. Background

2.1 Trend toward “collaborative commerce”

Nowadays, three major movements put additional requirements to enterprises: globalisation, outsourcing, and customisation. Organizations expand their scope to become really global, and differentiate their patterns of cooperation to encompass collaborative activities. Outsourcing and a focus on core competencies requires better collaboration, synchronization of processes, and appropriate handling of time and distance constraints. Customisation demands make-to-order manufacturing, better demand visibility, and more flexibility in general in order to execute faster and more efficiently. Closer collaboration with partners is required by globalisation, outsourcing, and customisation.

However, the trend towards closer collaboration is hindered by a number of factors. Current applications focus on single-tier environments, and provide limited support for complex partner relationships. Popular solutions which are available in the market today, such as Supply Chain Management applications, typically address cooperation within ‘paired relationships’. The latter means that companies are inclined to optimise the relationships with their closest suppliers and customers in a one-to-one fashion. Only the cooperation between an enterprise and its closest suppliers or customers is considered. The supplier’s suppliers and the customer’s customers are not taken into consideration. Although the logistics management of an enterprise towards its direct partners might be optimised, the overall supply chain is far from optimal.

Nevertheless, it is apparent that enterprises will have to adopt approaches such as “collaborative commerce” (or “c-commerce”) to remain competitive in most industry segments [3, 4]. Gartner defines ‘c-commerce’ as follows:

> “C-commerce is the collaborative, electronically enabled business interaction among an enterprise’s internal personnel, business partners, and customers throughout a trading community. This trading community can be an industry, industry segment, supply chain or supply chain segment.” [4]

Perhaps the most essential element of c-commerce is the extension of an enterprise’s knowledge assets to include those outside the enterprise. When intellectual capital is leveraged across enterprises, the benefits of c-commerce can be realized. Sharing intellectual capital and combining core competencies with partners are the major ingredients of collaboration.

C-commerce should be considered as a business model rather than a solution that can be offered by vendors. It benefits an enterprise by extending the enterprise’s visibility and cooperation throughout the value chain, thereby contributing to the realization of virtual enterprises.

2.2 Virtual Enterprises

Virtual Enterprises (VEs) are examples of implementations of the c-commerce business model. They are ‘set up’ from Enterprise Networks (see Figure 1). Such a network is a cooperative alliance of enterprises established to jointly exploit business opportunities through setting up virtual enterprises. The main purpose of a network is to prepare and manage the life cycle of VEs. It establishes mutual agreements among its members on issues such as common standards, procedures, intellectual property rights, and ICT, so that these time-consuming preparations can be significantly shortened when a customer request arises, and a VE is put in place. The network should be seen as a potential from which different VEs can be established in order to satisfy diverse customer demands. The network will seek out and await customer demands, and when a specific customer demand is identified the business potential is realized by forming a VE. Accordingly, compared to a virtual enterprise, a network can be perceived as a relatively long-term cooperation since it typically sets up multiple VEs. Conversely, the VEs have a more temporary nature.

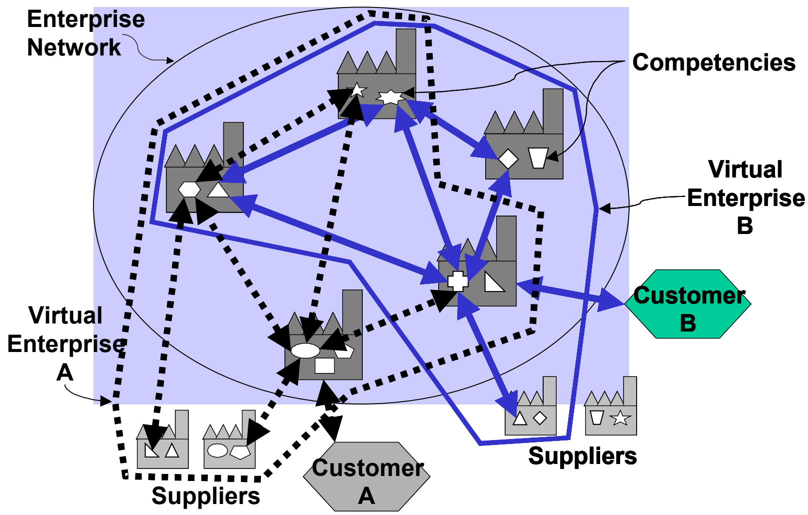


Figure 1. Enterprise Network and Virtual Enterprises.

A network is principally created based on core competencies and capabilities assigned from different cooperating enterprises. The network can therefore be characterized as a portfolio of core competencies that are available to realize products and/or services via VEs. This competence portfolio is dynamic in the sense that competencies can leave and join the network. In addition, a network can be characterized as a product-oriented network focusing on the strategically important, value adding partner competencies in the potential VEs, while typically excluding off-the-shelf suppliers [5].

A Virtual Enterprise is a temporary alliance of enterprises that come together to share skills or core competencies and resources in order to better respond to a business opportunity, and whose cooperation is supported by ICT (derived from [6]). Formation of the VE materializes through configuration of the core competencies and capabilities available in the network and possibly through inclusion of additional, required competencies provided by non-network participants, cf. Figure 1. Though being comprised by competencies from various partners, the VE performs as one, unified, and attuned enterprise. Hence its virtual nature. Accordingly, the business processes are not carried out by a single enterprise, but every enterprise is a node in the VE that adds some value to the product chain.

Please note that in the set-up of a VE from an enterprise network, the rather 'loose' relations that exist among enterprises in a network become 'solid' in a VE. In a network, there is no notion of a specific product or project. On the other hand, the VE is set up with a specific purpose in mind, i.e. a specific project delivering a specific product or service for a known customer. The configuration of the VE comprises the definition of the tasks/roles of individual enterprises and the relations between them. Concrete agreements are made regarding deliverables, schedules, payments, and so on, which are detailed in contracts and project plans.

2.3 Collaborative project management

This paper focuses on the one-of-a-kind industry. In this industry, enterprises participate in complex projects with significant durations and resource usages. These projects are split into many activities, deliverables, and milestones. They take place in a distributed environment within a temporary, product-driven, inter-enterprise structure (the virtual enterprise) and usually with geographically distributed sites (plants, construction sites, and so on).

Due to the characteristics above, collaborating enterprises are looking for reliable project plans with a shared model of project activities and requirements. That way, they can monitor the project through on-line access to activity progress, with real-time notification of events and 'alert' conditions, and impact evaluation for deviations based on changes of downstream activities. Among other things, this will enable enterprises to diminish risks, since unexpected events or deviations from the plan are reduced because of clear visibility between all activities. In addition, it will allow enterprises obtaining a higher level of adaptiveness and efficiency, responding faster to customer change requests, exploiting partner competencies from the network potential in a better way, and accelerating and controlling the flow of information during the project life cycle.

3. Extended Relationship Management (XRM)

3.1 Definition of relationships among partners in a VE

For the definition of relationships among partners in a VE, rather standard project management 'tools' should be used. These 'tools' are:

- *Work Breakdown Structure*, i.e. a deliverable-oriented grouping of project elements that organizes and defines the total work scope of the project. Each descending level represents an increasingly detailed definition of the project work [7].

- *Organisation Breakdown Structure*, i.e. a depiction of the project organization in which work packages are related to organizational units [7].

- *Project Network Diagram*, i.e. a schematic display of the logical relationships of project activities, which is always drawn from left to right to reflect project chronology. It is often referred to as a PERT chart [7].

- *Bill of Material*, i.e. a diagram presenting a hierarchical view of the physical assemblies, subassemblies, and components needed to fabricate a manufactured product. It contains the products that are required and must be produced, installed, assembled, and described in a hierarchical way.

The key point is the combination of these structures. A Work Breakdown Structure can be decomposed into more detailed activity structures, which eventually drill down to normal Bills of Material. The components in such a Bill of Material are provided by suppliers according to normal supply chain relationships. Tools are available to support these supply chain relationships. In addition, some project management tools support multi-enterprise Work Breakdown Structures. However, the combination is still unique.

3.2 Characteristics of XRM services

XRM services defining the relationships among partners in a virtual enterprise need to exhibit certain characteristics, namely they need to support a network view, viral effects, many-to-many relations, and 'configuration' of the integration infrastructure.

XRM services need to provide a *network point of view*. Enterprise applications such as ERP and SCM typically consider an enterprise or an enterprise plus its direct suppliers and customers. They adopt an enterprise view and an 'enterprise + tier 1' view respectively. However, XRM must go beyond the paired relationships and must create transparency across multi-tier boundaries. They take the whole supply chain or virtual enterprise and thereby the supplier's suppliers and the customer's customers into consideration. In addition, each individual virtual enterprise member has visibility into its position in the virtual enterprise, possibly restricted to one tier only, depending on the authorities it was given.

XRM services need to support "*viral effects*", so that partners can introduce their own suppliers and customers. While XRM services are sponsored and hosted by a single firm (usually a main contractor or dedicated service provider), partners can pay to extend the services to their other partners and customers. New partners, such as sub-subcontractors, can be integrated into the cooperation structure without central registration and administration by the main contractor. The inter-enterprise project is decomposed in a decentralised manner, and new levels and relations can be introduced without the explicit approval of the main contractor. The cooperation structure is expanded by rather autonomous actors, and the whole virtual enterprise can be set up more efficiently this way. Although the similarity of this phenomenon with a virus might be debatable, this paper uses the original term as introduced by [2].

XRM services need to support *many-to-many relationships*. In supply chains with rather standard products, a component manufacturer supplying to multiple OEMs, wants to give access to its production schedules to all OEMs. However, a building contractor hosting XRM services and collaborative project management applications does not want its subcontracted engineering firms to set up virtual enterprises with other, competing building contractors.

XRM services need to '*configure*' *the integration infrastructure*, i.e. regardless of where a partner is located in the virtual enterprise, it will be able to set security, encryption, alerts, permission and data access to enterprises further up or complementary in the value chain according to the defined cooperation structure. This way, information flows can be orchestrated.

3.3 XRM in the integration infrastructure

XRM is seen as one of the services provided by an integration infrastructure. Collaborative applications are positioned on top of the infrastructure. Van Busschbach *et al.* describe the capability stack of services needed for the complete integration backbone [8]. It consists of four functional layers (from bottom to top):

- *Connectivity Layer*, linking applications in different programming languages, databases, middleware, protocols, and other technologies.

- *Transformation Layer*, reconciling differences in data and functions on a functional level.

- *Routing Layer*, providing dynamic behaviour based on the contents of a message, to be configured by a business analyst.

- *Process Management Layer*, allowing the end user to dynamically trigger, execute and monitor business processes.

XRM services reside in the Process Management Layer. They use "yellow pages" about the enterprise network, which includes for example information about competencies of potential partners. In addition, documents such as general agreements, procedures, templates, and so on, can be stored for later use during the set-up and operation of a VE. XRM services model enterprises and their relationships in one or more projects based on Work Breakdown Structures, Organisation Breakdown Structures, Project Network Diagrams, and Bills of Material. These models form the basis for monitoring and management of the business processes in virtual enterprises by collaborative project management applications. The business processes managed in the Process Management Layer dictate the flow of information between applications and other data sources. Perhaps the ultimate goal of this layer is to provide inter-enterprise workflow management services that support multiple dynamic workflows crossing organizational boundaries.

4. An industrial Case study

Within the context of the GLOBEMEN project, XRM services have been developed and deployed as part of the C-Project prototype [9]. Though these services do not entirely implement the ideas as presented above, the basic principles behind the XRM services and especially their characteristics are identical. The services have been developed with the following reasoning in mind: enterprises close contracts; contracts contain obligations; obligations are linked to deliverables; deliverables can be organized in a project; every deliverable is related to a matched deliverable if this deliverable is subcontracted; and every planned deliverable is related to an actual deliverable.

The case is that of a paper mill producer (*PMP*), its customer (*C*), and one of its subcontractors (*SC*). *C* is customer of *PMP*. Both enterprises agreed on the delivery of (a part of) a paper machine by *PMP* to *C*. As a customer, *C* requests to be reported on the progress of the part of the paper machine that is developed by *PMP*.

PMP organizes the delivery of that paper machine as a project, and decomposes the paper machine in three parts (Conveyor, Wrapper, and Rolls) for internal project management and subcontracting of one part. The Rolls will be constructed by another company (*SC*) and it is agreed that *SC* will report progress on the total and on three deliverables/activities for the Rolls: Design, Build and Installation. For all deliverables, progress is being registered on actual deliverables that realize planned deliverables. Figure 2 shows the accompanying 'cooperation structure'. Note that this picture seamlessly integrates a Work Breakdown Structure with a sales order for a deliverable and a purchase order with one deliverable and three sub-deliverables.

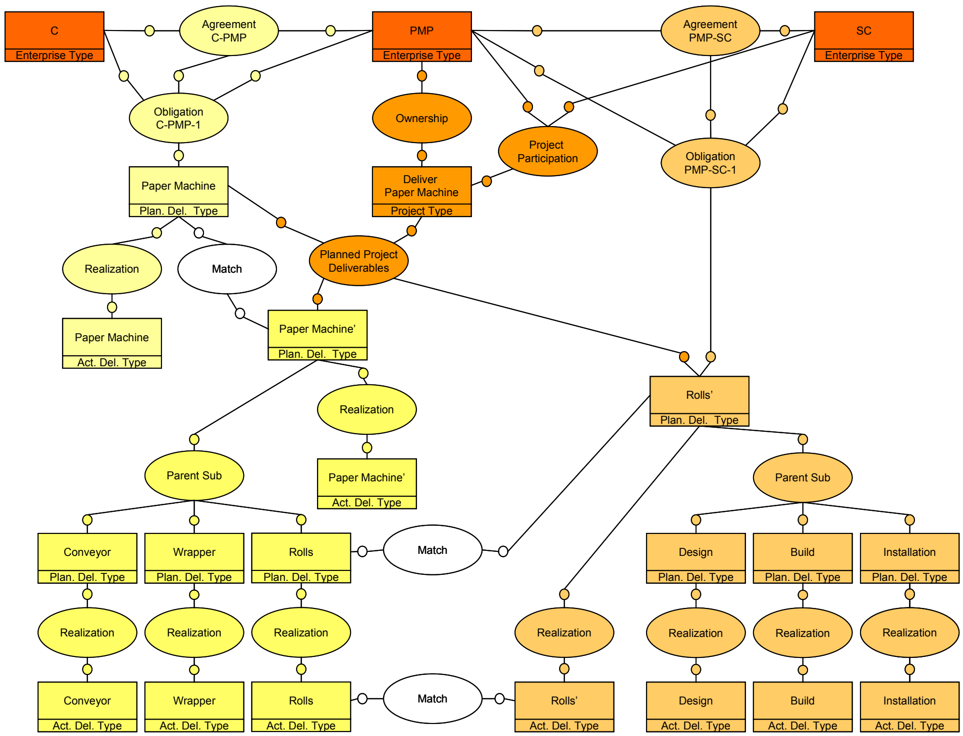


Figure 2. Cooperation structure.

SC reports the progress on the deliverables Design, Build, and Installation, and Rolls'. These instances are also in the scope of *PMP*, since *PMP* and *SC* have agreed on the deliverables and their structure. Therefore, it is possible for *PMP* to track the progress. Note that *SC* does not (yet) organize the delivery of the Rolls as a project. *SC* could define the parts of Rolls which are subcontracted again, thanks to the viral capabilities of the XRM services.[3]

PMP is able to track progress on a subcontracted part of the Paper Machine': Rolls'. *PMP* also tracks and reports progress on Paper Machine' and its sub-deliverables internally, and is able to report progress on the Paper Machine to customer *C*.

[3] The quotation mark is used to make a difference between two representations of the Rolls deliverable. The representation without quotation mark is the representation that both C and PMP agree on. The representation with quotation mark is the representation that both PMP and SC agree on.

5. Discussion

XRM services can be found in various forms in collaborative applications. After all, a cooperation can only be defined and detailed with XRM-like services. The cooperation structures and XRM characteristics mentioned in this paper are mostly based on experiences with collaborative project management applications in the one-of-a-kind industry. Other applications, e.g. focused on short-lived VEs such as virtual service enterprises, which fulfil services like maintenance, inspection or repair collaboratively, might need simpler cooperation structures [10].

This paper presents the first results obtained with XRM services within GLOBEMEN. Further research will focus on the genericity of the identified structures within the one-of-a-kind industry and on the genericity of the characteristics in XRM services. A prototype of an integration infrastructure realizing the desired XRM characteristics is also planned.

References

1. Zwegers, A., Wubben, H. & Hartel, I. (2002). Relationship Management in Enterprise Networks. Knowledge and technology integration in production and services – Balancing knowledge and technology in product and service life cycle. V. Marik, L. M. Camarinha-Matos & H. Afsarmanesh (eds.). Kluwer Academic Publishers, Boston (USA). Pp. 157–164.

2. Radjou, N., Orlov, L. M. & Child, M. (2001). Apps For Dynamic Collaboration. The Forrester Report. Cambridge, MA: Forrester Research.

3. Forrester. (2002). Various documents on URL: http://www.forrester.com.

4. Gartner. (2002). Various documents on URL: http://www.gartner.com.

5. Berg, R. van den, Hannus, M., Pedersen, J. D., Tølle, M. & Zwegers, A. (2000). Evaluation of state of the art technologies. Globemen EU (IST-1999-60002) deliverable D411.

6. Camarinha-Matos, L. M. (2000). Trends in virtual enterprise infrastructures. Proceedings of WCC2000/ITBM 2000 – IFIP World Computer Congress/ International Conference on Information Technology for Business Management. Beijing, China, 21–25 Aug 2000.

7. PMBOK. A guide to the Project Management Body of Knowledge (PMBOK® guide). (2000) Project Management Institute, Newtown Square.

8. Busschbach, E. van, Pieterse, B. & Zwegers, A. (2002). Support of Virtual Enterprises by an Integration Infrastructure. Collaborative Business Ecosystems and Virtual Enterprises. L. M. Camarinha-Matos (ed.). Kluwer, Boston (USA). Pp. 311–326.

9. Berg, R. van den, Wubben, H. & Zwegers, A. (2002). Towards a Tool for Inter-Enterprise Delivery Management. This book.

10. Hartel, I. & Burger, G. (2001). Virtual Service Enterprise – A Model for virtual collaboration in after-sales service in the one-of-a-kind industry. Proceedings of the IMS Forum, October 2001, Ascona, Switzerland.

Virtual Organisations in the Sales and Service Life-cycle Phases of a One-of-a-kind Product

Kim Jansson, Iris Karvonen and Martin Ollus
VTT Industrial Systems, Finland (e-mail: kim.jansson@vtt.fi)
Ingo Hartel and Gerhard Burger
Swiss Federal Institute of Technology Zurich – Center for Enterprise Sciences (ETHZ-BWI), Switzerland (e-mail: ingo.hartel@ethz.ch)
Yoichi Kamio
Toyo Engineering Corporation, Japan (e-mail: kamio@ims.toyo-eng.co.jp)

Abstract

Companies involved in the business of delivering one-of-a-kind products are facing new challenges. Efficient sales and service to increasingly complex products is becoming a key success factor. The sales and service functions provided must meet customer demand for qualified and quick operation support, independent of time and distance. The IMS GLOBEMEM project has developed the Virtual Enterprises Reference Architecture (VERA). The developed concept of Quotation Virtual Enterprise and Service Virtual Enterprise are special cases of the model. This paper takes an organisational view and explains the quotation virtual enterprise and the service virtual enterprise concepts and associated characteristics and features.

1. Introduction

Customer-relationship development has become one of the most important development actions in business. Due to globalisation, customers have nowadays more choices than before when buying products or services, which is the reason why organisations are focused on managing and developing relations with their customers. Customer Relationship Management (CRM) is a business strategy aimed at organising and handling the business actions connected with customer relationships through the entire life-cycle of partnerships with customers. It requires a customer-centred business philosophy and a culture that supports effective marketing, sales, and service processes.

The trend in one-of-a-kind business is towards internationalisation. Customers are spread over global markets. It is thus increasingly difficult and expensive to manage customer relations. Enterprises, and in particular small companies, that manufacture one-of-a-kind products often focus on engineering, procurement, and production/construction, while often neglecting marketing, sales and after-sales activities. Since these often have very limited human and financial resources, a major problem is how to organise the sales process and the delivery of after-sales services to the customer site. Interaction with the customer is high during these phases. New organisational structures are needed. The concept of Virtual Organisations is a form of collaboration that can be used to respond to CRM requirements.

The focus of this paper is on the sales and service life-cycle phases, which are in both ends of the product life-cycle. This paper presents the concept of Virtual Enterprise (VE) and different forms of VEs as an alternative solution to above-mentioned challenges.

2. Sales and service in the product life-cycle

Management of global marketing and distributed sales as well as remote services and operation maintenance support involves interaction with customers and users. The ICT systems supporting these important functions are building blocks for a larger Customer Relations Management system. Although the mentioned functions and life-cycle phases are at different ends of the product life-cycle, there is a strong need for integration of information between phases. Figure 1 shows the position of the phases in the product life-cycle.

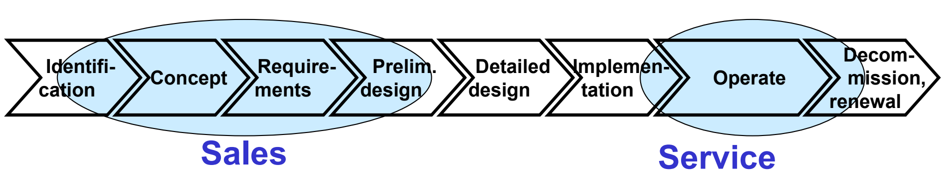


Figure 1. Sales and service in the product life-cycle.

The objective of sales is to receive orders from customers. For one-of-a-kind products the following activities are needed: market and technology research, analysis of the scope in terms of profitability for the contractor and the customer, pre-qualification of potential tender partners, preliminary design of the product, analysis of the required resources and the planning of the implementation, as well as bid preparation.

Service is located at the other end of the product life-cycle. Service includes different modes of activity: continuous monitoring and operation support, occasional and fast repair and recovery, planned maintenance and inspection, and improvement/renewal activities.

3. Virtual Enterprise

One of the trends in the global market is for enterprises to co-operate more extensively with other enterprises during the entire product life-cycle. This is related to business drivers, such as the need for cost reduction, flexibility, focus on core competencies and corresponding outsourcing. The result is anything from a rather stable alliance between partners as in a traditional supply chain to more transitory co-operation as in a Virtual Enterprise.

3.1 A short introduction to VERA

According to the GLOBEMEN view, the VE Framework contains logical, recursive relationships between the network entity, the VE entity, and the product entity [5]. Each of these three entities are represented by a life-cycle describing possible phases an entity can be in throughout its life span from identification to decommission. This means that a network can create VEs in its operational life-cycle phase and, correspondingly, that a VE can create one or more products and/or services in its operational phase. In other words, the life-cycle activities of the VEs are prepared in the network phases up to and including implementation. Likewise the life-cycle of the product or service is prepared and subsequently created in the operation phase of a VE. It should in this connection be emphasised that a network can establish several VEs, just like a VE can produce several products or services. The concepts of VE and VERA are explained in detail in other articles of this book.

3.2 Quotation Virtual Enterprise and Project Virtual Enterprise

Different VE can be generated for various phases in the product life-cycle. The types of virtual enterprise can be categorised in four groups [4].

The **Quotation Virtual Enterprise (QVE)** investigates the customer's requirements for a product, such as a production facility, provides consulting so that the requirements are satisfied, and creates a proposal. An alternative name, consulting virtual enterprise, is also used with the same meaning. The **Project Virtual Enterprise (PVE)** builds the product or the production facility on the basis of the proposal. Usually, the customer of these two virtual enterprises is a member company of the **Operation Virtual Enterprise (OVE),** which is the owner of the production facility. This virtual enterprise uses the production facility to produce the planned products, e.g. chemicals. The **Service Virtual Enterprise (SVE)** offers services such as maintenance support, repair or operation support to each company of the virtual operation enterprise

3.3 Characteristics of QVEs and SVEs

This paper focuses on the more short-term VE supporting sales and service. The quotation virtual enterprise and the service virtual enterprise have several common dominators. The characteristics of these two types of VE are summarised in Table 1.

Table 1. A comparison between characteristics of VEs for sales and service.

Characteristic	Quotation Virtual Enterprise	Service Virtual Enterprise
Trigger to set up	Extend to new markets	Time and cost saving
Time required to set up the VE	Short/medium	Short
Periodical and repetitive need for VE set-up	Small	Medium
Lifetime of the VE	Short/medium	Short or long (depending on the type of service)
Number of network partners	Large	Large
Number of partners	Small	Small
Need for local partners	Medium	High
Overlapping	Partial	Small
Need to involve customer	High	High
Information and communications technologies	No resources for implementation	No time for implementation
Information flow direction	Downstream	Up- and downstream
Information content	Dynamic, uncertain, large	Complex, large

The following features of the quotation virtual enterprise and the service virtual enterprise have been identified. The analysis contains common features as well as differences.

Trigger to set up: The triggers to set up a QVE or SVE are in most cases the ambition to provide localised sales and service to remote customers. Traditional sales and after-sales methods do not fulfil customer needs in distant markets. In service, the cost of plant downtime does not allow for the travel time of a service technician. Consequently, world-wide after-sales services require a new organisation in order to enable quick and reasonably priced service activities. Knowledge of local conditions, trends and specialised requirements is an advantage. Sales and service in a distributed environment generate additional triggers for network creation. A sales network may be needed to extend the market to new regions or customer groups. Offering service to the customer means extending the current products with new features, the implementation of which requires additional knowledge.

Time required to set-up the VE from the network. In sales, a fast reaction to emerging customer needs is an important advantage. In comparison, a short set-up time is a critical attribute for repair-service networks. This is because failures in the operational phase of the product may prevent its use and thus cause high economic losses. An additional challenge is that failures occur unexpectedly and thus cannot be scheduled. Consequently, the network should be ready to create (roll out) service virtual enterprises at short notice – in what amounts to hours not days. Proactive maintenance should nevertheless be planned carefully over time.

Periodical and repetitive need for VE set-up: The same one-of-a-kind product is not usually offered many times to the same customer. However, the same type of product can be proposed to the same type of customers and also to other customers. Repetitive set-up is typical for many planned service tasks, for example preventive maintenance. Though the activities required are not exactly the same in each case, the repeatability enables an extensive re-use of the VE design and planning. The possibility to foresee the need for the planned service action well beforehand also helps the partners to plan and allocate their resources.

Lifetime of the VE: The period of time between roll-out and termination of the service virtual enterprise is (hopefully) short for acute problems and repair services. The lifetime should be calculated in hours rather then in days. In the case of proactive maintenance, the lifetime may be long. Creating a proposal for a large plant may in certain cases be a very lengthy process.

The **number of network partners** that, depending on the specific market opportunity, band together to form the various quotation or service virtual enterprises. In order to obtain a global reach or a large geographical coverage, the number is large.

The **number of partners** in the VE for sales or service is usually lower than for delivery, as the sales or service tasks are most often not as extensive as deliveries. In sales there exists an opportunity for standby and extension when going from quotation VE to delivery VE.

The **need for local partners** is high when a fast reaction time for services or sales and marketing knowledge of local cultures, politics, financial systems and customs is needed. Some markets may even require a local supplier by law.

Overlapping: Virtual enterprises supporting the different life-cycle phases are partly overlapping. The project virtual enterprise usually includes the parties from the QVE, which is extended with additional partners. The additional partners can be manufacturers of standard goods or local contractors. The service virtual enterprise may be established or requested by the operational virtual enterprise.

Need to involve the customer: No sales without a customer! This is central both to the QVE and SVE. The interaction with the customer is the most intensive in sales and service.

Information and communication technologies: When the time to roll out the VE is short there is no time to implement ICT systems. Everything has to be in place already in the network infrastructure from which the VE is created. Standards and agreed formats should be used.

Information flow direction: The product-related information as a part of the sales information is the natural starting point. The information is communicated downstream throughout the life-cycle. In service it is important to acquire customer data to perform service requests. Additionally, it is necessary to generate information feedback from the operation of the product to sales.

Information content: In the early phases of the product life-cycle the information is often loose and imprecise. In subsequent steps of the life-cycle the amount of information increases exponentially. The amount of information needed in order to repair a complex product can be extremely high. The information flow in both up- and downstream directions may reside on different media. Sophisticated tools are needed to manage it in a fast and reliable way.

4. Roles of Partners/Participants in QVEs and SVEs

The participating enterprises in networks and VEs in various sales and service phases are listed below. The list is a collection of the enterprises involved in the industrial cases of GLOBEMEN. The enterprises included are:

- The **customer,** which usually is the end-user of the product.
- The **project contractor/network manager**: the enterprise that takes total responsibility for the product vis-à-vis the customer in the delivery phase. The project contractor is in a central position during sales and delivery. It usually operates as the Network and VE manager for tendering and delivery. Quite often it also acts as the manager of the marketing network; another possibility is that it has a strategic partner managing the marketing activities. The project contractor's activities more often than not extend from the marketing and sales to operation support and service. This means that the project contractor may also have a managing role in the operation support. Thus, it has the major role and potential in communicating information upstream and downstream in the product life-cycle. For example, marketing may utilise information about the improvement and renewal needs of the customer.

- **Sales agents and offices**: these only have a role during the sales and marketing phase. They may operate as partners in the marketing network of the project contractor. Another possibility is that they manage the marketing network as a strategic marketing partner of the project contractor.
- **Subsidiary companies** of the enterprise may operate on a specific geographical area or specific fields. They may participate in sales but also in delivery and service.
- **Strategic manufacturing partners** of the project/main contracting enterprise are companies that have the closest long-term relationships with the contracting enterprise. They operate together with the project contractor in most of the customer deliveries. It is quite clear that they should take part also in other phases, not only in the delivery.

- **Subcontractors, suppliers and consultants** operate in the networks of the project contractor for tendering, delivery or service. The sub-suppliers, furthermore, operate on a lower level in the networks of the subcontractors, suppliers and consultants. Thus they are necessarily not visible to the project contractor. However, they must be taken into account in integrating and developing the inter-enterprise processes.
- **The service manager** may take responsibility for the service and operation support vis-à-vis the customer. Quite often the same company may offer both the delivery and the operation support and service. The customer may also have several service providers for different tasks.
- **Service partners** operate in co-operation with the service manager for operation support and service tasks. They may partly be the same as the subcontractors in the delivery.
- **The system integrator** provides ICT services for VEs and networks.

5. Conclusions

The rapid development of information and communication technologies has enabled new forms of co-operation. The concept of the virtual enterprise has been elaborated in the GLOBEMEN project. The quotation virtual enterprise and the service virtual enterprise are specialised forms of virtual enterprises, which are characterised by their fast set-up and short duration. The described organisational forms require extensive use of information and communication technology. The appropriate ICT infrastructure must be in place in the networks to allow for fast roll-out of the virtual enterprises. New markets are opening up in the one-of-a-kind industry where even small and medium-sized enterprises can enter into networks with their specialised skills. Existing sales and service strategies must be reviewed and redesigned. Collaboration with other companies demands a minimal measure of trust and accommodation together with a mature ICT infrastructure.

References

1. Jansson, K., Ollus, M. & Karvonen, I. (2001). Methods and IT Models to Support Information Management in the Sales and Service Life-Cycle Phases of a One-of-a-kind Product. Automation 2001, Automation days, Helsinki, Finland.

2. Karvonen, I., Jansson, K., Ollus, M., Hartel, I., Burger, G., Anastasiou, M., Välikangas, P. & Mori, K. (2002). Inter-enterprise eCollaboration in Sales and Service of one-of-a-kind products. In: B. Stanford-Smith, E. Chiozza & M. Edin (Eds.). Challenges and Achievements in E-business and E-work. IOS Press/Ohmsha, Berlin, Germany. Pp. 1388–1395.

3. Karvonen, I. (2000). Management of one-of-a-kind manufacturing projects in a distributed environment. Espoo, Finland. VTT Research Notes 2044. 54 p.

4. Hartel, I., Billinger, S., Burger, G. & Kamio, Y. (2002). Virtual organization of after-sales service in the one-of-a-kind industry. In: L. M. Camarinha-Matos (Ed.). Collaborative Business Ecosystems and Virtual Enterprises. Kluwer Academic Publishers, Boston, USA. Pp. 405–420.

5. Tølle, M., Bernus, P. & Vesterager, J. (2002). Reference models for virtual enterprises. In: L. M. Camarinha-Matos (Ed.). Collaborative Business Ecosystems and Virtual Enterprises. Kluwer Academic Publishers, Boston, USA. Pp. 3–10.

6. Hartel, I., Sonderegger, S., Kamio, Y. & Zhou, M. (2002). The Information Roadmap of Virtual Enterprises. In: B. Stanford-Smith, E. Chiozza & M. Edin (Eds.). Challenges and Achievements in E-business and E-work. IOS Press/Ohmsha, Berlin, Germany. Pp. 1380–1387.

7. GLOBEMEN (2000–2002). Global Engineering and Manufacturing in Enterprise Networks. IMS 99004/ IST-1999-60002, http://globemen.vtt.fi

A Reference Model for Collaborative Service

Ingo Hartel and Gerhard Burger
Swiss Federal Institute of Technology Zurich – Center for Enterprise Sciences (ETHZ-BWI), Switzerland (email: Ingo.Hartel@ethz.ch)
Yoichi Kamio
Toyo Engineering Corporation, Japan
(email: kamio@ims.toyo-eng.co.jp)
Mingwei Zhou
CSIRO Manufacturing & Infrastructure Technology, Australia
(email: Mingwei.Zhou@csiro.au)

Abstract

Small and medium-sized enterprises have to deal with increasing requirements on customer services. Having globally spread customers these enterprises are not able to decrease their service delivery times and costs on their own and, as a consequence, they have to team up with external partners to build up service cooperations. To support this development a model will be described to enable these enterprises fulfilling services collaboratively by using the basic concept of the virtual organization.

1. Introduction

Global manufacturers are facing an increasing challenge in offering adequate and timely fulfilment of customer services (see [1]). This is particularly urgent for those small and medium-sized enterprises (SMEs) serving the one-of-a-kind industry, as they find it difficult, if not impossible, to maintain their own worldwide service networks at reasonable costs. One approach is to collaborate by selecting cooperating network partners based on their individual core competencies during the fulfilment of various after-sales services.

However, setting up and maintaining such a network organization, as well as developing and implementing a successful business process for global collaboration, are often beyond the knowledge and capacity of a SME. Therefore, a reference model including guidelines to form inter-enterprise service collaboration is essential and can be critical for its success.

2. Virtual Organization

In the search for organization forms for the twenty-first century, the virtual organization concept is beginning to make headway as a dynamic structural pattern. Under this model, organizational units (also called as virtual enterprises) are created, restricted to the primary business purposes and thus, this structural simplicity allows maximum economic efficiency.

A virtual enterprise can briefly be characterized as a short-term inter-enterprise cooperation where individual enterprises join core competencies in order to establish a value chain configured exactly to meet a specific customer demand. When the customer demand has been fulfilled, the virtual enterprise is decommissioned [2].

For the one-of-a-kind production, different types of virtual enterprises can be set up based on their deliverables (see [3]): The **quotation virtual enterprise** investigates the customer's requirements for a product (such as a production facility), provides consulting so that the requirements are satisfied, and creates a proposal (e.g. quotation). The **project virtual enterprise** engineers and builds the product on the basis of the proposal. Usually, the customer of these two virtual enterprises is a member company of the **operation virtual enterprise**, which is the user of the production facility. This virtual enterprise uses the production facility to produce the planned products (chemicals, for example). During the use of the production facility the **service virtual enterprise** offers services such as maintenance support, repair, or operation support to the plant owner or operation virtual enterprise.

In addition to the described deliverables the four different type of virtual enterprises and networks have different characteristics like for example [3]: Length of time required to build the virtual enterprise, lifetime of the virtual enterprise, number and necessary competencies of network partners, number of partners in the virtual enterprise, used information and communication technologies and applications.

This paper will now focus on the service virtual enterprise type. This kind of virtual organization usually consists of three main entities: The service network of all potential network members, the service virtual enterprises (SVEs) of selected members, and the services as a product offered by the SVEs. To provide a structural arrangement and to capture the characteristics of these entities, the Virtual Enterprise Reference Architecture (VERA) has been developed in the IMS GLOBEMEN project (see [4] and [5]). VERA is based upon the GERA component (modelling framework and associated concepts) of GERAM [6].

Figure 1 shows that the network in its operational phase creates SVEs and a SVE carries out some service product life-cycle phases (indicated by the double arrows). Each of the three entities is represented by use of the three dimensions of the GERA modelling framework: The life-cycle dimension, the genericity dimension, and the modelling view dimension. More elaborate description of VERA dimensions can be found in [7, 8].

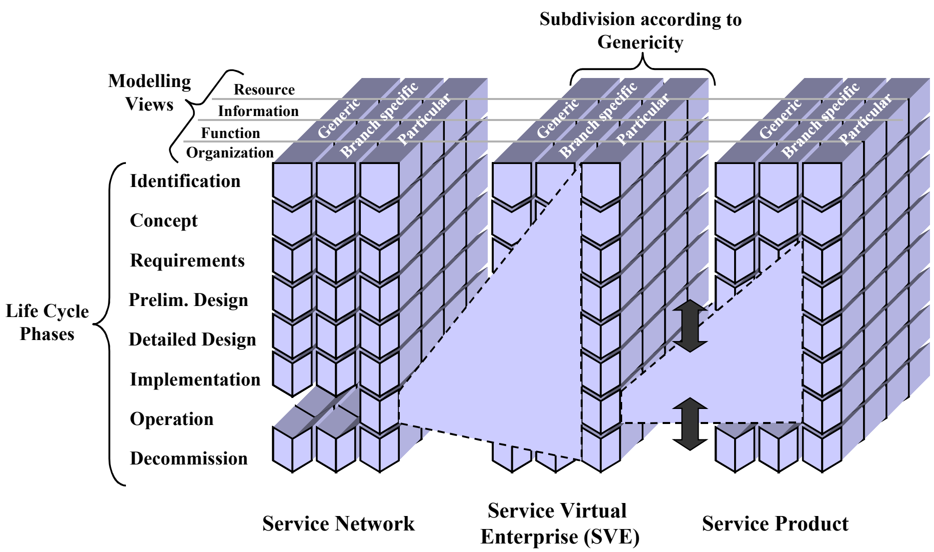


Figure 1. Virtual Enterprise Reference Architecture (VERA).

A **service network** in the operation phase has an array of service products, which they can offer to customers. A **service product** consists of one or many service modules, which each targeting different customer needs through its single or combined characteristics. A more elaborate description of service products and their configuration from service modules can be found in [3]. If a customer reports a problem, suitable network members will be selected and a **service virtual enterprise** will be set up that can best deliver the service product as defined by the given customer requirements.

3. Collaborative Service

The reference model for collaborative service introduced in this paper describes the activities that are pertinent during the life-cycle phases of the three different entities described above. These life-cycle phases encompass all activities from identification to decommissioning of the entity (see chapter 3.1). To decrease the apparent complexity the reference model uses the view concept from GERAM that allows the operational process to be described as an integrated model, but to be presented to the user in different sub-sets, in so called modelling views (see chapter 3.2).

3.1 Life-cycle

This chapter briefly describes a procedural view of life-cycle activities necessary for setting up a service network organization and its service virtual enterprises. The procedure was designed having the specific business model in mind, which allows companies to collaboratively fulfil after-sales services. In other business models the sequence of described activities might be different.

In the reference model the life-cycle is modelled in various level of detail. The top-level view helps to grasp the entire content and illustrates the procedure for setting up a network organization and its SVEs and finally, fulfiling the customer demand by providing the service product. Based on this the following level shows in more detail, i.e. what has to be done in the different life-cycle phases. As an example Figure 2 illustrates on the left side, the overview of the business process and on the right side the depiction of the set up network process in detail.

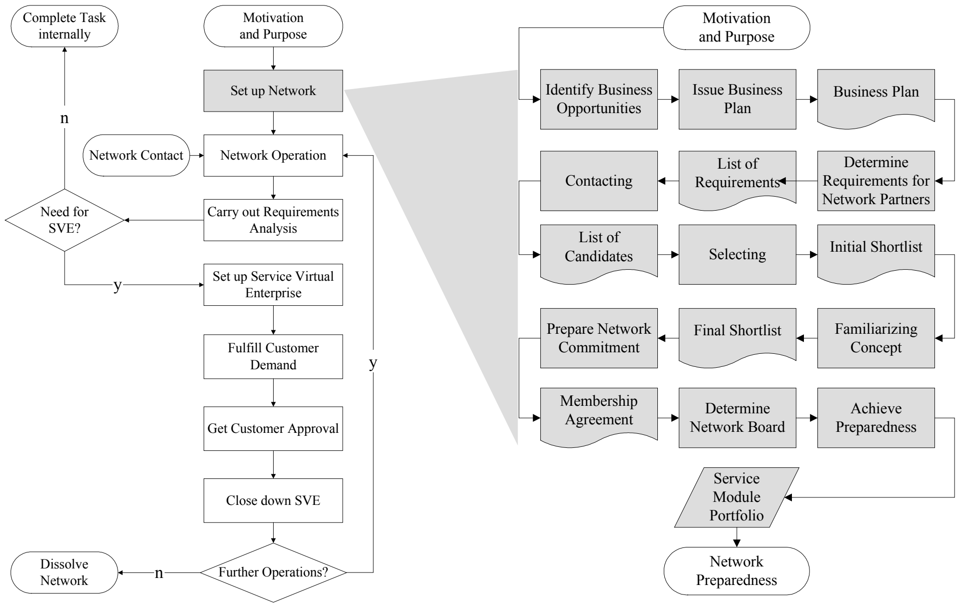


Figure 2. A top-level view and a detailed view of set up network process [9].

3.2 Modelling views

Modelling views contain a subset of facts present in an integrated reference model, allowing the user to concentrate on relevant questions during modelling of its service organization. The following subchapters aim to give an overview of the four different modelling views (organisation, function, information and resource), which are used in the reference model.

3.2.1 Organizational view

This view describes the organizational structure of the relevant entities and the roles that exist in theses entities with their responsibilities and tasks. The main organizational entities of a virtual service organization are the production facilities delivered from the one-of-a-kind producers, the service network, the resulting service virtual enterprises and the delivered service products.

Production facilities can be characterized by their locations, type of installed machines and installations, production processes, history of services, and modifications since production start up. The size of the owners may range from SMEs with one production location to large corporations with a number of globally distributed locations. The production facility can be made up of machines or installations purchased from one or more one-of-the-kind producers.

The **service network** consists of independent enterprises that are working together to exploit a particular service opportunity by jointly offering **service products** to the market, based on common interests and partnership-oriented business relations. Network members can be one-of-a-kind producers and a multitude of independent service companies, suppliers, vendors or ICT infrastructure providers. The distinctive features between them are competencies, technical aids and available ICT, locations, and capacities. In addition the one-of-a-kind producers are characterized by size, branch, and position in the value chain. Thus, networks can be comprised of one-of-a-kind producers of the same or different sizes and in the same or different branches. As to position in the value chain, company activities can be at the same level (so-called horizontal) or downstream or upstream levels (so-called vertical). Collaboration among companies within the same branch, and thus potential competitors, is necessary when a critical mass is required in global markets in order to gain an advantage over local competitors.

The **service virtual enterprise** is formed of selected network members. Together these network members can fulfil the specified service. The service is divided into different tasks. Each network member in the SVE is responsible for performing a part of these tasks in accordance with its competencies and available technical aids and ICT. Sometimes collaboration is necessary in order to perform a task, such as, for example, when a local service company repairs a machine by installing new spare parts but does not have the know-how to reset machine controls after completion of the repairs. Under the remote direction of the one-of-a-kind producer, however, the service company can do the resetting. Here the network members depend upon modern ICT for coordination. Communication can be very efficient using video conferencing and wearable computers, for example.

The reference model distinguishes seven **roles**, six of them are active and one is auxiliary. The active roles include the customer, the network or project initiator, the network members, the project board, the network board and the audit team. The information system of the network organization plays a supporting role facilitating the information exchange between the active roles. More elaborate description of the roles can be found in [9].

If there is more than one one-of-a-kind producer in the service network, the question of **responsibility for tasks**, like network operation, contacts with customers, evaluation of potential new network members, etc. must be clarified. These management tasks are normally part of the network board and audit team role. Small and medium-sized one-of-a-kind producers have based on their size very oft not the financial and personal resources to fulfil these roles in a sufficient way. If only this type of enterprises form a network then it can be useful to outsource management tasks to an external company and financial tasks to a bank or insurance company. Some possible networks variants are:

- *External:* None of the one-of-a-kind producers is responsible for tasks like network operation and customer contacts. Here an external company takes on these tasks.
- *Single:* One of the one-of-a-kind-producers takes over the responsibility for the management of the network. The company may exercise this role for the entire lifetime of the network or turn responsibility over to another one-of-a-kind producer at a later time.
- *Mutual:* All of the one-of-a-kind producers in the network share the tasks of the network management.

Further differentiation of networks could lead to hybrid forms. For instance, the one-of-kind-producers might divide up the various tasks. Each would be responsible for particular part-tasks. Hierarchical structures are also possible. Responsibilities might also be divided up according to market or customer segmentation.

3.2.2 Functional view

The functional view represents the hierarchical structure and the relations of functionalities (activities). In functional models activities related to the management and operation of the virtual service organization are represented, as well as support activities. An example of a function model for the SVE entity is illustrated in Figure 3. It is possible, that the same activity has to be fulfilled several times, e.g. in different life-cycle phases of one entity or in life-cycles of different entities.

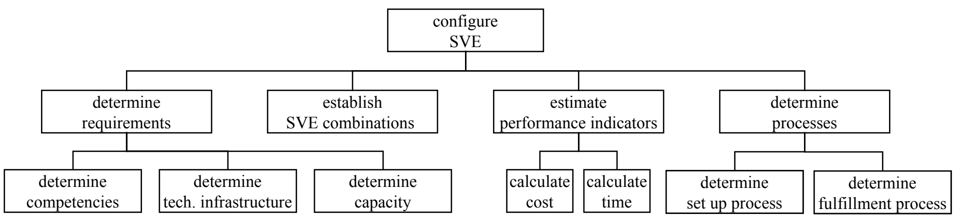


Figure 3. Function model for service virtual enterprise configuration.

Based on the presented function model for the service virtual enterprise configuration the following methodology to support the configuration process has been developed (see Figure 4):

The goal of enterprise configuration is to set up the SVE that can best deliver the service as defined by the given requirements. Based on the identified problem of the customer, the service needed is broken down into individual tasks and the competencies and aids that these tasks will require are identified. Taking the network members' capacities into account, possible SVE combinations to fulfil the tasks are worked out. For each of these combinations, costs and time required for service fulfilment are calculated based on the location of customers and network members. The optimal configuration of the SVE is finally determined on the basis of the given costs, time, and other restrictions using a solution procedure such as a heuristic, decision tree, or complete enumeration The division of tasks, the temporal process of collaboration, and the required ICT are documented in a process representation (such as an organization-oriented process diagram) and turned over to the companies involved. The diagram is constructed through the aid of a process and ICT library that contains standard processes and possible ICT combinations.

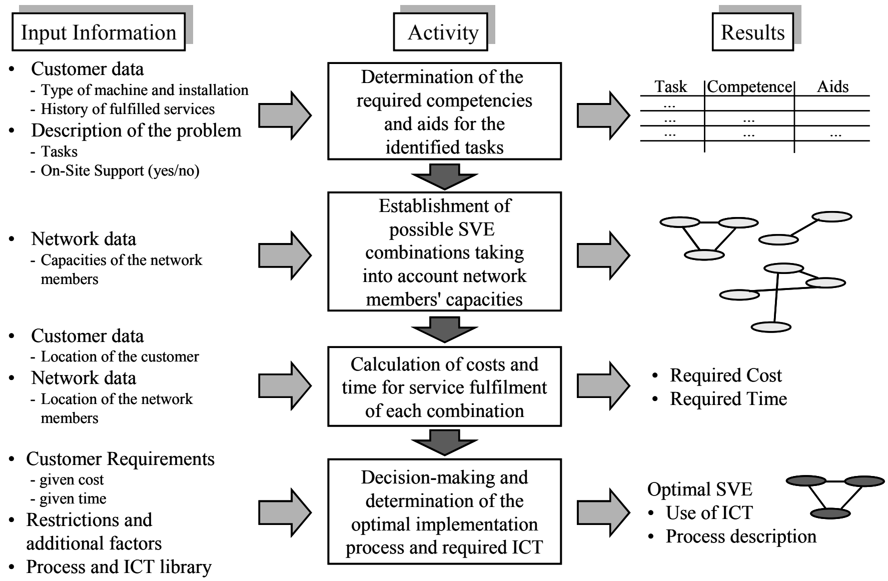


Figure 4. Methodology for configuration of service virtual enterprises.

3.2.3 Information view

The information view is describing the content and flow of information, which is created, shared, used, modified and disposed along the life-cycle of the different entities of a virtual service organization. Junction points of information exchange among the defined network roles are indicated and key information occurring during the set up and operation of a service network and SVEs are structured and illustrated as different information objects. These information objects can be used to support the design of a data schema for an information system. Figure 5 presents the information exchange between different roles during the set up of the network (**P** means information provider, **R** means information receiver).

Each information object is described in further detail and the information content presented. The business plan and the service module portfolio stand representatively for the entire collection of information objects (see Figure 5).

Service Module Portfolio

Configuration
- Components
- Organisation
- Processes

Classification
- General Support
- Self Support
- Remote Support
- On-Site Support

Lifecycle Phases
- Pre-Sales
- Sales
- After-Sales

Specification
- Keywords
- Description
- History

Business Plan

Executive Summary
- Introduction to Business Idea

Organisation
- Network and VE Type
- VE Characteristics
- Corporate Business Processes

Product
- Service Module Specifications
- Service Module Configurations
- Service Product Delivery

Market
- Marketing Plan
- Competitive Advantage

Operation
- IT Infrastructure
- Communication Settings

Finance
- Investment
- Profit & Loss Statement

Management
- Specification of the Roles

	Information Objects	Type of Information							Roles						
		Network	Project	Product	Production	Financial	Legal	Others	Customer	Network Initiator	Partner	Project Board	Network Board	Audit Team	Information System
1	Service Module Requirements			x					P	R					
2	Project Organisation Form		x						P	R					
3	Marketing	x	x	x		x		x		P/R					
4	Network Operation	x						x		P	R				
5	Financial Data					x				P	R				
6	Management	x	x					x		P	R				
7	Business Plan	x	x	x	x	x	x	x		P	R				
8	List of Requirements	x	x	x	x	x	x	x		P	R				
9	List of Candidates	x								P	R				
10	Preliminary Selecting Criteria	x	x	x	x	x	x	x		P	R				
11	Initial Shortlist	x								P	R				
12	Detailed Selecting Criteria	x	x	x	x	x	x	x		P	R				
13	Final Shortlist	x								P	R				
14	Network Principles	x	x	x	x	x	x	x			P/R				
15	Membership Agreement	x	x	x	x	x	x	x			P/R				
16	Members of the Network Board	x						x			P/R				
17	Service Module Portfolio			x							P/R				

Figure 5. Information exchange and information objects whilst setting u a service network.

Business plan: The business plan encloses all information gathered during the previous phase of the network set up process. It shows how the network organization should look, how the deliverable service products should be configured and the operative management is also defined. Also the business plan takes the market into account by presenting the competitive advantage of setting up a network organization. The part called management specifies the roles within the network and its SVEs (introduced in section 3.2.1).

Service module portfolio: The service module portfolio encloses the core competencies delivered by the network organization. Service components and its interdependent service process supported by the appropriate service organization configure each service module. If the customer's demand requires the combination of several service modules then a service product will have to be designed. Each service product is assigned a support class and its corresponding life-cycle phase. The section called specification in the service module portfolio supports in finding the right service module via the information system by providing keywords that describe the module that the search engine is looking for.

3.2.4 Resource view

The resource view represents the resources of the network members as they are used in the course of the network and SVE set up and operations. Resources can be, for example, competencies and know-how to fulfil service tasks, capacity of service technicians, material or machines needed to produce spare parts or specific diagnostic software and hardware, etc. These resources have to be assigned using resource models to the defined activities and organizational entities.

4. Industrial Case Study

The proposed reference model is currently being established and exploited in a use case from the GLOBEMEN project. In this case a Japanese one-of-a-kind producer ("OKP1") develops and sells large chemical plants. For the manufacture of these plants, it has a large network of suppliers and vendors. Worldwide there are 100 of these plants in operation by customers. In the past, OKP1 developed service components, such as a remote plant monitoring system and a training simulation system, to support after-sales services. However, OKP1 does not have its own team of service technicians. A customer ("C1") operates several plants in Asia and has its own teams for inspection and maintenance. A Japanese telecom company ("TC") maintains a communication network in the Asian region. TC offers also services to collect information from production equipment for safe control and use, provides network accounting, collection and authentication functions and a place to register a variety of applications to access remotely. Below the first steps of modelling the organizational view will be briefly described:

Structure of the service network: In the first phase the service network is established in the Asian region and is made up of OKP1 with selected suppliers and vendors, C1's service teams and the network infrastructure from TC. In a second phase – to offer world-wide services – another one-of-a-kind producer ("OKP2"), which is not a direct competitor of OKP1 but works at the same level in the value chain, and has world-wide a great number of own service stations, will join the network (see Figure 6).

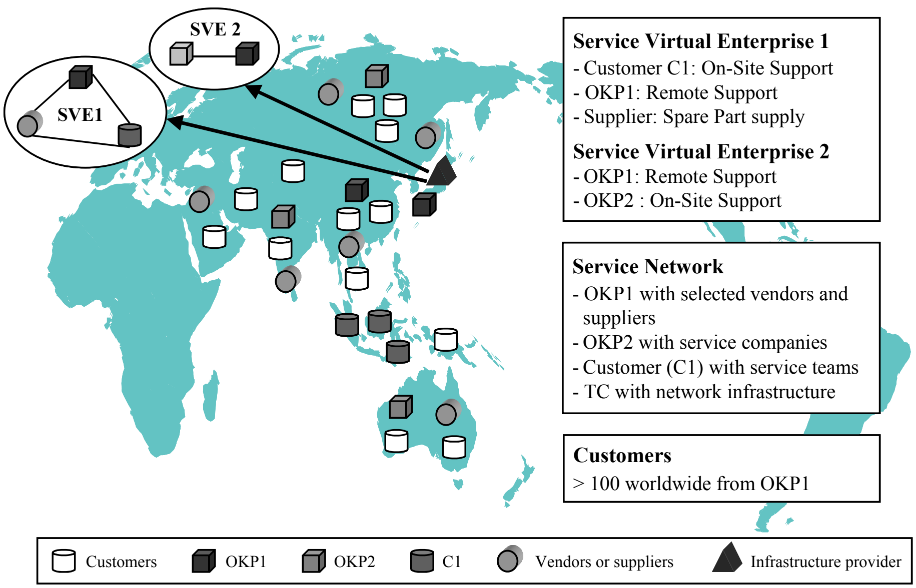


Figure 6. Structure of the service network.

Collaborative service products: The operating service network will provide a wide range of service products, which are configured from existing service modules from the network members. Collaborative service products will be for example:

- *Hosting Service:* Long term data gathering of plant and process data and monitoring using remote plant monitoring system, which is installed at TC. Suppliers and vendors can also access the remote plant monitoring system and are responsible for observing their specific parts of the plant.
- *Process Performance Evaluation:* Based on gathered data from the hosting service an evaluation of the current status of the overall plant will be carried out. For the evaluation a process flow simulator from OKP1 and knowledge about plant operation from C1 are needed. The results of the evaluation will contain recommendations to change the current operation condition (e.g. pressure, temperature or flow) or to establish plant services (e.g. inspection).
- *Equipment Performance Evaluation:* The objective of this service is the decision support if a specific equipment (e.g. Heat Exchanger) has to be opened for cleaning or for repair.

- *Plant Services:* These services are maintenance, repair, inspection, etc. and have to be carried out by service teams on-site.
- *Operator Training*: This service includes training of plant operators before and after plant acceptance using the training facilities of C1 and training simulation system from OKP1.

Based on these products an **enterprise configuration** scenario could look as follows: Due to the equipment performance evaluation the requirement for maintenance on a reactor and replacement of spare parts of the supply pipes is identified. The service virtual enterprise will then take the following configuration: A service team from C1, which has reactor training, goes on-site to the customer. At the same time, a supplier delivers to the customer the pipes it has manufactured or drawn from inventory. During the repair procedures, the member of the service team receives additional required information from engineers at OKP1 using mobile and internet-based ICT.

Figure 7 shows on the left side an example how a sequence of configured service products can look like. For each of these service products it has to be defined during the configuration of the service virtual enterprise how network members contribute to the different tasks. In the use case a single contribution per task and also multiple contributions of several enterprises per task is possible (see Figure 7 right side).

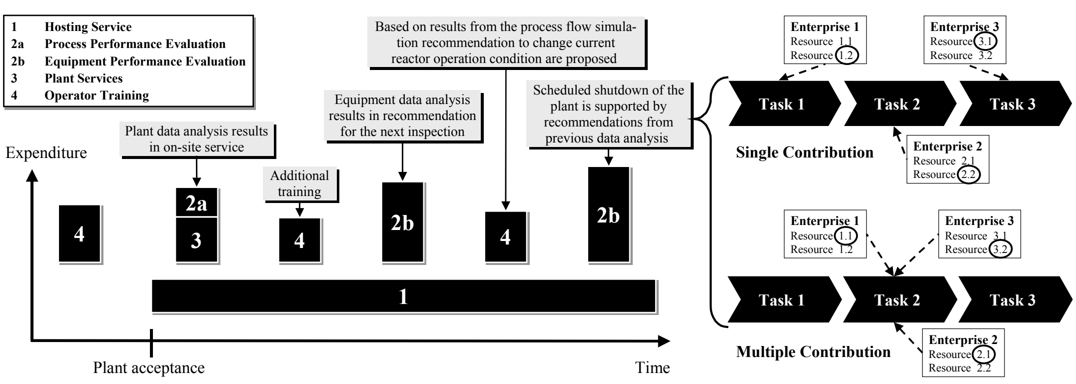


Figure 7. Sequence of service products and type of contribution.

The benefits of the described type of cooperation are as follows: Through implementing various service components, OKP1 can actively offer after-sales services and gather valuable experiences for new product design. C1 benefits from collaboration with OKP1, because they will have better utilization of their service team capacities. In addition, technicians from C1 will benefit from enlarged experience through service work at other companies.

5. Conclusion

The present contribution introduced a model of how future collaboration in after-sales services in the one-of-a-kind industry might look like. The proposed reference model for collaborative service is intended to provide a guideline to set up an inter-enterprise service organization based on the principles of the virtual organization. During the application of this model, in industrial use cases, it may be adjusted individually, but it still helps especially SMEs to increase the ability of setting up a network organization and of running its service virtual enterprises successfully.

References

1. Hartel, I., Burger, G., Schnetzler, M. & Rüf, C. (2001). Company survey Successful Service Management – Trends and Practices in the After-Sales. ETHZ-BWI, Zurich, Switzerland.

2. Zwegers, A. J. R. & Gijsen, J. W. J. (2001). Integration issues in virtual enterprises supported by an architectural framework. In: Ferroni, B., Boer, C. R. & Anderson, C. M. (Eds.). International IMS Project Forum 2001, A common platform for cross-fertilization among IMS projects and promotion of the IMS program. Nexus Design sagl, Lugano, Switzerland. Pp. 246–254.

3. Hartel, I., Burger, G., Billinger, S. & Kamio, Y. (2002). Virtual organization of after-sales service in the one-of-a-kind industry. In: Camarinha-Matos, L. M. (Ed.). Collaborative Business Ecosystems and Virtual Enterprises. Kluwer Academic Publishers, Boston, USA. Pp. 405–420.

4. GLOBEMEN (2000–2002). Global Engineering and Manufacturing in Enterprise Networks. IMS 99004/ IST-1999-60002. http://globemen.vtt.fi. The Swiss region is sponsored by the Swiss Commission for Technology & Innovation (CTI).

5. Hartel, I. & Burger, G. Virtual Service Enterprise – A Model for virtual collaboration in after-sales service in the one-of-a-kind industry. In: Ferroni, B., Boer, C. R. & Anderson, C. M. (Eds.). International IMS Project Forum 2001, A common platform for cross-fertilization among IMS projects and promotion of the IMS program. Nexus Design sagl, Lugano, Switzerland. Pp. 255–262.

6. GERAM (1999). Generalized Enterprise Reference Architecture and Methodology. ISOIS15704:2000, IFAC/IFIP Task Force on Architectures for Enterprise Integration. (available at http://www.cit.gu.edu.au/~bernus)

7. Vesterager, J., Bernus, P., Larsen, L. B., Pedersen, J. D. & Tølle, M. (2001). Use of GERAM as Basis for a Virtual Enterprise Framework Model. In: Mo, J. P. T. & Nemes, L. (Eds.). Global Engineering, Manufacturing and Enterprise Networks. Kluwer Academic Publishers, Boston, USA. Pp. 75–82.

8. Vesterager, J., Bernus, P., Pedersen, J. D. & Tølle, M. (2001). The what and why of a Virtual Enterprise Reference Architecture. In: Stanford-Smith, B. & Chiozza, E. (Eds.). E-work and E-commerce, Novel solutions and practices for the global networked economy. IOS Press / Ohmsha, Berlin, Germany. Pp. 846–852.

9. Hartel, I., Sonderegger, S., Kamio, Y. & Zhou, M. (2002). The Information Roadmap of Virtual Enterprises. In: Stanford-Smith, B., Chiozza, E. & Edin, M. (Eds.). Challenges and Achievements in E-business and E-work. IOS Press / Ohmsha, Berlin, Germany. Pp. 1380–1387.

Modelling of the Information Roadmap of a Service Virtual Enterprise

Mingwei Zhou, Angela Williams, John Mo and Laszlo Nemes
CSIRO Manufacturing & Infrastructure Technology, Australia
(e-Mail: Mingwei.Zhou@csiro.au)

Ingo Hartel and Stephan Sonderegger
Swiss Federal Institute of Technology Zurich
Center for Enterprise Sciences (ETHZ-BWI), Zurich, Switzerland
(e-Mail: Ingo.Hartel@ethz.ch)

Yoichi Kamio
Toyo Engineering Corporation, Chiba 275-0024, Japan
(e-Mail: kamio@ims.toyo-eng.co.jp)

Abstract

Along the lifecycle of a service virtual enterprise (SVE), extensive amount of critical information is created, shared, used, modified and disposed. The Information Roadmap (iRoadmap) introduced in this paper attempts to trace the content and flow of such information in the whole life of a SVE, therefore enables the development of tools and methods for information management and establishment of necessary ICT infrastructure. A modelling tool called InfoMap has also been implemented to depict this information roadmap (iRoadmap), and further support its implementation for a SVE. InfoMap can be used to capture and visualise the information roadmap, which can be further implemented as guideline and checklist for the operation of the SVE.

1. Introduction

The information along the lifecycle of a service virtual enterprise (SVE) may cover wide areas such as product, supply, production, distribution, service or even finance. Currently, there is a lack of a formal way of depicting, never mention the handling or controlling, the occurrence of such kind of information in a SVE. The Information Roadmap, which is introduced in this paper, attempts to describe the content and flow of such information and therefore provides companies with guidelines to manage the information during the set up and operation of their network organizations and virtual enterprises.

For the one-of-a-kind production, we can set up different types of virtual enterprises based on their deliverables (see [1]). For example, in order to support the operation of a one-of-a-kind product such as a chemical production facility, a SVE could be established to offer the plant owner with services such as maintenance, repair, and operation support.

We can identify that this kind of virtual service organization usually consists of three main elements – the service network of all potential service partners, the service virtual enterprises of selected partners (SVEs), and the services as a product of the SVEs. To provide a structural arrangement and to capture the characteristics of these entities, the Virtual Enterprise Reference Architecture (VERA) is currently being developed in the IMS GLOBEMEN project (see [2]).

A SVE consists of selected network partners. Together they can fulfill a specified service product. The service product is divided into different tasks. Each network partner in the SVE is responsible for performing a part of these tasks in accordance with its competencies and available technical aids and ICT. Network partners could be one-of-a-kind producers or a multitude of independent service companies, suppliers or vendors. A service network in the operation phase has an array of service products, which they can offer to the customers. A service product consists of one or many service modules, which targets different customer needs through its single or combined characteristics. A more elaborate description of service products can be found in [1].

2. The Information Roadmap

2.1 The iRoadmap for SVE

The iRoadmap [3] is intended to depict an information view of the three entities that are introduced in the model of a virtual service organization. According to the lifecycles depicted in the VERA, each phase of VERA is then described in more details, along with its business process flows illustrated, and the information exchange with the corresponding information objects defined. Information objects are identified in key information occurrence during the lifecycle of a service network and its SVEs. These information objects can then be used to support the design of a data schema for an information system. A number of trigger points, such as the exit points whilst setting up a service network or SVE, were identified and corresponding criteria assigned during the depiction of the iRoadmap.

2.2 Pattern of analysis

To be useful, a roadmap should provide a depiction of the road in various level of detail and scope of coverage. Similarly, the iRoadmap concept is also presented with different levels. For example, the top-level overview helps to grasp the entire content and illustrates the business process of setting up a network organization and its SVEs. As the iRoadmap is intended to show a multidimensional character, a separation in different stages of analysis would be helpful to draw more valuable conclusions. The pattern of analysis is used to present the content of the iRoadmap. Thereby, the focus is set on the information exchange between different functional roles during the entire process of the SVE, which is modeled by determining and depicting the information objects being exchanged between the assigned roles. The analysis is completed with the illustration of the business process flow and the identification of the trigger points.

2.3 Roles in a network organization and its SVE

The iRoadmap concept distinguishes seven roles, six of them are active and one is auxiliary. The active roles include the customer, the network or project initiator, the partner, the project board, the network board and the audit team. The information system of the network organization plays a supporting role facilitating the information exchange between the active roles.

Customers come up with different service requests and thus, influence the strategic and operational requisites that the service network should feature. The network initiator identifies the business opportunities and sets up the network. The project initiator accepts the customer request, carries out the requirements analysis and sets up the SVE. The network consists of partners. Partners can be one-of-a-kind producers, service companies, suppliers or vendors. Every partner can initiate and take part in projects. The project board is the operating unit during the lifetime of a SVE and is in charge of the project management. The network board is the normative and strategic unit of the network. The network board reviews the membership requirements and benchmarks the organization recurrently and accomplishes the needed adjustments. The audit team screens the network partners recurrently and gives support to those that did not comply with the network requirements anymore. The information system builds the auxiliary unit of the network and VEs. It supports the acting roles in their daily business and guarantees consistent and efficient data management.

2.4 iRoadmap: Overview

Following the pattern of analysis explained above, the entire business process of setting up a service network organization and its SVEs and finally, fulfilling the customer demand by providing the service product is illustrated (see Figure 1).

Set up network: Triggered by enough motivation and identified business opportunities, the process of setting up a network starts. The network initiator writes a business plan to describe the conceptual form of the emerging network and determines the requirements that future network partners must fulfill to join the network.

Having contacted potential companies and called them for proposals the selecting process can be initiated. The initial shortlist will contain all companies that comply with the network requirements and thus, selected by the network initiator. These companies will be familiarized with the business plan and later, prepared for the network commitment. Prior determining the service module portfolio of the network, the companies, remained of the selecting process, must sign the membership agreement and achieve network preparedness.

Start network operation: Having achieved the network preparedness, the network gives way to its operational status. Fulfilling customer requests and keeping the network running are the two main tasks that must be completed whilst operating the network. The separation in two network operation phases shows the fact of having two parallel running business processes. On the one hand, members of the network intend to do business that means to create revenues by fulfilling customer requests; on the other hand, they imply to operate with a qualified successful network organization. The separation of the network operation phase in the customer request and the screening process accommodates this aspect and treats the two processes separately.

Carry out requirements analysis: Having issued the preliminary task description during the network operation phase, the requirements analysis must be accomplished. The project manager, determined by the project initiator, will identify the task again prior to defining the project management. The preliminary task description must be completed, so that the requirements specification can be issued. As soon as the customer request has been understood extensively, the project initiator decides whether he will complete the task internally or intends to set up a VE to fulfill the customer demand.

Fulfill customer demand: The project board starts designing the service product that is delivered to the customer. It uses available service modules to configure the service product. If those modules are not available new service modules are designed and added to the service module portfolio of the network. The service product is produced based on the modules and is customized if it is not applicable in its standard form. The service product is delivered to the customer. It could happen that the provided service does not suit the requirements on-site and thus, must be customized again. After having designed the final service product the customer's demand can be fulfilled. The task is completed.

Get customer approval: Prior to closing down the SVE the customer has to approve the service, delivered to him and agree with the result of it respectively. If the customer approves the service, the service report can be finished and provided to the project board.

Close down SVE: As soon as the service report was handed over to the project board, the billing process starts and the invoice can be made out. Prior to dissolving the SVE, the project board reviews the entire project and draws important conclusions for further projects. Afterwards, the SVE is dissolved and the network runs in its operational phase.

The decision whether the customer demand is completed internally or by setting up a SVE is made upon the risk analysis of the project initiator. Choosing the approach of acting on the project initiator's own initiative would not trigger any business processes of the network organization.

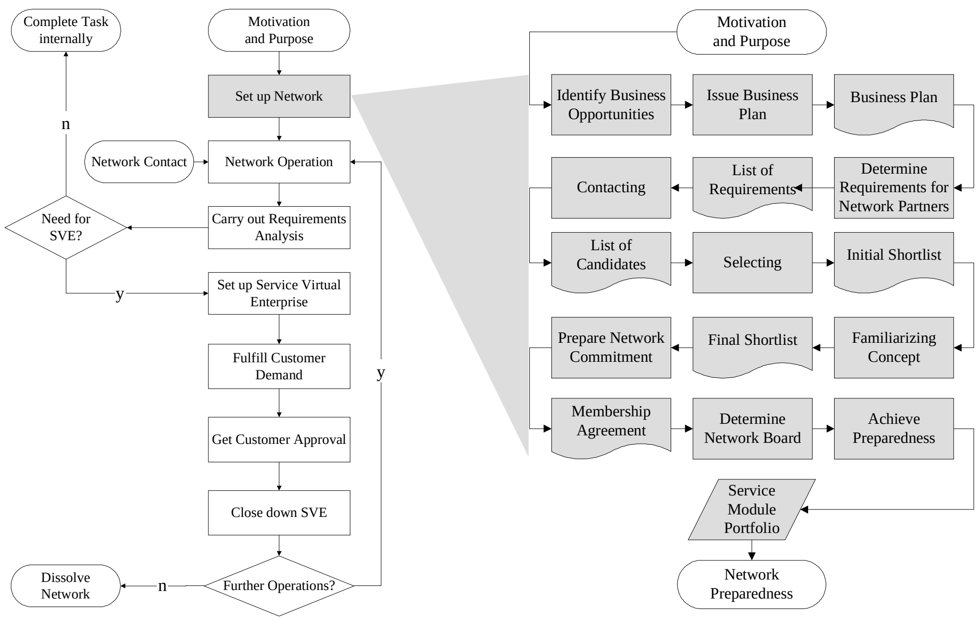


Figure 1. Business process flow: overview (left) and set up network (right).

2.5 iRoadmap: Set up network

To show the content of the iRoadmap concept the set up network process is chosen and presented in detail in this section. Following the pattern of analysis, introduced in section 2.2, the business process is illustrated first, before presenting the information exchange analysis, which contains the key data of the iRoadmap concept. Two of the 17 information objects, identified during the set up network process, are showed and explained. They are called business plan and service module portfolio. The depiction of the information modeling completes the section of the information exchange analysis. The iRoadmap concept closes by identifying the trigger points of the corresponding business process.

Business process flow: On the one hand, Figure 2 shows the overview of the business process; on the other hand the depiction of the set up network process in detail. In the following section the entire business process is explained comprehensively.

Network identification: Enough motivation and a real purpose to do business in a network organization must be taken for granted, before starting to set up a network. It is not suggestive to strive for this form of cooperation without improving the company's profit in a long-term aspect. The business opportunities must be identified. Coming from the product side, service modules not included in the current product portfolio yet, but containing an additional customer benefit, must be defined. Besides determining such products, the needed project form has to be chosen. If a virtual organization suits the project organization requirements the best, a real business opportunity for setting up a network is found.

Network concept: A business plan is issued to show how a network organization makes the new venture grow. The business plan contains relevant information about how the service product can be delivered to the customer using a virtual organization as the form of project. Literally, the business plan represents the network concept.

Network requirements: Partners, who intend to join the network, have to comply with the requirements determined by the network initiator. The list of requirements, a further key document along the process, is used to make the upcoming selecting process transparent and clear as well as to guarantee that only suitable companies join the network. It also specifies the roles, principles and core competencies of the network and determines the requisites for future network partners, derived from the business plan.

Network preliminary design: The network initiator contacts companies that he thinks are able to comply with the list of requirements and thus call them for proposals first. Most likely, he has already done business with those companies;

if not, additional endeavours must be made to create a peer relationship that helps to gain the necessary working trust. Having contacted the companies favoured, they are called for proposals. A list of candidates is compiled that is used for the following selecting process. In order to issue the initial shortlist of possible network partners, the list of requirements is used to screen the list of candidates. The network initiator determines, which companies fulfill the requirements, defined earlier in the process and presents the initial shortlist enclosing those potential network partners.

Network detailed design: In a further step, the candidates acquaint themselves with the business plan. The initiator conducts single interview sessions and holds workshops with the potential network partners as well as intends to prove the candidates' understanding of and commitment to the network way of doing business. Eventually, the final shortlist containing the partner of the emerging network can be compiled. As a network commitment, all partners and the network initiator itself, have to sign a membership agreement. The underlying network principles are elaborated along with all network parties and are built from scratch. Finally, the network parties sign a membership agreement, which bind them in honor to the principles. Companies that do not agree with the membership principles are forced to leave the network organization.

Network implementation: Electing representatives of the network partners, the network board is determined. It is in charge of leading the implementation phase intending to achieve the network's operation preparedness. The service module portfolio defines the range of deliverables by the network. Literally, it determines the network competencies consisting of the partner's core competencies.

Information exchange analysis: The information exchange whilst setting up the network is pushed by the network initiator particularly. First, the network initiator gathers all needed information to issue the business plan and determines which requirements have to be fulfilled by potential network partners. The range of information covers all different types that have been assigned to the information objects identified in Figure 3.

	Information Object	Types of Information							Roles						
		Network	Project	Product	Production	Financial	Legal	Others	Customer	Network Initiator	Partner	Project Board	Network Board	Audit Team	Information System
1	Service Module Requirements			x					P	R					
2	Project Organisation Form		x						P	R					
3	Marketing	x	x	x		x		x		P/R					
4	Network Operation	x						x		P	R				
5	Financial Data					x				P	R				
6	Management	x	x					x		P	R				
7	Business Plan	x	x	x	x	x	x	x		P	R				
8	List of Requirements	x	x	x	x	x	x	x		P	R				
9	List of Candidates	x								P	R				
10	Preliminary Selecting Criteria	x	x	x	x	x	x	x		P	R				
11	Initial Shortlist	x								P	R				
12	Detailed Selecting Criteria	x	x	x	x	x	x	x		P	R				
13	Final Shortlist	x								P	R				
14	Network Principles	x	x	x	x	x	x	x			P/R				
15	Membership Agreement	x	x	x	x	x	x	x			P/R				
16	Members of the Network Board	x						x			P/R				
17	Service Module Portfolio			x							P/R				

Figure 2. Information exchange whilst setting up the network organization.

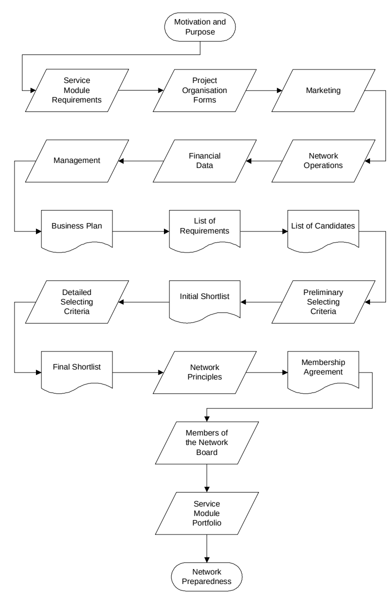
Business Plan
Executive Summary
Introduction to Business Idea
Organisation
Network and VE Type
VE Characteristics
Corporate Business Processes
Product
Service Module Specifications
Service Module Configurations
Service Product Delivery
Market
Marketing Plan
Competitive Advantage
Operation
IT Infrastructure
Communication Settings
Finance
Investment
Profit & Loss Statement
Management
Specification of the Roles

Service Module Portfolio
Configuration
Components
Organisation
Processes
Classification
General Support
Self Support
Remote Support
On-Site Support
Lifecycle Phases
Pre-Sales
Sales
After-Sales
Specification
Keywords
Description
History

The information objects business plan and service module portfolio

	Criterion	Event
1	Unrewarding investment	Revise business plan
2	Too few candidates	Intensify contacting and complete list of candidates
3	Membership agreement is not signed	Revise membership agreement

Trigger points during the process of setting up a network



The information flow of setting up a network

Figure 3. Information objects, information flow and trigger points.

After starting the selecting process network information is provided, which includes the company's data of the potential partners. Important to prepare the membership agreement, the principles of the network organization will be elaborated and later used to compose the membership agreement. Having elected the network board all data, related to the actual products delivered by the partners, is gathered to generate the service module portfolio. The information occurring during the set up of the network is presented in Figure 2 (P means information provider, R means information receiver). Each information object is described in further detail and the information content presented. The business plan and the service module portfolio stand representatively for the entire collection of information objects.

Business plan: The business plan encloses all information gathered during the previous phase of the set up network process. It shows how the network organization should look, the deliverable products should be configured and the operative management should be defined. The business plan takes also the market into account by presenting the competitive advantage of setting up a network organization. The part called management specifies the roles within the network and its SVEs, introduced in section 2.3.

Service module portfolio: The service module portfolio encloses the core competencies delivered by the network organization. Service components and its interdependent service process supported by the appropriate service organization configure each service module. If the customer's demand requires combining several service modules, there will be designed a service product. Each service is assigned a support class and it is corresponding lifecycle phase. The section called specification supports in finding the right service module via the information system by providing keywords that describe the module that the search engine is looking for.

<u>Information modeling:</u> The iRoadmap concept shows the information flow based on the information objects identified during the entire process of setting up a network organization (see Figure3). Documents that are issued during this process are indicated by the rectangles with one curly line, besides general data that are illustrated as rhomboids.

Trigger point identification: Relevant trigger points that cause events are identified in the iRoadmap concept. A trigger point causes an event after complying with a criterion that has been defined before. An event describes an activity that must be accomplished by any role of the network organization or delivers a decision-making function. Literally, costs incurred could be one criterion that forces the project board to close down the virtual organization. Identifying the trigger points during the lifecycle of the three entities allows controlling the whole business process more efficiently. Additionally, it helps to estimate the risk more effectively and thus to manage VEs more successfully.

Figure 3 presents three trigger points. If the investment presented in the business plan is not rewarding, the business plan should be revised or even the process be aborted. There could also happen that too few candidates send their proposals during the selecting process. The network initiator would be forced to intensify the contact to the potential partners or even add new companies to the list of candidates. As a last example, the case is described when the selected partners do not sign the membership agreement. Since only unanimous decisions are accepted within the network, the membership agreement must be revised.

3. InfoMap – A Modelling Tool for iRoadmap

3.1 InfoMap modelling methodology

The iRoadmap is intended to depict the information flow in a virtual enterprise. It requires the depiction of both the information types and the information operations at various granularities, and we expect that the iRoadmap should be implemented, visualised, or executed in some way. We tried a number of the commercial-on-the-shelf modelling tools, and we found none of them are suitable for this purpose.

The PipeNet, a unified information modelling methodology proposed by one of the authors [4] was adopted to model the iRoadmap. The PipeNet was originally developed for describing both the structural definition of and operations on product information. An associated prototyping language has also been developed to enable the instantiation, navigation, and evaluation of a product information model by constructing an executable prototype.

The PipeNet is based on an extended Petri net, where a *place* is used to represent an information entity, while a *transition* represents an operation on the information entity. The relationship between entities can be represented by a set of transitions called relationship operators.

3.2 Implementation of InfoMap

The InfoMap modelling tool was based on the PipeNet methodology. A set of information entities (places) and information operations (transitions) were defined to facilitate the modelling process. Both the places and transitions are defined using XML DTD. Therefore the InfoMap modelling tool is highly reconfigurable and customisable for defferent application domains. A prototype of the InfoMap has been implemented using Java.

Figure 4 shows a snapshot of the InfoMap modelling tool. The information entity will only link to information operators, and the information operator will only link to information entities. Both the information entities and information operators can be further decomposed to finer granunarity. The attributes of each information entity and information operator can also be specified, as shown in Figure 5, which can be used in the following simulation, execution, or implementation of the iRoadmap.

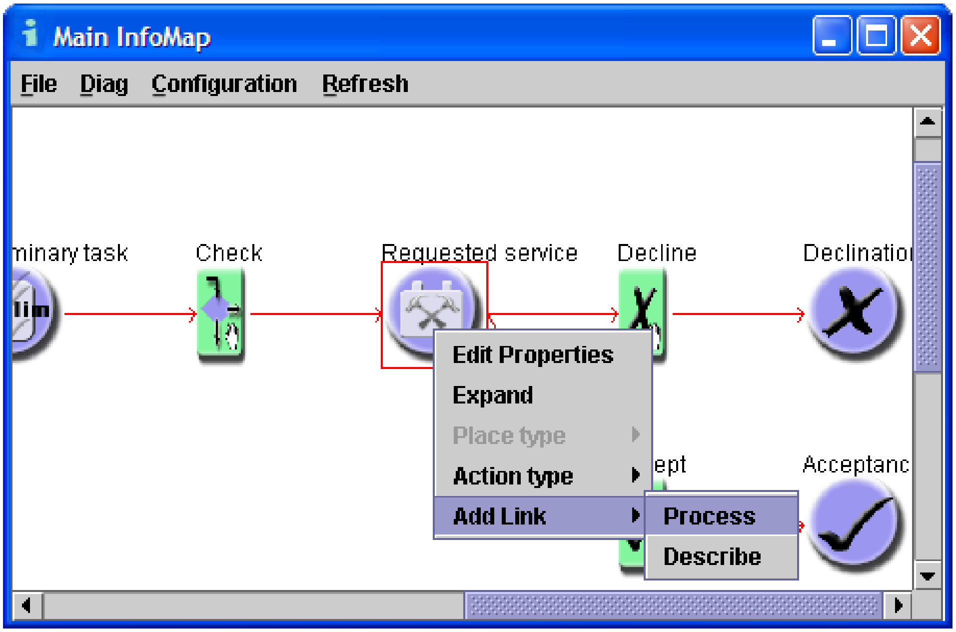


Figure 4. A snapshot of InfoMap modelling tool.

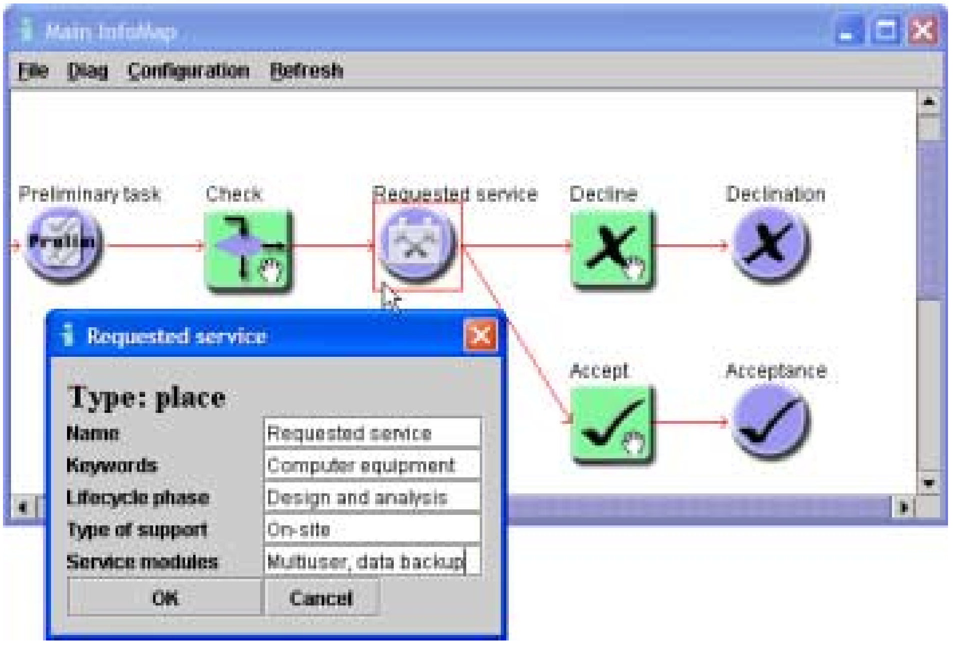


Figure 5. Attributes of an information entity.

3.3 Execution of InfoMap models

As the PipeNet modelling methodology was based on an extended Petri Net, It has the advantage of enabling the simulation or execution of the InfoMap. For example, the popular operations such as receiving, despatching, filling, extracting, synthesizing, checking, and re-using of information can all be simulated and makes the iRoadMap more useful.

We are also in the process of evaluating the usefulness of executing the InfoMap as a set of web pages. The information entities are presented as a page, while the operators becomes the links embedded in the pages. We expect such kind generated pages could serve as an on-line guide for the service virtual enterprise operation. It could also be used to automate some part of the information flow in the VSE.

4. Industrial Case Study

Toyo Engineering Corporation (TEC) as an engineering company has over 40 years of history and has successfully constructed many chemical and petroleum plants all over the world. In order to expand the service base, the firm has decided to develop a business model for after-sales services of urea processing plants, and invited one of the customers as a partner to jointly develop the new process. The iRoadmap has been used in the development of this business model. More details of the case study have been presented in a separate paper in this book.

5. Conclusion

The iRoadmap concept is intended to provide a guideline to facilitate the set up of a service network organization and the operation of its virtual service enterprises. It consists of seven main business processes that are depicted all in detail. Furthermore, in the analysis of the seven information exchange points, 54 information objects and 16 trigger points are identified along the entire VSE business process. The iRoadmap concept also provides outlines for further development of concepts for virtual organizations. A prototype of a modelling tool, the InfoMap has been implemented to facilitate the design of the iRoadmap.

During the application of the iRoadmap concept in industrial use cases, the iRoadmap concept can be adjusted individually and in parallel with the determination of the architecture of a sophisticated information system. The InfoMap modelling tool can help visualise the information flow and provide guidelines for necessary changes. Thus, the iRoadmap concept and the InfoMap tool help to increase the probability of setting up a network organization and of running its virtual service enterprises successfully.

References

1. Hartel, I., Burger, G., Billinger, S. & Kamio, Y. 2002. Virtual organization of after-sales service in the one-of-a-kind industry. In: Luis M. Camarinha-Matos: Collaborative Business Ecosystems and Virtual Enterprises. Kluwer Academic Publishers, Boston (USA), 2002. Pp. 405–420.

2. GLOBEMEN. Global Engineering and Manufacturing in Enterprise Networks. IMS 99004/ IST-1999-60002, http://globemen.vtt.fi, 2000–2003.

3. Sonderegger, S. 2002. iRoadmap – Depiction of the Information Roadmap of Virtual Service Enterprises. Diploma thesis of the Swiss Federal Institute of Technology (ETH) Zurich (CH), 2002.

4. Zhou, M. 1996. An Approach to Product Information Prototyping. Ph.D. Thesis of the University of Leeds, UK, 1996.

5. Kamio, Y, et al. Providing Remote Plant Maintenance Support through a Service Virtual Enterprise. The Globemen Book, 2002.

Part II

Sales & Services

Web-based Instruction System Using Wearable Computer

Yoshiro Fukuda
Hosei University, Tokyo, Japan,
Takao Kurahashi
NTT Cyber Solutions Laboratories, Kanagawa, Japan
Yoichi Kamio
Toyo Engineering Corporation, Chiba, Japan
Eml: fukuda@k.hosei.ac.jp

Abstract

In our research, the Web-based Instruction System using the wearable computer is developed. The system consists of a wearable computer, a wire-less communication system and web-applications. Web-applications are included to a time estimation system, a simulation system, an active instruction manual system, a scheduling system and a status acquisition system.

In this paper, a system configuration is described, each application is explained, and the result of application is summarised. And in this paper, we pointed out the issues for using the system in the assembly line.

This system has been developed under the GLOBEMEN project in the IMS program.

1. Introduction

Recently, manufacturing systems have begun change from mass-production to small-batch and frequent change of production volume. And also, manufacturing systems change from full-automation to manual operation. In order to operate the system, we should consider instructing effectively the operation to operators in the system [1]. Especially, in global manufacturing system, operation planning division and operation site are at long distance. It is necessary to direct operations based on operation situations.

In order to solve the issues, the Web-based Instruction System using the wearable computer is developed. The system consists of a wearable computer, a wire-less communication system and web-applications. Web-applications include a time estimation system, a simulation system, an active instruction manual system, a scheduling system and a status acquisition system.

The web-applications are located in the server in the network. The operators wear the computer and operators can get the necessary information from the server. The wearable computer is equipped with a camera and a bar-code reader. Operation planning division staff can get the operation status through the camera and bar-code reader. Operators and Operation planning division staff can communicate through the system and network.

In this paper, a system configuration is described, each application is explained, and the result of application is summarised. And in this paper, we point out the issues for using the system in the assembly line.

This system has been developed under the GLOBEMEN project in the IMS program.

2. Operation Instruction System

Recently, assembly systems are installed cell production system, because production volume becomes smaller than ten years ago. The cell production system is a small shop that consists of a few operators [2]. Operators in the Cell have many operations to be assembled. Operators have responsibility to complete the product. Typical Cell system as shown in Figure 1. However, operators cannot share training time for a new model to be assembled. Therefore, it is necessary to use instruction system for assemble operations in real time.

Figure 1. Typical Cell Production System.

We analyzed operations in the cell production system, and then we extracted the requirements for a real time operation instruction system. These issues are the following:

1. To indicate information for operation
2. To indicate the newest information.
3. To inform the operator on moving to station.
4. To indicate the easyly understandable information.

To satisfy the requirements, we are developing the web-based instruction system by a wearable computer (WBIS).

The system consists of the simulation system on the web-application, wearable computer and the wireless LAN. The system configuration is shown in Figure 2. This wearable computer is XYBERNAUT Mobile Assistant IV.

Web application includes the instruction manual, simulation and scheduling based on the progressing operation. The web-application is called "web-instruction simulation system (WISS)".

Wearable computer can indicate the operation instruction on working the operation [3, 4]. Wearable computer is equipped with the wireless LAN. Therefore the operator can get the context for instruction from web-server computer. Also wearable computer has a video-camera near by operator's eye. The camera can take a view and send the visual data to server.

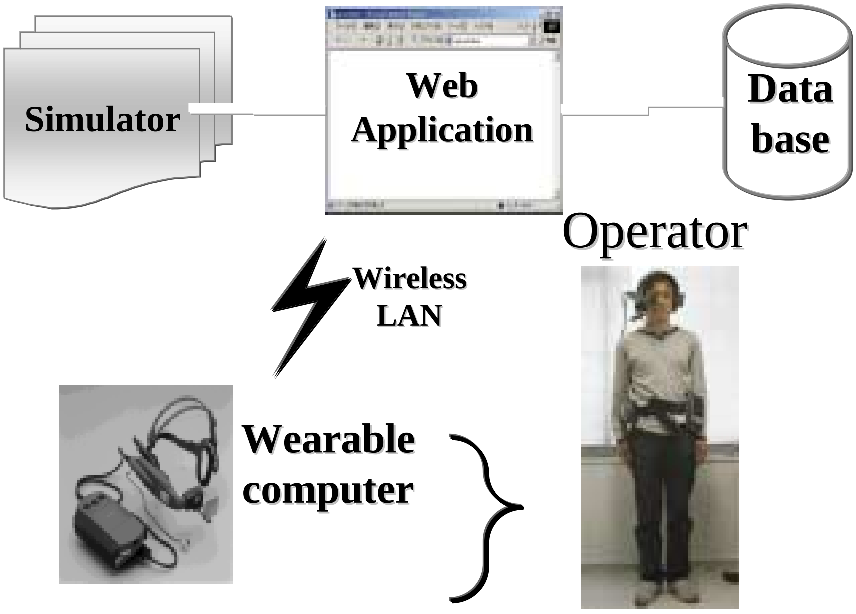


Figure 2. The System Configuration.

3. Web-Instruction Simulation System

3.1 System Configuration

The Web-Instruction Simulation System (WISS) is a core system in the Web based operation instruction system. WISS provides the contents to the wearable computer. The system configuration is shown in Figure 3.

WISS has a simulation for work time estimation. This simulation decides the work time and work movement depending on the work order from the supervisor. The simulator has a database for work elements in the assembly shop. The database provides the work element for assembly job to simulator. The simulator can calculate the working time. However, the calculated time does not include the moving time from present position to working position. Operator inputs the position data by wearable computer on finishing previous work.

Simulator will indicate the next work and the next position on the screen in the wearable computer. And also, if operator requests the working procedure, wearable computer can provide the manual to operator. The operator manual is edited by the simulators.

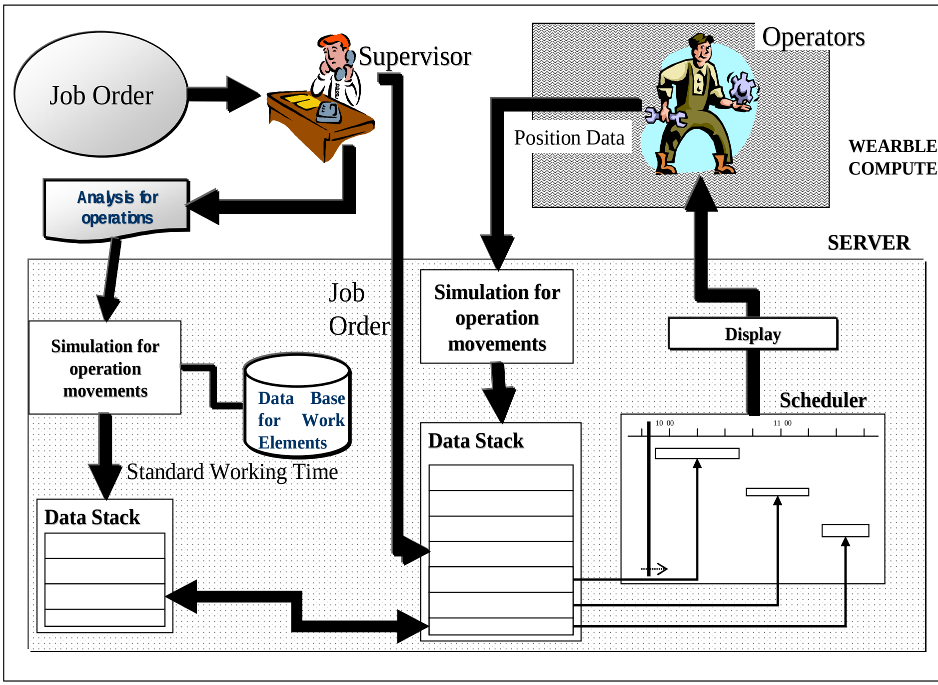


Figure 3. WISS System Configuration.

3.2 Simulator For Time Estimation

The simulator is for estimating the assembly time and the movement for the assembly work. Assembly work breaks down into the elements of work, such as handling, walking and waiting. The element also breaks down into motion elements such as Reach, Grasp, Move, Position and Release. The system calculates the assembly time based on the motion elements. The system has the formulated functions for estimating the time [5]. Example of the function is followings;

Time of operation to hold (Grasp)

S = The size of the parts to hold (path)

$2 < S < 8$ (mm)

In the case of perpendicular supply

$T = 10^{0.94-0.03S} \times 1/100$

In the case of level supply

$T = 25.12\ S^{-0.56} \times 1/100$(Unit 1/100sec).

And then, each motion element is aggregated to the assembly work by the simulator. The simulator can consider the effective sequence and can display the result, as Figure 4. The human model in the simulator can be animated. And the result is also in the manual for assembly operator. The human model can be adaptable based on the individual physical size.

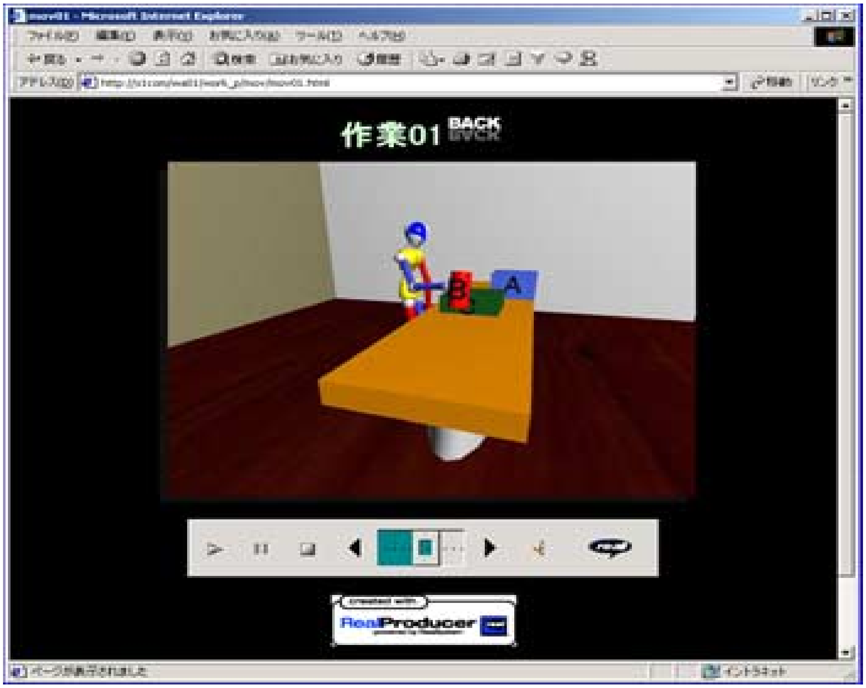


Figure 4. Simulation Output.

3.3 WISS human interface

WISS is equipped with some applications, such as moving analysis, scheduling, position information, assembly manual, notification, and animation for assembly work. And also, WISS has a database for standard time and a database for work assignment.

However, operators do not need much information on working. Therefore, WISS is separate from the information which is processed by supervisor and operator. Supervisor side prepares the moving motion and the standard time for assembly by simulator and analyzer. Supervisor side also makes a plan and a schedule by the scheduler, and makes manuals and notifications for assembly work by the simulator. This information is stored in the web-server by HTML format.

The operator side inputs the individual physical data before working. The operator inputs signal after working. If the operator needs the information, he requests the data on the screen of the wearable computer. Software configuration is shown in Figure 5. The software is running on the Table 1 specifications.

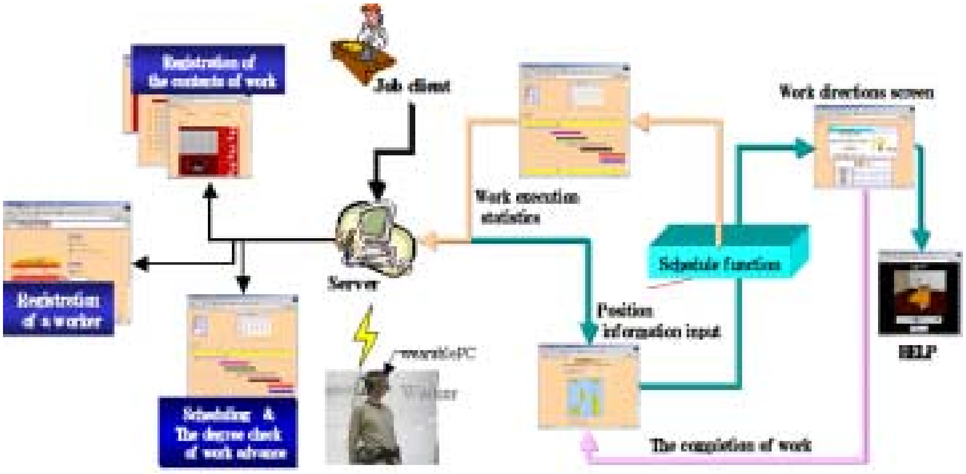


Figure 5. Software Configuration in WISS.

Table 1. Software Specification.

Operation System	Windows2000 (server), Windows CE(Client)
Web server	IIS5.0 (Internet Information Server)
Database Server	SQL 7.0 & Microsoft Access 2000
Programming	ASP, SQL, Java, HTML, JavaScript
Browser	IE5.5

4. An Implementation Example

For evaluating the proposed system, we have done a simple experiment. The experiment environment is U-shape assembly system. The operator is equipped with a wearable computer. Operator assembles three parts into a product depending on the web-instruction. The experience scene is in Figure 6.

Figure 6. Experience Scene.

We have two experiences, one is with wearable computer, and another is without wearable computer. In each experience, 8 students are as testee. They are working the same jobs. The results are Figure 7 and Figure 8. According to the results, WISS squeezes the amplitude of the working time. All students can understand the work sequence by WISS system.

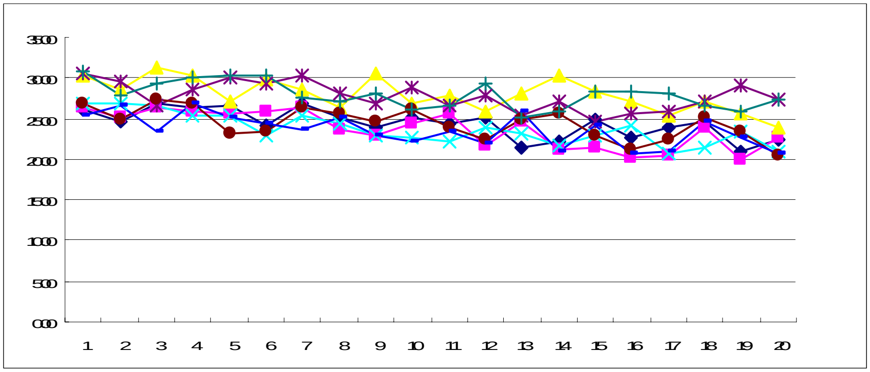


Figure 7. Assemby Time without WISS.

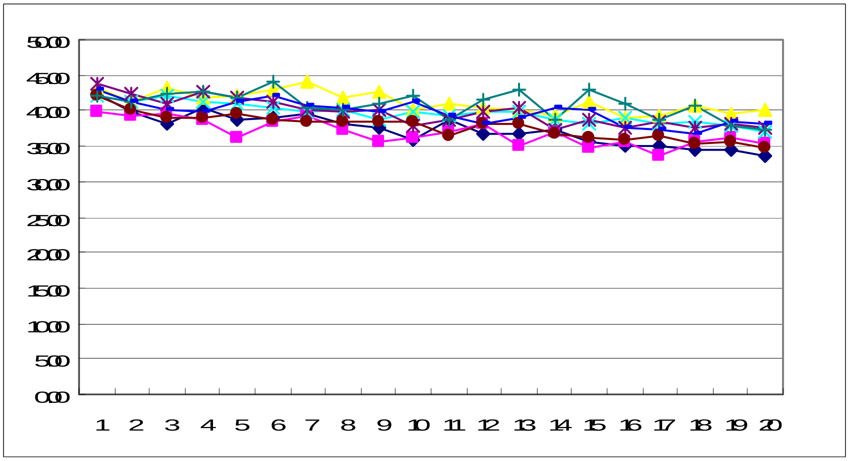


Figure 8. Assembly Time with WISS.

5. Conclusion

We have developed the Web-based Operation Instruction System using a wearable computer and we applied it to an assembly system. The system can communicate the data on working the job. But some problems are clarified by our experience. Wearable computer has a poor display function on working, and a poor input function on wearing.

It is not necessary to use the system in a simple job; however we can believe in the usefulness of the tools for maintenance and repair field. Web-manual and web-application are powerful tools for instructing a complex work. And we can change easily the content in the web-server from assembly to maintenance.

6. Acknowledgement

This research has been carried out under GLOBEMENproject, one of the projects in the IMS International Research Program. The authors would like to acknowledge all members of GLOBEMEN project for various supports.

References

1. Morita, K., Kawashima, K. & Fukuda, Y. 2000. Web-based Maintenance Manual with Tree-Dimensional Simulation Model. Global Engineering Manufacturing and Enterprise Networks. Kluwer Academic Publishers. Pp. 212–219.

2. Mori, K. & Yoshikawa, N. et al. 2000. Neo-Kaizen Application on the Generic Operations Support and Renewal. Global Engineering Manufacturing and Enterprise Networks. Kluwer Academic Publishers. Pp. 236–243.

3. Barfield, W. & Caudell, T. 2001. Fundamentals of Wearble Computer and Augmented Reality, LEA.

4. Yanagihara, Y., Muto, S. & Kakizaki, T. 2001. Evaluating User Interface Multimodal Teaching Advisor Implemented on a Wearable Personal Computer. Journal of Intelligent and Robotic Systems, Vol. 31, No. 4, pp. 423–438.

5. Ido, M. 1998. Research on Functional Type Working Time Estimation System. Doctor Thesis, Hosei University.

6. Baber, C. 2001. Wearable Computers: A Human Factor Review, International Journal of Human-Computer Interaction, Vol. 13, No. 3, pp. 123–145.

An Internet-based Platform for Distributed After-sales Services in the One-of-a-kind Production

Martin Kauer
Buhler AG, Switzerland (email: martin.kauer@buhlergroup.com)
Gerhard Burger and Ingo Hartel
Swiss Federal Institute of Technology Zurich – Center for Enterprise Sciences (ETHZ-BWI), Switzerland (email: Gerhard.Burger@ethz.ch)

Abstract

Professional and innovative after-sales services are getting more and more a key success factor for companies in the one-of-a-kind industry operating with globally spread customers. Customers expect maximum use of the purchased plant and expect qualified and quick service independent of time and distance [1]. On the other hand not each company can afford its own worldwide service network and the increasing complexity of one-of-a-kind products requires a lot of specific service know-how by the service personnel. These claims call for a high grade of technical and organizational innovation by the service providers.

One possible approach is the intensification of cooperation relations between one-of-a-kind producer, customer, service partners and suppliers [2]. It is the objective of this article to describe an organisational and technical approach how small and medium enterprises can improve and extend their future service business by setting up cooperation networks. With the focus on the service fulfilment process an internet-based service platform basing on the PDM SmarTeam® and the JAVA2 enterprise technology – called E-Service Support System (E3S) – for distributed After-Sales Services used by the Buhler company will be described. The description outlines how different already available technologies can be combined to support different parties involved in the service. The paper will end with a scenario outlining the use of the service support system to solve a given customer problem.

1. Introduction

Nowadays new information and communication technologies allow closer cooperation to companies operating in a global environment. They allow easy and quick access and exchange of information between customers, producers and service partners independent of time and distance. Hence service processes can be designed faster and more efficient. Especially this circumstance offers great opportunities for after-sales services because short reaction and repair time are very often essential factors for optimal use of a customer plant.

The service virtual enterprise represents such a concept (see [2] and [3]). This concept describes the organizational and technical framework for inter-enterprise collaboration in the after-sales. The suggested Internet based service platform called E-Service Support System (E3S) represents a possible approach for the technical realization of such an information system. It combines all services on a unique platform for the execution of service fulfilment and provides customer specific services based on service products.

2. The concept of a service virtual enterprise

With the focus on the one-of-a-kind industry, the service virtual enterprise (SVE) can be defined as "a short-term form of cooperation to fulfil services among legally independent one-of-a-kind producers, service companies, suppliers or sub-contractors in a service network of long-term duration" [3]. The services aim to provide support to the customer in the operation of their machines and installations and to solve problems as immediately and as cost-effectively as possible.

The main elements of the model are the customers of one-of-a-kind producers, the service network with the network partners, and the resulting service virtual enterprises (see Figure 1). More elaborate description of this model can be found in [2] and [3] and in the paper "A Reference Model for Collaborative Service".

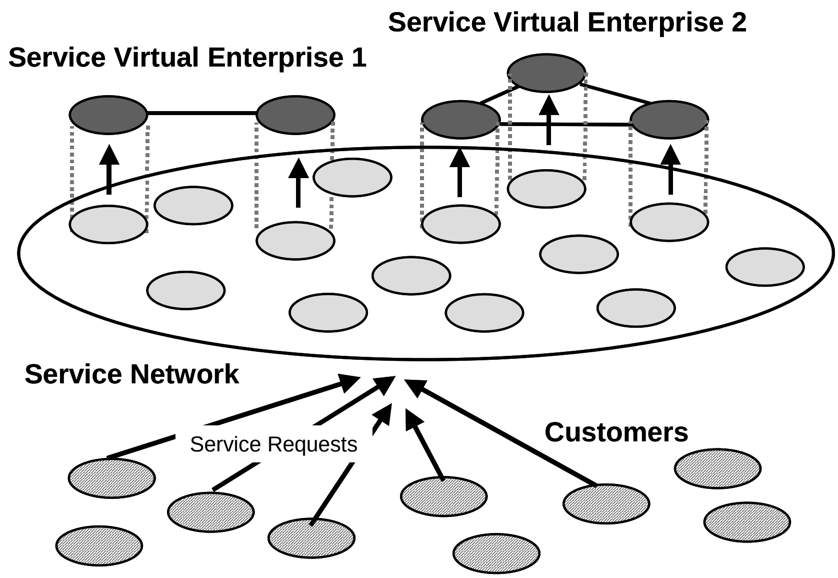


Figure 1. Model of the service virtual enterprise.

2.1 Process of setting up a Service Virtual Enterprise

There are many tasks to be accomplished in order to run service business in collaboration. The fundamental processes of setting up and operating a service virtual enterprise takes on a central role. If a customer reports a problem, it is essential that suitable network partners be selected as rapidly as possible – according to the criteria of competency, location, availability, and so on – and that the service tasks to be provided are managed and controlled. The following outlines a possible schema for the proceeding that comprises four steps (see Figure 2) implemented in the GERAM Model [4]. It starts with the identification and the analysis of the problem and proceeds to set-up of the SVE and fulfilment of the service and, finally, to documentation, feedback, and billing.

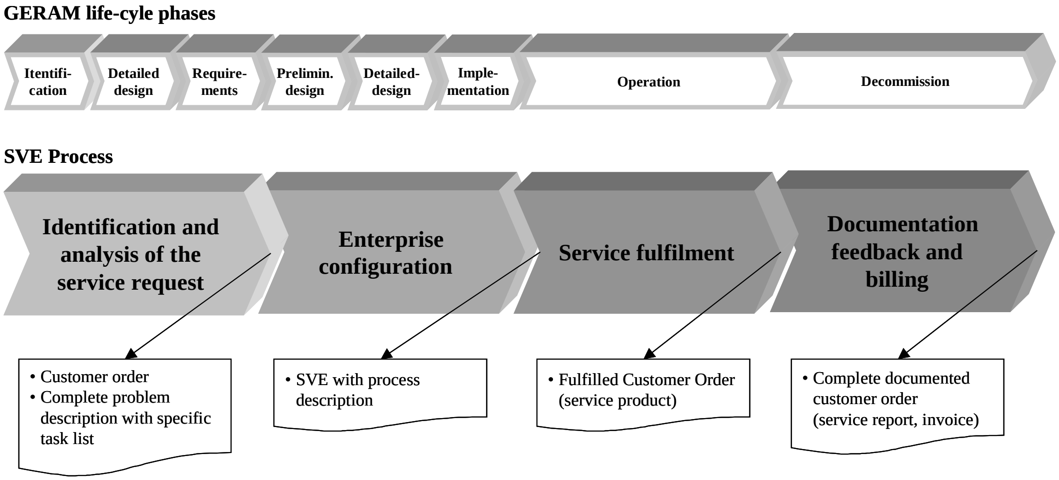


Figure 2. Service process in a service virtual enterprise.

Identification and analysis of the problem: The goal of this step is to identify the problem that the customer is experiencing and to rapidly produce as accurate as possible a description of the problem. Once the problem has been identified, the measures required to solve the problem can be determined. If there is no clearly identifiable cause of the problem, measures to aid identification may be undertaken. These may include additional investigations with the help of electronic aids and systems (problem tree, diagnostic and expert systems, and so on) or on-site analysis by a specialist. Once the measures have been decided upon, a SVE is set up and contracted to provide the service (see steps 2 and 3).

Enterprise configuration: The goal of enterprise configuration is to set up the SVE that can best deliver the service as defined by the given requirements. Based on the results of problem identification and analysis, the service needed is broken down into individual tasks and the competencies and aids that these tasks will require are identified. Taking the network partners' capacities into account, possible SVE combinations to fulfil the tasks are worked out.

Service fulfilment: Service fulfilment begins with activating the necessary ICT infrastructure among the network partners involved. Depending upon the problem, service is fulfilled on site, remotely, or on-site with remote support. In the case of on-site service fulfilment – in addition to the electronic availability of information, data and documents on the machine – the possibility for mobile, online communication with other SVE partners is particularly important.

Documentation, feedback, and billing: After completion of the service fulfilment, the process of problem solution with all steps, utilized resources, and required time is documented. Finally, the services performed by the SVE are reviewed for quality control. If the service performed for the customer is billable (not a goodwill or warranty service), an invoice is prepared. The revenue is divided among the members of the SVE. Once the service task is completed, the SVE is terminated.

The entire service process is triggered by a service request of a customer or automatically depending on the purchased service products defined in service contracts. These services are described in the following section.

Services of the service virtual enterprise

Based upon the type of communication between one-of-a-kind producer or service partner and customer the services of a one-of-a-kind producer can be grouped in four categories [5].

- **General Support** consists of services that involve the use of basic means of communication, such as language, mail, fax, chat, and so on.
- **Self Support** utilizes aids and information that a one-of-a-kind producer, or service partner, makes available without playing an active role in their use. No person-to-person interaction takes place between the one-of-a-kind producer, or service partner, and the customer.
- **Remote Support** is ICT-supported interaction between one-of-a-kind producer, service partner, and customer that requires the exchange of images or machine data. This can take place with audiovisual aids.
- **On Site Support** requires that an employee of the one-of-a-kind producer or service partner is present at the customer's plant.

In addition, it is possible to utilize the scheme for all sales phases through the entire sales life-cycle. The service model reveals that many services can also be utilized in the sales or pre-sales phase. Very often customers are not interested in specific services because they expect problem solutions. This can be taken into account by service products. As a rule, service product is understood here as a combination of individual services. This service product, or combination of services, is provided to or offered for sale to the customer by the one-of-a-kind producer or service partner. For example the shaded services in the service portfolio (Figure 3) represent a service product that might consist of spare part management, remote consulting, remote diagnostics, repair and optimisation. This service product is applied in scenario (see section 5).

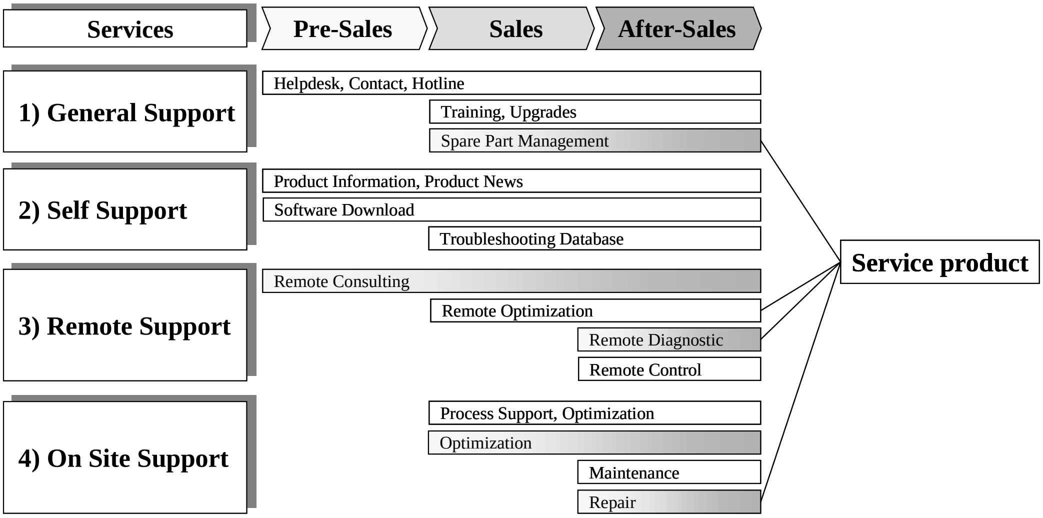


Figure 3. Service portfolio of a one-of-a-kind producer or a service virtual enterprise.

The service portfolio represents the service spectrum of a company or a service virtual enterprise.

4. E-Service Support System

Managing worldwide services in a service network requires that the involved parties are supported with proper services and applications. This is very important in all phases of the service process especially in the service fulfilment phase where different users with different skills have to deal with complex machine- and plant equipment and complicate information exchange is required by all participants (compare Figure 2). In this phase there are also some critical information that are only directed to selected users.

In a service virtual enterprise at least four different main user groups (roles) that are directly involved in fulfilling specific service tasks have to be handled by an information system:

- Service Centre Staff: These persons can be an after-sales manager, product specialists, after-sales administration personnel or persons from the sales.
- Service Technicians: Service technicians are spread worldwide and solve customer problems on customer site.
- Customers: At customer side the mainly involved persons are the plant operators, engineers or maintenance personnel.
- Service Partners: Service partners can be spare-part suppliers but also service technicians that perform specific service tasks for the one-of-a-kind producer.

Depending on the required service or application communication can take place from user to user, user to machine or machine to machine. The three channels for information exchange of the E-Service Support System are shown in Figure 4.

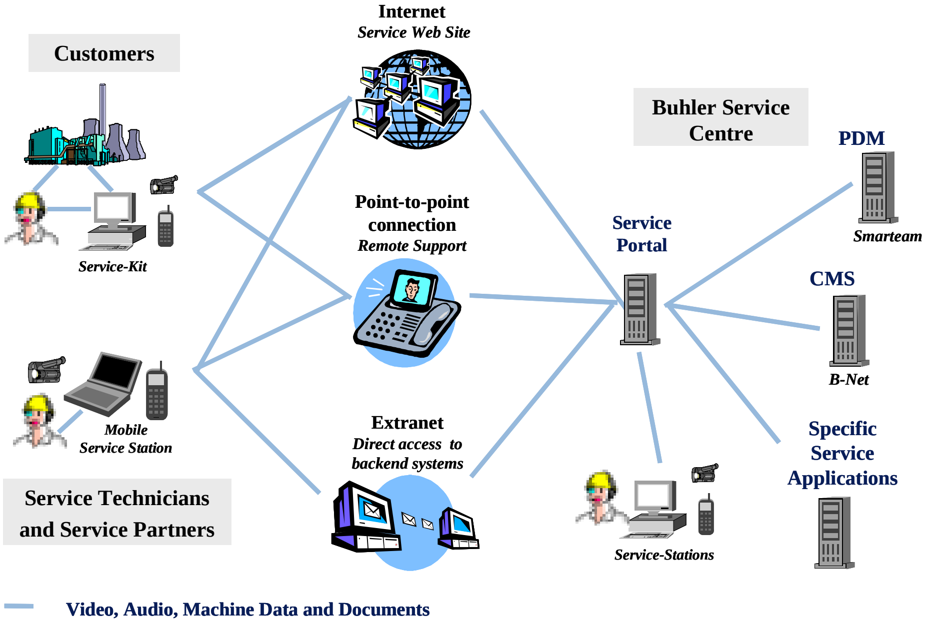


Figure 4. Concept of the E-Service Support System.

The three communication channels of the E-Service Support System are an Internet Channel, a Point-to-Point Channel and an Extranet-Channel. These communication channels allow the different users to establish interactive communication with other parts in the SVE and to access service information according to their specific needs and to the required service mission. The relations between the information channels, the users and the related services are shown in Figure 5.

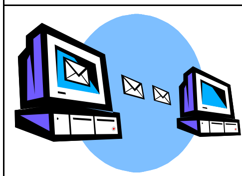
Channel	Type of channel	Main users	Services
	**Internet: Service Web-Site with** • Public area • Common area *(Password required)* • Customer area *(Service contract required)*	• Customers • Service Centre Staff • Service Technicians	FAQ, Product information Downloads Documentation Remote Diagnostic
	**Point-to-Point connection:** • Telephone • Videoconference • Application sharing • Exchange of data via FTP (pictures, videos, drawings, machine data...)	• Customers • Service Centre Staff • Service Technicians • Service partners	Remote Consulting and Diagnostic
	**Extranet:** • Secure connection to Buhler Backend Systems *(e.g. PDM, B-Net,)*	• Service Centre Staff • Buhler Service Technicians	Access to expert database Buhler forum Buhler yellow pages

Figure 5. Communication channels of the E-Service Support System.

At Buhler side persons at the Service Centre are equipped with so called "Service Stations" that include personal computers, web-cams for video conferencing, phones etc. A connection to different data sources like a product management system (PDM), content management system (CMS), service specific application like remote monitoring software and access to the internet are established over a central server [6]. Service technicians are equipped with mobile computing hardware (e.g. laptops, digital video cameras, hand-held, etc.) being able to communicate with others independent of their current location. At customers side a so called "service kit" is installed to make communication to other parties possible. In the future also mobile computing equipment like e.g. wearable computers might be used in order to cooperate interactively with Buhler experts during a service mission.

Scenarios

The following scenario outlines the execution of the after-sales service process (cf. Figure 2) in a service network and the use of the E-Service Support System triggered by a customer request. Figure 6 illustrates the overall situation.

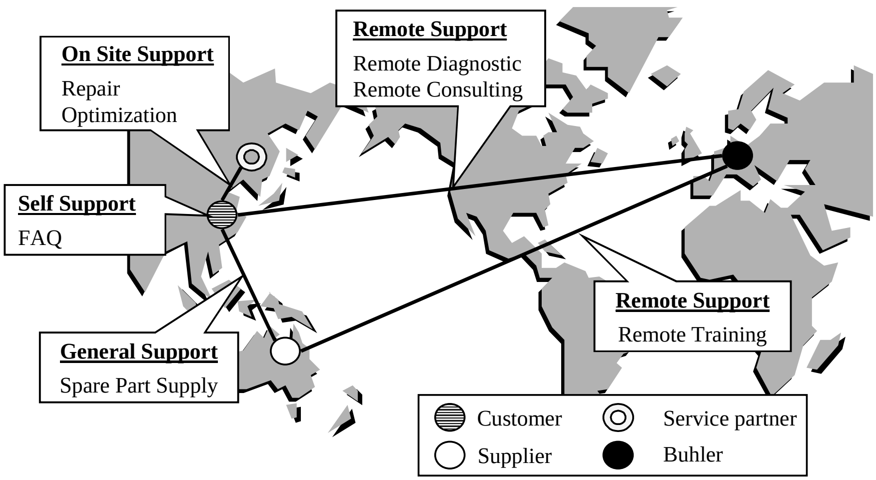


Figure 6. Distributed collaborative after-sales service.

In the Buhler case service execution is based on the generic service virtual enterprise process described in section 2.1. The entire service process and the related services (service product) are illustrated in Figure 7.

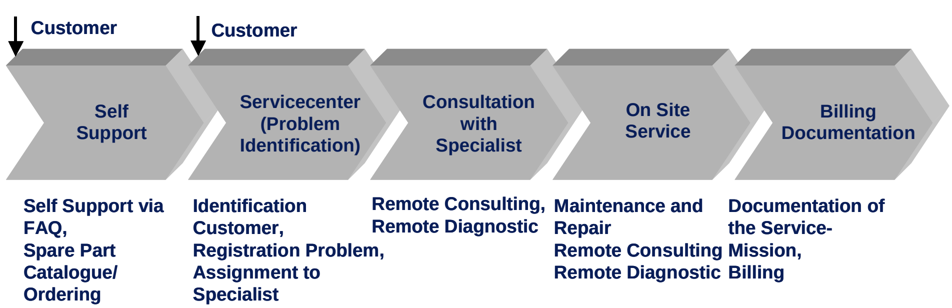


Figure 7. Buhler specific service virtual enterprise process.

The SVE-process is triggered if a problem on a customer plant occurs and the customer is accessing the service support system or directly by contacting the world-wide service centre.

Scenario: A customer in Asia is experiencing reduced output on his feed processing plant. The cause of the failure is not known. Because some years ago the customer has signed a service contract with Buhler he has access to specific service products. The service products may e.g. include access to FAQ, online diagnostics and remote monitoring service and 20 hours free online consulting.

In a first step the customer accesses the service portal (Figure 8).

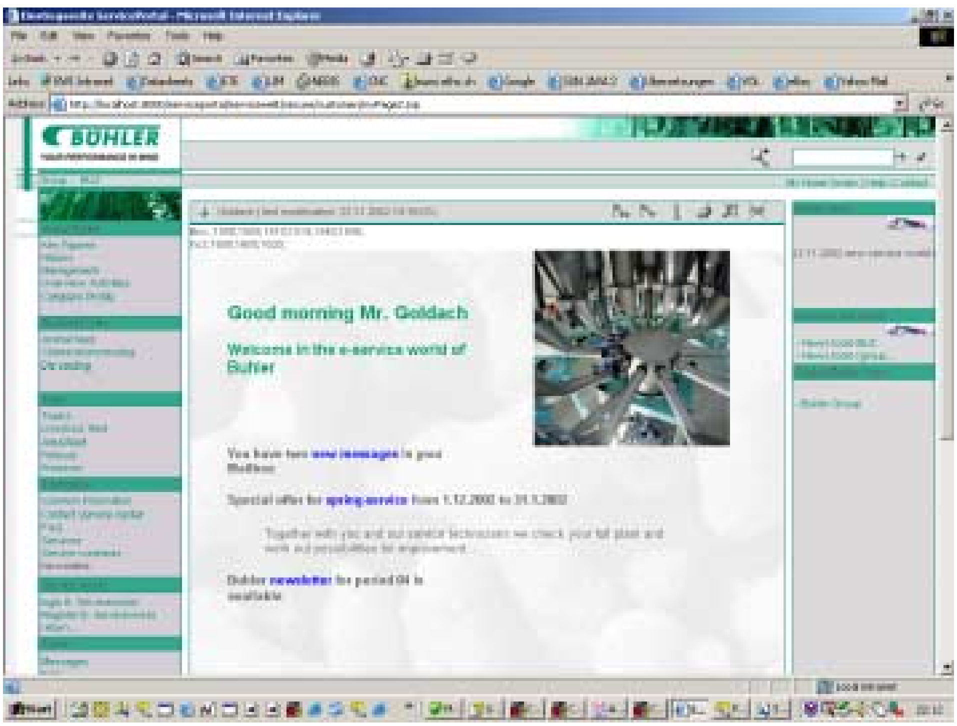


Figure 8. Example of login screen.

After logging in to his personalized web-page the customer searches in the specific FAQ database for similar problems that may have occurred in the past (*Self Support*). As the customer does not receive an appropriate hit, the customer calls the service centre. The service manager at the service centre performs a remote login (point-to-point connection) to the plant control system of the customer *(Remote Diagnosti*c). With the help of the process status visualization tool the plant conditions are inspected. The process visualization system shows that there is a problem with the pellet mill. During the remote diagnosis the service manager stays in contact with the customer and gives advice on how to change the process parameters of the pellet mill. The change of the production output is tracked by both the customer and the service manager. It becomes apparent that the problem is caused by the press rolls of the pellet mill. Unfortunately the customer can’t perform the required service by himself. The service manager looks for available Buhler service personnel. In the required time period there is no expert available but a proper service partner with a skilled service technician can be identified and a service request for a service mission is delegated to the partner company. At the same time a temporary service account especially for this service case is created in the PDM-system SmarTeam®. The account covers all service related information in a secure environment and is only available to the users currently involved in this specific service mission. The history of the current service case is documented and during the journey to the customer the hired service technician can survey the service activities that have already been performed on the regarding plant and the pellet mill.

Figure 9. Utilities for remote consulting (service kit).

As the hired service technician is not an expert in the service of pellet mills he accesses the multimedia online repair manual in the PDM-system through the internet and performs the disassembling of the pellet mill as described in the manual.

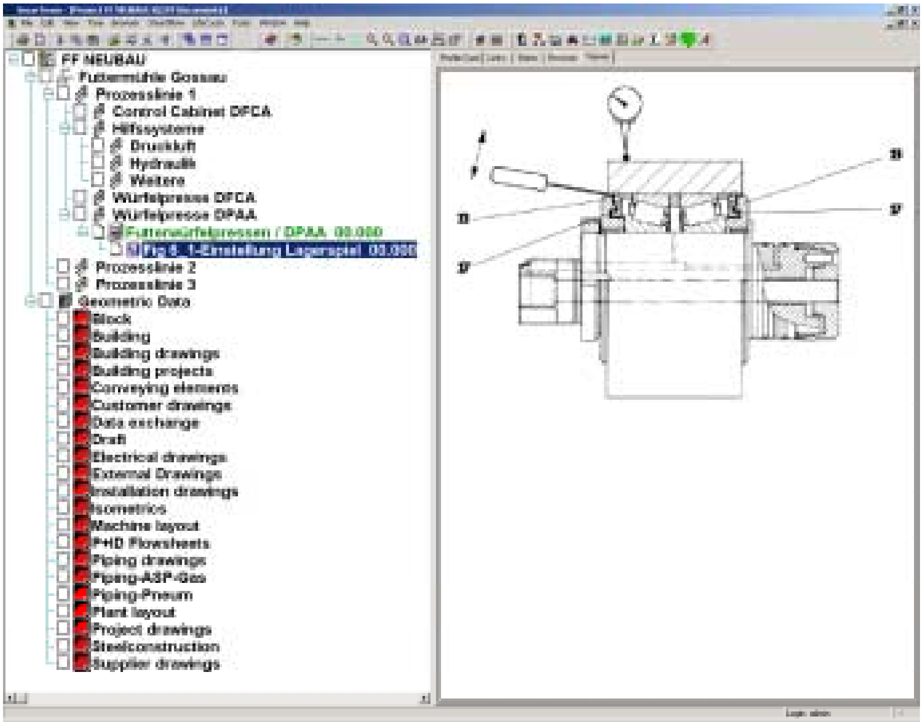


Figure 10. Repair step for setup of the slackness of the main bearing of the press roll.

The service technician is supported by remote consulting from the service centre. Based on the remote diagnostic data the service manager in the service centre detected also that the machine settings had not been chosen optimally. The service manager explains to the service technician how to optimize the machine settings after completing the repair task. From now on the plant is running as expected. In the last process step the service account is closed and the service case is stored in the PDM-System SmarTeam©. An invoice is made according to the service contract held by the customer and sent to the customer.

This scenario shows that the customer's demands (rapid repair of the machine failure at a reasonable cost) require a tight setup and coordination of all parties involved in the SVE. In the common endeavour, each selected partner in the network contributes its skills, core competencies, or capacities. The one-of-a-kind producer alone would not be in a position to resolve the problem in a comparable period of time.

Conclusion

The advancing development of new information and communication technologies has created the basis for virtual presence at any time, any place worldwide. Continual development of these technologies also opens up new possibilities for the one-of-a kind industry with regard to design and delivery of services. The article describes the utilisation of the service virtual enterprise concept that has been elaborated in the GLOBEMEN project. The E-Service Support System illustrates how the different already available technologies and applications can be combined to support a distributed after-sales service process dependent on the different needs of the parties involved in the service. However, there are still a lot of technical challenges in the support of a world-wide service organisation. Service data and knowledge are bound to individual companies with their own specific information systems and technologies. But success also does not only depend on technical perfection and availability. The same service products require that the generic after-sales service process will be aligned to individual customer wishes, cultures and problems. The existing mentality of all service partners and service strategies must also be revised and redesigned. One today's slogan is "a global service organization for local needs".

Abbreviations

B-NET	Buhler Intranet
CMS	Content Management System
E3S	E-Service Support System
FAQ	Frequently Asked Questions
FTP	File Transfer Protocol
GERAM	Generalized Enterprise Reference Architecture and Methodology
ICT	Information and Communication Technologies
PDM	Product Data Management
SmarTeam®	PDM-software provider
SVE	Service Virtual Enterprise

References

1. Burger, G., Hartel, I., Schnetzler, M. & Rüf, C. 2001. Company survey "Successful Service Management – Trends and Practices in the After-Sales". ETHZ-BWI, Zurich, Switzerland.

2. Hartel, I., Burger, G., Billinger, S. & Kamio, Y. 2002. Virtual organization of after-sales service in the one-of-a-kind industry. In: Camarinha-Matos, L. M. (Ed.). Collaborative Business Ecosystems and Virtual Enterprises. Kluwer Academic Publishers, Boston, USA. Pp. 405–420.

3. Hartel, I. & Burger, G. Service virtual enterprise – A Model for virtual collaboration in after-sales service in the one-of-a-kind industry. In: Ferroni, B., Boer, C. R. & Anderson, C. M. (Eds.). International IMS Project Forum 2001, A common platform for cross-fertilization among IMS projects and promotion of the IMS program. Nexus Design, Lugano, Switzerland. Pp. 255–262.

4. GERAM 1999. Generalized Enterprise Reference Architecture and Methodology. ISOIS15704:2000, IFAC/IFIP Task Force on Architectures for Enterprise Integration. (available at http://www.cit.gu.edu.au/~bernus)

5. Burger, G., Hartel, I. & Billinger, S. 2001. Electronic service using advanced information and communication technologies: In: Stanford-Smith, B. & Chiozza, E. (Eds.). E-work and E-commerce, Novel solutions and practices for the global networked economy. Volume 2, Section 2.1 Mobile Applications for Business and Work. IOS Press / Ohmsha, Berlin, Germany. Pp. 644–650.

6. Fraunhofer Institut für Systemtechnik und Innovationsforschung 1997. Teleservice einführen und nutzen, Formell-Verlag, Karlsruhe, Germany.

Providing Remote Plant Maintenance Support through a Service Virtual Enterprise

Yoichi Kamio and Fumio Kasai
Toyo Engineering Corporation, Japan (email: kamio@ims.toyo-eng.co.jp)
Toshiaki Kimura
Japan Society for the Promotion of Machine Industry, Japan
(email: kimura@tri.jspmi.or.jp)
Yoshiro Fukuda
Hosei University, Japan (email: fukuda@k.hosei.ac.jp)
Ingo Hartel
Swiss Federal Institute of Technology Zurich – Center for Enterprise Sciences (ETHZ-BWI), Switzerland (email: ingo.hartel@ethz.ch)
Mingwei Zhou
CSIRO Manufacturing and Infrastructure Technology, Australia
(email: Mingwei.Zhou@csiro.au)

Abstract

This paper discusses a scheme that allows all parties involved in the maintenance of a chemical plant: the plant owner (customer), the engineering company, the equipment vendors, and the maintenance firms, to form a service virtual enterprise (SVE) whenever a maintenance service is necessary, in an attempt to provide required services more timely. This paper also discusses the requirements for knowledge management and risk management in such a SVE environment, and proposes a secure hosting service environment that allows all the parties to share information and applications, and to collaborate during plant operation and service fulfilment. To evaluate and demonstrate the feasibility of this scheme, a prototype of the remote maintenance system developed for a fertiliser plant in Indonesia is presented. Finally, a scenario of how to utilise such a remote maintenance system, the possibility of collaboration among SVE partners, and the advantages of utilising the proposed hosting services in SVE are also discussed.

1. Introduction

Modern chemical plants are getting more and more sophisticated, and the number of equipment vendors needed for each plant is also increasing. The provision of after-sales services, such as the maintenance of plants and keeping the plant at a good level of efficiency, safety and reliability, has become an increasingly challenging business opportunity for those engineering companies who constructed those plants. The customers who own and run those plants, on the other hand, are also trying to rationalise their plant operations by out-sourcing their maintenance services in order to concentrate themselves on their core competencies. All these demand for a new business scheme that can provide cooperative service by all parties involved, including the engineering company, the various equipment vendors, maintenance firms, and the plant owner (customer).

This paper attempts to address such issues. We are proposing herewith a remote supporting technology where engineering companies, equipment vendors and customers will be able to co-operate and solve problems quickly by exploiting the latest IT technologies.

2. Business Requirements

Plant owners endeavour to operate their plants safely and enhance their production efficiency. However, the engineering companies who built the plant, and various vendors who provide equipment for the plant are getting more and more internationalised, the provision of the required services by traditional means is increasingly difficult. It would be very hard, if not impossible, for any of these business partners to provide a solution separately and independently which at the same time satisfies the interests of all parties involved. Therefore, it is necessary for them to work out a cooperative arrangement among themselves.

The business requirements from each party are described in more detail below.

2.1 Requirements from customers

Inherently, customers as plant owners usually maintain their own operation department or service department in an endeavour to operate their plants in an optimal manner. However, plant systems are becoming more and more complex due to the enhanced functionality of plants and environmental considerations, all of which require service personnel to have a higher level of analysis and judgment capability. In addition, while the service departments need a certain level of manpower for periodical inspection, such manpower may become redundant for daily routine inspection. Because it is unsustainable to keep a maximum required size of service personnel in house, plant owners will have to find out ways to keep it at a minimum and to outsource necessary work when required.

2.2 Requirements from engineering companies

Engineering companies have been traditionally concentrating on the so-called EPC (Engineering, Procurement and Construction) business sector, and try to minimize the amount of small and lingering after-sales jobs whenever possible. However, due to recent severe competition for new projects in the global market, and increasing demand from customers for complete solutions, engineering companies are expected to extend their services to cover the entire life cycle of plants constructed by them, and to keep a good relationship with their customers.

However, since customers (plants) are distributed throughout the world, it would not be cost effective for engineering companies to extend their support services world-wide all by themselves. Therefore, engineering companies are looking for local partners to extend their support services. As the equipments used as components in the plants are procured from vendors scattered around the world, a sound linkage with these equipment vendors is essential for servicing such components.

2.3 Requirements from equipment vendors

Vendors have recognized the importance of maintenance service of their products, and therefore have established maintenance service network systems by using local manpower or over the phone support. However, once their products are included in a complex system such as a plant, the effect of maintenance services by vendors alone would be limited, because a linkage with system analysis or simulation services is an indispensable part of quality service. Furthermore, it would be inefficient for each vendor to construct a separate service network. Hence, cooperative actions with engineering firms or other vendors has become necessary.

3. Model of SVE [1, 2]

A service virtual enterprise (SVE) is a temporary business entity established from a network of partners formed to provide after-sales services to a customer. Each partner is an independent entity that is equipped with its own unique capabilities and competencies, assuming responsibility to perform the allocated work. For example, when an engineering company, a group of equipment vendors and maintenance firms, and a customer (factory) organized a SVE using a hosting service (see Section 4.2), equipment in the plant made by various vendors can receive services by means of remote monitoring systems, some minor operational difficulties could be rectified through remote maintenance. Furthermore, periodical repair tasks can now be planned based on a more accurate judgment: when a material repair work (such as replacement of components) is necessary, the customer can order parts via a Web-based system, and maintenance firms can schedule in advance to perform the repair or replacement of the equipment on time. The engineering company can also carry out simulations of entire plant systems using actual data collected and will be able to provide the customer with valuable advice such as parameters for optimal operations. A conceptual image of a SVE is shown in Figure 1.

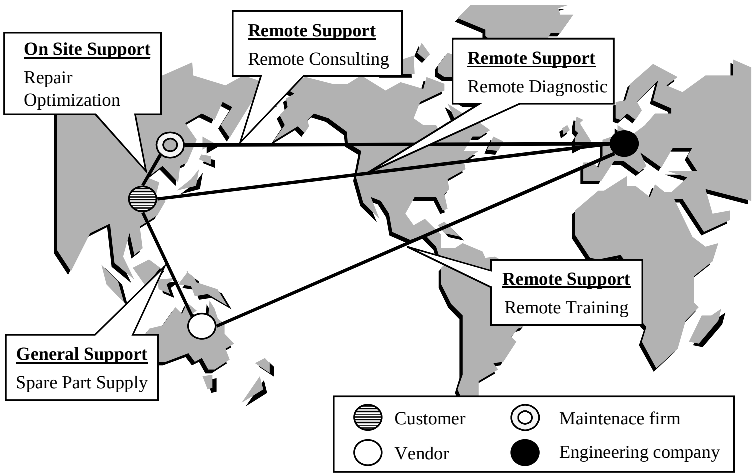


Figure 1. Example of a service virtual enterprise.

4. ICT environment for SVE

4.1 Remote Plant Monitoring System (RPMS)

Distributed plant operations are usually controlled by a DCS (distributed control system), from which plant information (mainly operational data) can be downloaded and forwarded to a data server through an Internet connection.

Figure 2 illustrates our proposal on how relevant partners can share the information. As the plant operates continuously, its operational behaviour does not change suddenly during normal operation. Therefore, plant data can be transmitted on a daily basis at the least busy time zone of the network. Furthermore, only part of the information needs to be accessed by each partner. As shown in Figure 2, a list of data items, entries on P&ID diagrams and trend graphs have been made available. The time and frequency of data transmission may be adjusted according to the customer's requests or the engineering company's judgment.

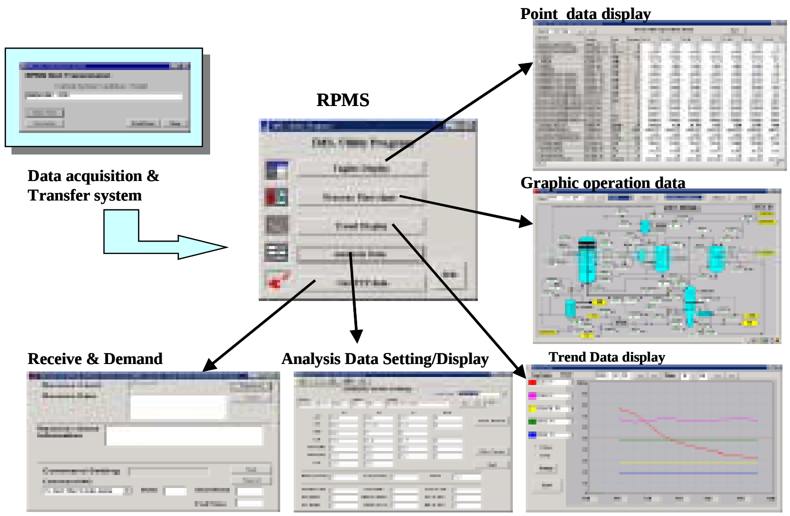


Figure 2. Remote Plant Monitoring System.

4.2 Hosting Service

Normally, a virtual enterprise (VE) or a project team is organized when constructing a plant. An engineering company usually plays the role of a prime contractor, interacting with both the customer and the equipment vendors and coordinating technical problem solving and work schedules.

This arrangement is convenient for the customer because the interaction between equipment vendors is simplified and no day-to-day coordination is necessary on behalf of the customer. This is convenient for the equipment vendors too, because they do not need to coordinate with one another on an individual basis.

After the construction of the plant is finished, and the manufacturing facilities have been commissioned, the engineering company is deemed to have successfully completed its commitment, and the responsibility for the plant is passed on to the customer (owner). Normally, a service department is set up by the customer to carry out all service and maintenance work. As we discussed above, this is a costly burden on the customer.

Due to the potentially large number of suppliers/contractors, the system to support the services intended to be provide be SVEs, it is proposed that the system should be operated by a “hosting service” rather than be implemented on the computers of each separate supplier/contractor, as shown in Figure 3. The core of the system is a data center that links the customer (factory owner), the engineering company, the equipment vendors, and the servicing or maintenance firms. Through this system, the customer accesses the service and maintenances services as specified in agreements with equipment vendors and the engineering firm. The management of data center security services and computer maintenance will be carried out by an independent data center company. The data center company also manages all service applications for all registered companies. Conventionally, the customer needs to ask the engineering company or the equipment vendors to send in their engineers to do the repairs and maintenance of equipment installed in each plant. This has been a costly and time consuming task, and if not handled promptly, may interrupt the normal production in the plant. By exploiting the above mentioned hosting service, a more cost effective and speedy maintenance service could be expected. In addition, each vendor could provide more efficient after-sales activities.

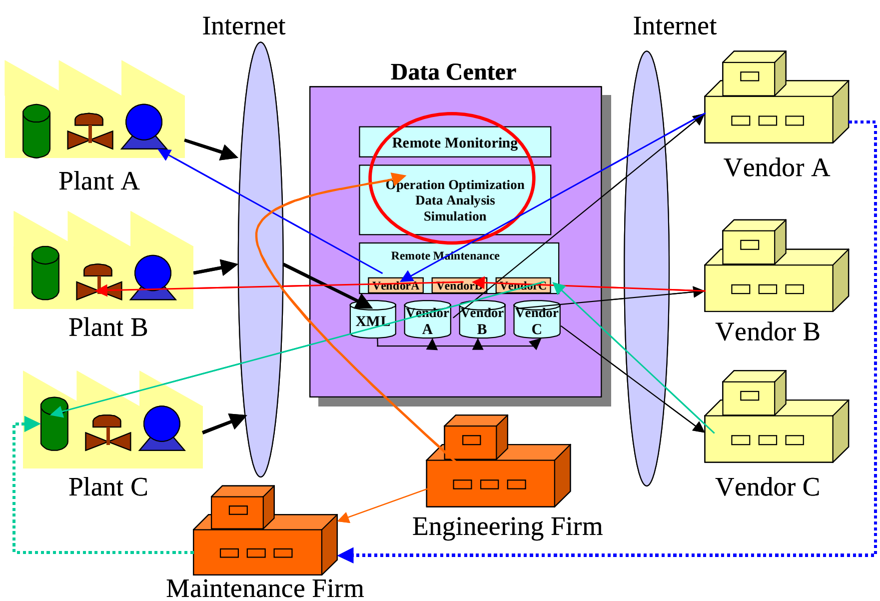


Figure 3. Hosting Service.

5. Industrial Case Study

Toyo Engineering Corporation (TEC) as an engineering company has over 40 years of history and has successfully constructed many chemical and petroleum plants all over the world. In particular, TEC has the license for urea processing, using which the company has built more than 100 plants and enjoys about 25% share of the world market. TEC has so far provided after-sales services such as technical support, training simulator development and turn around (T/A) support. In order to expand the service base, the firm has decided to develop a business model for after-sales services of urea processing plants, and invited one of the customers as a partner to jointly develop the new process. The first parts of the business model will be briefly described as follows:

Structure of the service network: After a review of techniques and tools that TEC and this customer can offer, it was found that we are in a reciprocal position. (For example, TEC owns design know-how and tools while the customer owns operation and maintenance know-how of plants). It was also made clear that by combining the know-how, we would be able to offer more useful services. So we planned to construct a service network with TEC and the customer as the core, and establishing a SVE that best complies with requests of other urea plant owners and to provide the best service possible. Other partners invited to the service network include equipment vendors and maintenance firms.

Collaborative after-sales service scenarios: A prototype developed is shown in Figure 4. The hosting server is connected to the Internet, and is accessible from outside by using applications such as SecurID. Also it should be mentioned that the application developed can be operative on thin client PCs by using a SBC (Server Based Computing) tool such as “Go Global” Data pertaining to plant operation are accumulated in the hosting servers through the data servers and are utilized for various services as listed below.

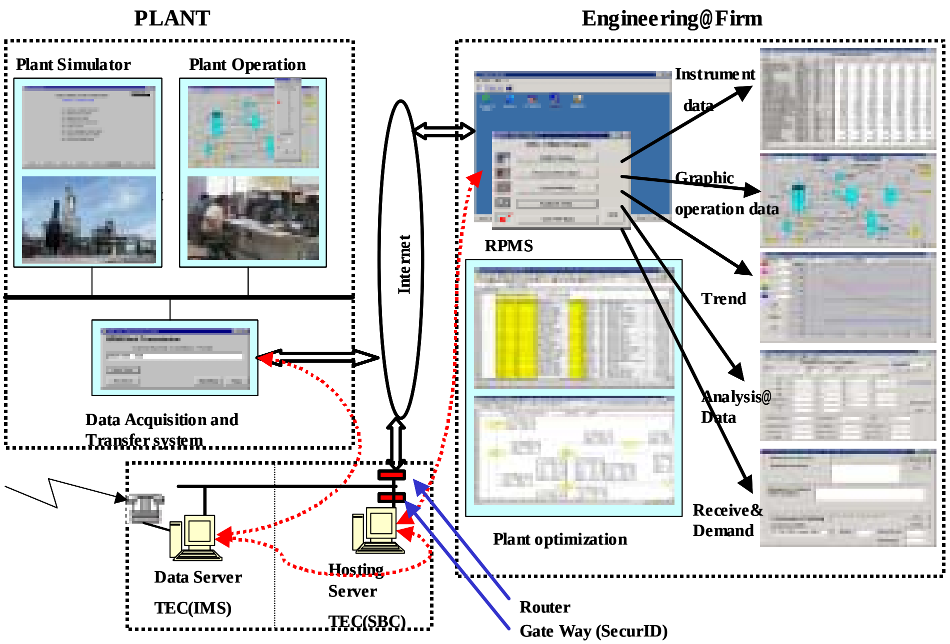


Figure 4. Prototype system.

Plant monitoring: This is a basic service where the operational situation of a plant is demonstrated by means of various graphs.

Preventive maintenance: The data obtained are analysed and simulated to provide a warning before reaching irregular situations.

Trouble-shooting of complex units: Complex units, such as reactors, are diagnosed to find out irregularities.

Total plant system simulation: Mass balance and heat balance of the plant as a whole are calculated from the data obtained.

Equipment performance evaluation: Equipment performance (such as heat transfer performance of heat exchanger) is evaluated.

System performance evaluation: The total system of plant is evaluated.

Training: Operators of the customer are trained by means of training simulators.

Knowledge Management: The optimal maintenance and service parameters are accumulated and reused in the whole-of-life service.

Risk management: Paying attention to the critical paths and the potential risk triggers to ensure service on cost and on time.

Conceivable examples of the services that use the above are: plant monitoring (basic), periodical training, performance evaluation of equipment and plant, and scenarios combining various trouble shooting measures.

The benefits of such setup are: partners who participate in the service network can play the roles as SVE members without any additional need for ICT infrastructures; by sharing data and IT infrastructures, and by reciprocating one another's the technologies and tools, each partner will be able to provide services that would have been impossible by individual effort.

6. Conclusion

In this paper, we took a chemical plant as an example, and proposed a business model of collaborative after-sales services in a "one-of-a-kind" industry, and designed a prototype. Although we recognize that more specific aspects of the business are yet to be studied in more detail, we believe that the methodology as introduced herein can be commonly applied to large-sized and complex facilities where many business entities are involved.

7. Acknowlegement

This research has been carried out under the IMS GLOBEMEN project (see [3]). The authors would like to acknowledge all the members of the GLOBEMEN project for their valuable discussion and technical support.

References

1. Hartel, I., Burger, B., Billinger, S. & Kamio, Y. 2002. Virtual organization of after-sales service in the one-of-a-kind industry. In: Camarinha-Matos, L. M. (Ed.). Collaborative Business Ecosystems and Virtual Enterprises. Kluwer Academic Publishers, Boston, USA. Pp. 405–420.

2. Hartel, I., Sonderegger, S., Kamio, Y. & Zhou, M. 2002. The Information Roadmap of Virtual Enterprises. In: Stanford-Smith, B., Chiozza, E. & Edin, M. (Eds.). Challenges and Achievements in E-business and E-work. IOS Press / Ohmsha, Berlin, Germany. Pp. 1380–1387.

3. GLOBEMEN 2000–2002. Global Engineering and Manufacturing in Enterprise Networks. IMS 99004/ IST-1999-60002. Project web page: http://globemen.vtt.fi

Management of Information in Collaborative Sales

Maria Anastasiou
INTRACOM S.A., Greece (mana@intracom.gr)
Evangelos Tsagkas
INTRACOM S.A., Greece (etsa@intracom.gr)

Abstract

In order to meet the demands of an increasingly competitive and globalised business environment, INTRACOM, the largest Greek manufacturer of telecommunication equipment and information systems, aims at reinforcing its competitiveness by strengthening its international presence. To fulfil the above targets, the company has establishes a business network for providing world wide advanced telecommunications products and services.

In this context and during the GLOBEMEN project, INTRACOM has developed and demonstrated the use of a proof of concept prototype called AGORA with the objective to support the management of information related to the Pre-Sales and Marketing process in an inter-enterprise environment.

The aim of this paper is to present the rationale behind INTRACOM's participation in the GLOBEMEN project, the suggested solution, as well as the first result derived from evaluating the research work.

1. Introduction

Founded in 1977, INTRACOM is the largest Greek manufacturer of telecommunication equipment and information systems. In cooperation with its business partners consisting of manufacturers, suppliers, sub-contractors and engineering offices around the world, the company provides products and services to the Greek public and private sectors, while the company also develops a significant international presence. Through its operations in a network of partners, the company aims to increase its productivity and profitability and become a supplier of choice in both local and global markets, and thus contribute to its effort to meet the demands of an increasingly competitive and globalised business environment.

1.1 Motivation and objectives

The new trend of market liberalisation, privatisation, deregulation and rapid technological change characterises the telecommunication sector as an uncertain and rapidly changing business. These trends have lead to major changes in the way telecommunication companies operate. Particularly, due to the market liberalisation, the established monopolies are currently being divided up at the same time as new companies are entering the market. In addition, the new emerging technologies of Internet and B2B e-work in all kinds of business operations place the telecommunications companies in fierce competition. In order to keep up with the rapid technological changes and trends and maintain their competitiveness, the companies establish strategic collaborations with globally distributed partners and suppliers.

To ensure their place in the market over the coming years, telecommunication companies must take the right approach now in response to each of the following mission critical issues:

Deregulation – The opening of new markets by the deregulation of the telecommunications industry has spurred increased competition in all service areas.

Mergers and acquisitions – The wave of mergers and acquisitions racing through the industry has resulted in a dual edged sword: merged companies gain the ability to offer new services along with the challenges of integrating the systems that provide them.

New technologies – The emergence of new technologies and standards enhance services. Many telecommunication companies are anxious to embrace them. However, these technologies require substantial initial investments to acquire them and keep them up-to-date. Companies must wisely choose the technologies in which to invest.

Capital market demands – Combining the difficulty of sifting through the expensive new technologies to take on board are the demands of the capital market. Telecommunications companies feel squeezed by the effort to produce topline revenue growth, while demonstrating bottom-line cost control.

These mission-critical issues have motivated the telecommunications companies to consistently strive to outpace their competition in many ways, including:

- Customer acquisition and retention through increased customer satisfaction
- Fast provision of new and bundled services, while maintaining efficient operations
- Creation and support of the efficient operation of remote and cross-organisational virtual teams
- Facilitation of global communications and efficient operation of multi-cultural work processes
- Investment in e-business solutions and knowledge management systems enabling business collaboration and knowledge sharing.

Having identified the above-mentioned necessities, INTRACOM's strategy focused on increasing the responsiveness of its core business processes. Within the GLOBEMEN project the company research efforts concentrate on the Sales and Marketing process aiming at identifying way to increase its responsiveness and enabling rapid and successful response to global market opportunities. At the global level, the Sales and Marketing process activities are planned and executed in co-operation with INTRACOM's regional partners. Their main responsibility is to promote INTRACOM's products and services in their local market, as well as to monitor the local market and report on marketplace competitions, potential partnerships, and identified opportunities and potential problems in the market place that can influence the productivity and operations of the network in the region.

In this context and during the GLOBEMEN project, INTRACOM has developed a proof-of-concept prototype of a knowledge-sharing environment called AGORA with the purpose of supporting the management of information and knowledge related to the Sales and Marketing in INTRACOM's inter-enterprise environment.

2. The AGORA Environment

The AGORA environment is a distributed environment based on a dynamic object model that consists of practices and applications to enable:

- The efficient structuring, access and maintenance of knowledge of market, competitive situation and technology, acquired during the Sales and Marketing activities.

- New ways of working that promote information and knowledge sharing in an enterprise network.

The AGORA environment exploits productive INTERNET technologies and tools that support the rapid design, refinement, extension and integration of the various applications.

The objective for AGORA is to act as an environment that supports the set up of an enterprise network infrastructure, as well as the management of the knowledge that is shared between the various network members.

2.1 AGORA's Distributed Architecture

AGORA environment is designed with a *distributed* architectural model in mind, in order to maintain enterprise autonomy and assign network responsibilities to the appropriate parties. This model implies that the collection of *applications*, *services* and *knowledge* is not stored at an easily congested central server, as is the case with the *centralized* architectural model, but instead is distributed over a network of communicating parties. However, the communication protocol between the parties in a distributed system has to be designed in such a way as to hide the effects of distribution. The protocol's main utility is to provide the user with a view of the system similar to that of a system run by a central provider.

2.1.1 Different kinds of distributed systems

Distributed systems come in different flavours depending on the degree of distribution supported by the communication protocol. A lot of distributed systems have recently appeared under the heading of Peer-to-Peer (P2P) technology.

Peer-to-peer systems have been developed to support *distributed computing, file sharing, groupware-collaboration, knowledge-based systems, search engines* and other application domains. Indicative examples of P2P systems are:

- Napster, a file sharing, P2P application, was the system that gave peer-to-peer, distributed technology its notoriety. It is considered a distributed system, although it used a central server to register all its users and their files. The user requested a file and received a list of users that have the file. Once the user makes a selection from the list, she was disconnected from the central server freeing up the system's connection space and subsequently communicated directly with the selected other user to download the file.

- Gnutella is a system like Napster, only it is even more distributed. With Gnutella there is no central server. Requests propagate from peer to peer until a match is found or the *Time To Live (TTL)* for the propagated request expires.

- SETI (Search for ExtraTerrestrial Intelligence) is a distributed computing P2P system that uses the computational resources of users to process part of huge amounts of astrological data in an attempt to detect an extraterrestrial signal.

2.1.2 Description of AGORA's distributed architecture

AGORA is a distributed system with a central server that acts as a central directory and authentication portal that directs access within the business network. Although the function of the central server in the system is similar to that of the central server in Napster, AGORA is not a peer-to-peer system because direct peer-to-peer connections do not get (dynamically) established. AGORA uses a distributed, hierarchical system architecture that works well in the context of an inter-enterprise environment.

Each enterprise member in INTRACOM's Business Network is responsible for running and administrating an AGORA proxy that represents the enterprise within the AGORA network. The AGORA Enterprise Proxy encapsulates all AGORA functionality at enterprise level. It is the contact point for all enterprise personnel with access to AGORA. The AGORA Proxy is also responsible for associating enterprise knowledge with the AGORA system, maintaining access control lists and permissions for that knowledge, storing information of user groups and roles, as well as general enterprise profile information. The main benefit of maintaing an AGORA proxy at enterprise level is that the responsibility (and related overhead) of maintaining all enterprise information at a consistent state can be handed over to the different network partners.

The AGORA Enterprise Proxies communicate with the AGORA Central server responsible for coordinating all inter-enterprise activities. The Central server maintains a list of all member enterprises and their proxies, as well as indices of all AGORA knowledge. It is responsible for dispatching inter-enterprise queries to the appropriate parties (i.e., AGORA Enterprise Proxies). In short, the AGORA Central server encapsulates all AGORA functionality at inter-enterprise level.

Users connect to their appointed AGORA Enterprise Proxy to get access to the AGORA environment. Any request for information/knowledge that is not part of the users' appointed AGORA Proxy is forwarded to AGORA Central server to see if other AGORA Proxies on the business network can satisfy it.

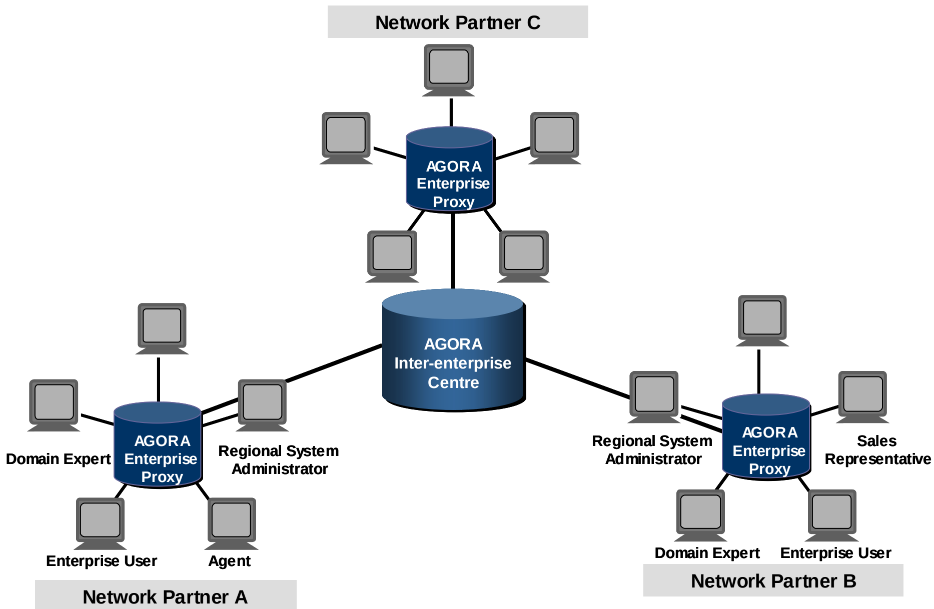


Figure 1. The distributed architecture of the AGORA environment.

2.2 AGORA's Dynamic Model

The type of information exchanged between INTRACOM's regional partners and the Sales and Marketing Headquarters is more of a qualitative nature. It is related to market and technology trends, market place competition, identified opportunities and potential problems in the regional market, and regional customers' requirements and problems. In addition, it refers to the continuously changing domain that characterises the Telecommunication industry.

In an effort to successfully structure such types of information, a dynamic object model is used capable of evolving in the face of changing market conditions, technology, and solutions provided by the network, as well as changes of the network itself.

A *dynamic object model* allows the types of objects to change at runtime, including an addition of new types, a change of existing ones, and an alteration of the relationships between types. Taken together, all types and their relationships form a domain-specific model.

A system based on a Dynamic Object-Model represents classes, attributes, relationships, and behavior as metadata. The system is a model based on instances rather than classes. Privileged users change the metadata (object model) to reflect changes in the domain. These changes modify the system's behavior. In other words, the system stores its Object-Model in a database and interprets it. Consequently, the object model is adaptable; when the descriptive information is modified, the system immediately reflects those changes similar to a UML Virtual Machine described by Riehle et al. [1].

More particularly, the AGORA environment uses a model that is based on the observation framework, as this is defined in [2], and further extended in [3]. The observation framework allows the dynamic description of different types of phenomenon by recording both quantitative and qualitative information.

The Market Observation framework is a generic framework for ”attributed composite objects". The framework allows users to construct a complex business object (like a new policy or a new type of enterprise) from existing components and to let users define a new kind of component without programming.

It has been identified that the information needed for the market description applications can be thought of as a set of observations about people, organisations, products/services, regions and also relationships among them. An observation describes a phenomenon valid for a given period of time. Observations play a large role in the marketing domain, because they associate specific conditions and measurements with opportunities at a given point in time. Some typical market observations are market trend, product or service saturation, brand monopoly, and technological and legal constraints. Some more specific types of information can be seen for following up high-risk markets.

Therefore, by use of this model in the case of the AGORA environment, the information collected during market research, technology research, or during an interview with a customer or from a prospect (either potential customer or partner), is captured and documented in the form of market observations.

Prior to writing a market observation, privileged AGORA users define the observation template together with appropriate access control lists for users to use it, with the support of the *observation type editor*. Thus, the AGORA environment will provide its users with a pool of observation templates that will be dynamically updated.

Then, when a participant of the Sales and Marketing process needs to write a market observation she/he selects the appropriate template and then writes up the report, by use of the *observation editor*. The user can associate this new market observation with an observation already existing in the AGORA network, and / or attach to it information components.

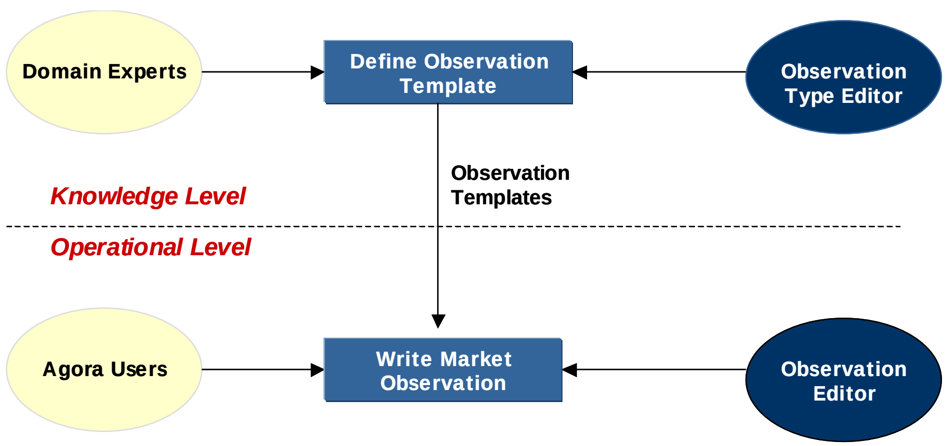


Figure 2. Using the observation framework.

3. Expected benefits

During the sixth semester of the GLOBEMEN project, INTRACOM evaluated the AGORA prototype. As the prototype is not yet used in real business environment, it is difficult to measure the expected benefits. Therefore, this evaluation aimed also at identifying performance indicators to be used in future for measuring the expected benefits. The later was achieved through interview meetings with key personnel involved in the Sales and Marketing process that they responded to questionnaires that were developed for this purpose.

The results from this evaluation indicated that AGORA's perceived value is significantly high. It is believed that it will heavily contribute to the reduction of the management cost of information exchange in the business network. One consideration is that the distributed architecture of the environment entails more effort on behalf of each partner, in order to maintain the information that they contribute to the network. However, the fact that the members of the network will have not only responsibilities, but also benefits, since they will have controlled access to well structured information provided by other members, compensates for it. In any case, it is believed that in order to ensure proper use of the environment, each member's responsibilities and authorities should be legally certified in the cooperation agreement between INTRACOM and its partner.

All in all, it is expected that in the long term the use of AGORA will highly contribute to the development of a "knowledge sharing" culture between the partners. The updating rate of the information registered to the system could be an indicator of the creation of such culture.

It is also expected that AGORA use will increase the level of awareness and its impact on new partnerships, but most significantly to the improvement of existing ones. It is strongly believed that the application of AGORA will increase what is called partners's loyalty to the company. It is very important for partners to feel that they are offered the appropriate tools to perform their tasks, as well as that they don't have only to offer but also to benefit from this procedure. Measuring partners' loyalty is quite complex. The degree of partners' dedication to maintain the information that they have to contribute to the network could act as an indicator of their loyalty.

Finally, the evaluation phase of AGORA indicated also new functionalities that AGORA users are interested to have in future. Part of future development plans should be analysis tools that will be able to relate and compare different market observations, thus supporting the decision-making activities involved in the process. Great interest also exists for AGORA to act as an environment for the management of network competences.

4. Conclusion and future work

This paper presented the rational behind INTRACOM's development efforts in the GLOBEMEN project, and provided a description of the AGORA environment. In addition, the first results of the evaluation of the AGORA environment were presented together with the expected benefits and some indicators to measure benefits in the long term. Future work will be focused on engineering the proof-of-concept prototype into a full environment. Afterwards, the company will examine to expand the use of AGORA in other product life cycle activities, as well as to enhance its functionality to address new user requirements such as analysis tools and support for network competence management.

References

1. Riehle, D., Fraleigh, S., Bucka-Lassen, D. & Omorogbe, N. The Architecture of a UML Virtual Machine. Proceedings of the 2001 Conference on Object-Oriented Program Systems, Languages and Applications (OOPSLA ’01), October 2001.

2. Fowler, Martin 1997. Analysis Patterns, Reusable Object Models. Addison-Wesley.

3. Yoder, Joseph W., Balaguer, Federico & Johnson, Ralph 2000. From Analysis to Design of the Observation Pattern.
   URL: http://www.joeyoder.com/Research/metadata/Observation/ObservationModel.pdf

Renewal Support Services for Manufacturing Systems

Ken-ichiro Mori
OMRON Corporation, Japan (email: mori@fox.omron.co.jp)

Abstract

We developed a method, tools and services that support design for agile set up or agile renewal of manufacturing systems in order to reduce total lead-time. As a manufacturing system is considered as a set of objects, the system from MES (manufacturing execution systems) to programmable logic controllers are designed and built by distributed object model technology. We integrated a variety of technologies for verification of system performance by simulation and effective execution of the renewal process. In this paper, we propose Renewal Support Services based on distributed object oriented model. The results of implementing the framework to a machining line are reported. It was verified that the prototype system had enough functions and good performance.The system shows that the Renewal Support Services provide good factory design support functions in order to reduce total lead-time of the re-design of shop floors in factories of global inter-enterprise network.

1. Introduction

Recently, re-use of the manufacturing facility is widely common in order to produce many kinds of products in small batch size because requirements of the global market are changing rapidly. Renewal of the facility to improve the productivity is required [1]. Especially, when new products are started to be manufactured in the renewed facility, the problem is that of reducing lead-time including preparation time by re-use of the design and modules.

Our target is renewal of a shop floor consisting of a machining center, gantry robots for transfer, etc., which is based on virtual enterprise and extended enterprise models. A demonstration system was designed on a processing and assembly system. The demonstration scenario describes renewal services of the information systems and control systems in the shop floor. The characteristics are as follows.

- To verify the processing and assembly of the product in the virtual facility models for renewal and design of the manufacturing systems.
- To build the real facility after the verification.
- To realize the productivity and verify the quality in the virtual facility models.

The renewal of existing equipment should be prepared while it is still in operation. For starting the production of a new product, the renewal period from designing equipment to renewing and starting the production is required to be shortened. Renewal services should be solutions to provide the engineering companies, vendors, and operators with agile renewal design functions by supporting the design in the virtual models.

The Renewal Support System concept can be summarized as follows.

- Support facility object information sharing and collaborative design in a distributed environment.
- Identify the equipment object interface and implement by plug-in technology.
- Benchmark of the renewal design in the virtual model on a virtual network.
- Obtain the productivity and quality of the system in advance within the virtual model.

The total lead-time for design, evaluation, and implementation of the renewal can be shortened because all the actors of the system concerned use the common facility object that can be implemented by plug-in technology and web-top renewal design tools. A simple renewal, as a demonstration, is implemented in the test bed system at Japan Society for the Promotion of Machine Industry as described in Section 3.

2. Concept of the Renewal Support Service

2.1 Background

The Renewal process services are aimed at lead-time reduction, maximum throughput, optimal productivity, space reduction, effective buffering and the maintenance ability for manufacturing systems. In this section, the renewal support services based on industrial requirements for manufacturing systems in shop floor are described. We defined a renewal process including re-design of the major changes and feedback from the operation and maintenance processes. We named this feedback the KAIZEN activity and support [2, 3, 4].

Manufacturing systems must yield maximum throughput and lean production costs by continuous improvement. Facilities adjust and tuned the performance by minor changes in the KAIZEN activity by the operators. If the result is not adequate, then major changes of the facility or re-design and re-construction processes are required. These two types of changes are called the renewal process.

The reasons for major changes to the machine cells or the facilities are defined as follows.

- Renewal of the production process for higher productivity.
- Addition of new products to the machine cells.
- Improvement of machine layout to enable maximum throughput.
- Reduction of set up time.
- Renewal for smaller batch size.
- Increase machine tools to improve the bottleneck of the production lines.
- Change buffering and routing in order to reduce stocks.
- Electrical change for controllers, sensors, and motors for transfer speed up.

- Change in control logic for improvement of the workflow.
- Adjustment of control parameters or robot paths for reducing production tact time.
- Improvement of safety by addition of area sensors, switches, and exception control programs.
- Reduction of energy cost.
- Environmental improvement for workers.

The renewal support is a typical collaborative process between design engineers and operators of manufacturing systems. The use cases are described as follows.

- Facility design engineer plans the renewal of the machine cell.
- Facility design engineer designs the machine cell and its control for new product manufacturing using the design tools to decide the process in virtual facility objects.
- Facility design engineers and plant managers of a factory can evaluate the benchmarking in advance.

2.2 Overview of the demonstration

The Renewal & Design Support demonstration, which we developed, shows a model and the tools for design and operation support of the renewal service process for inter-enterprises and networks. The demonstration is an industrial prototype including shop floors manufacturing systems. The services support design to enable agile set up and agile renewal of the manufacturing systems in order to reduce the total lead-time.

An overview of the demonstration is shown in Figure 1. Plant managers, operators, engineers of engineering company and facility vendors will share facility objects by use of a common object database and network. The system supports collaborative design services and benchmarking of the design among factories, machine-tool vendors and engineering companies. These actors perform a virtual enterprise network operation and exchange support services and information of the renewal design.

The Renewal services get not only the status of the machine cell, but also the status of its controllers and its devices. Design support functions will be provided by the Operation Virtual Enterprise. The services have a four-step process as follows:

(1) Status data gathering for the renewal

(2) Analysis of the gathered data and finding the problems

(3) Renewal design support

(4) Model implementation support.

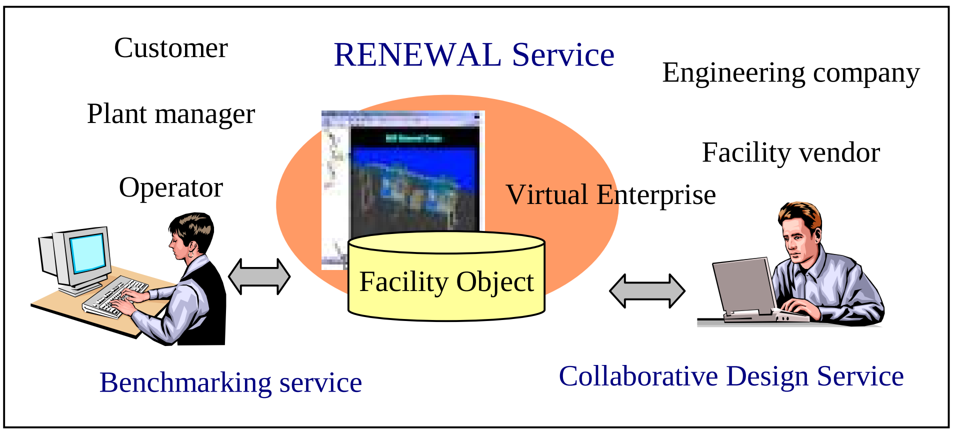


Figure 1. Overview of Renewal and Design Support.

3. System Architecture

3.1 Object technology for shop floors

As a manufacturing system is considered as a set of objects, the systems from ERP (enterprise resource planning), PLCM (product lifecycle management), maintenance and MES (manufacturing execution systems) to PLC (programmable logic controllers) are designed and built by distributed object model technology (Figure 2). We applied the object technologies to control level functions for effective execution of the renewal process.

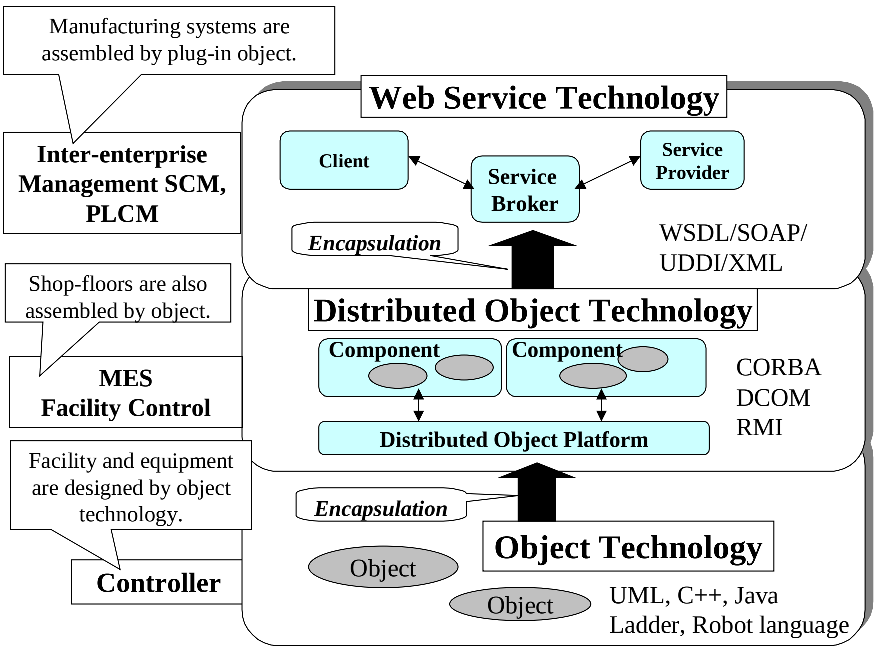


Figure 2. Object Technology.

- Re-use of facility objects through the Internet
- Object type control framework covering MES to device I/O for agile design
- Flexible, extendable and plug-in object interface to connect the services
- Simulation based design and verification
- Virtual-real model data transparency by distributed object model.

Control equipment has a variety of vendor specific interfaces and functions because of critical real-time or control issues compared with MES information systems. A flexible and extendable plug-in object interface is required for Robots, NCs and programmable logic controllers. Figure 3 shows that open and simple interfaces of control objects should be defined because control objects should connect directly to MES, PLCM, Maintenance and other services.

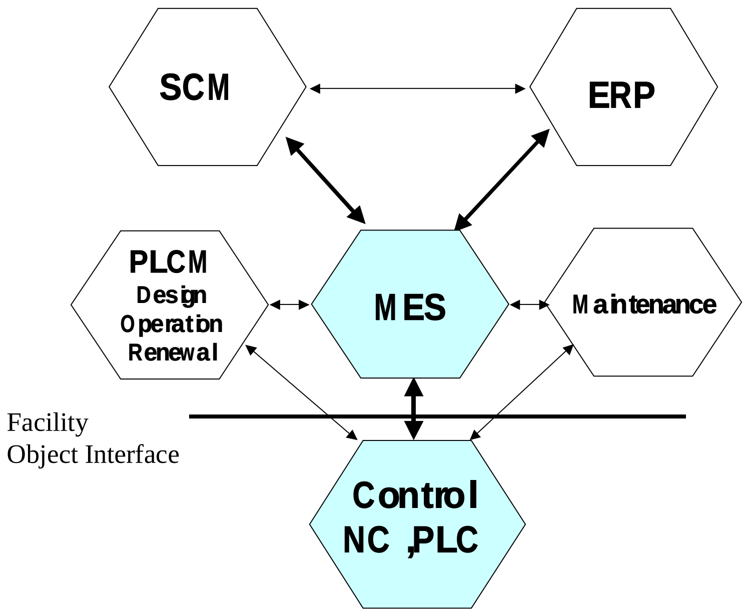


Figure 3. Facility Object Interface.

3.2 Renewal & Design Support System Configuration

Figure 4 shows Renewal &Design Support system configuration. Transfer Management Object in Open MES server directs a transfer start to Control Object in Embedded Controller by the remote method call function. Transfer Control Object is a control program that monitors the input and the status and decides the output signal. I/O Access Object executes the input and output ports. Virtual Facility Server includes a machining cell simulation model with Transfer Machine, a virtual controller with Virtual I/O Access Object and Control Object. The embedded controller and the virtual controller have the same distributed object interface by CORBA ORB.

The facility engineers re-design for the renewal of the cell by use of the Renewal Design Tool. They modify Control Objects and test in the Virtual Facility Server. After the verification of the Control Objects in the virtual system, the renewed object is downloaded to an embedded controller instead of the current object.

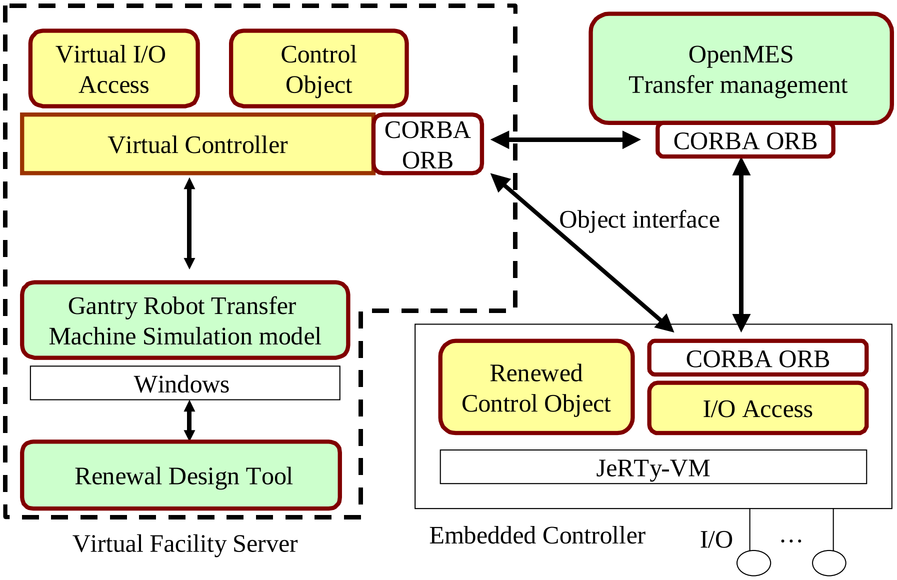


Figure 4. Renewal & Design Support System configuration.

- Java based controller as an open logic controller

A control framework for embedded Java platform and components for I/O controls are provided. The Java platform supports an open and disturbed object oriented technology. Java objects run on any embedded controllers and personal computers, MS-Windows, UNIX, Real-time OS, and mobile phones. OMRON supports a Real-time Java Virtual Machine (JeRTy-VM) for controllers [5].

- OpenMES (Manufacturing Execution system)

Open MES is a Java and CORBA component based framework for production management [6]. The specification document is open. IBM Japan provides Open MES Framework as a product.

- Cimstation model for simulation and evaluation

Re-design in the virtual facility models are performed in the renewal services. Cimstation supports an object oriented simulation model for the shop floor. Mitsui shipbuilding is the vendor.

- CORBA object

Common Object Request Broker Architecture is used for communication between OpenMES and the controllers. VisiBrocker on the PC and VisiBrocker on the controller are connected according to the CORBA standard.

4. Prototype System

4.1 Proposed Use

A case study of improving the safety of the machining cell system was designed. Figure 5 shows the system configuration of a prototype. In this prototype, the equipment object interface is clear and additional functions can be implemented by plug-in methods.

(1) To improve safety, sensors are put in the machining cell to prevent accidents between operators and the gantry robot.

(2) The total lead-time of the renewal process for design, evaluation, and implementation are minimized by means of a virtual-real system and a web-top design tool. These functions are included in the Renewal Design Tool.

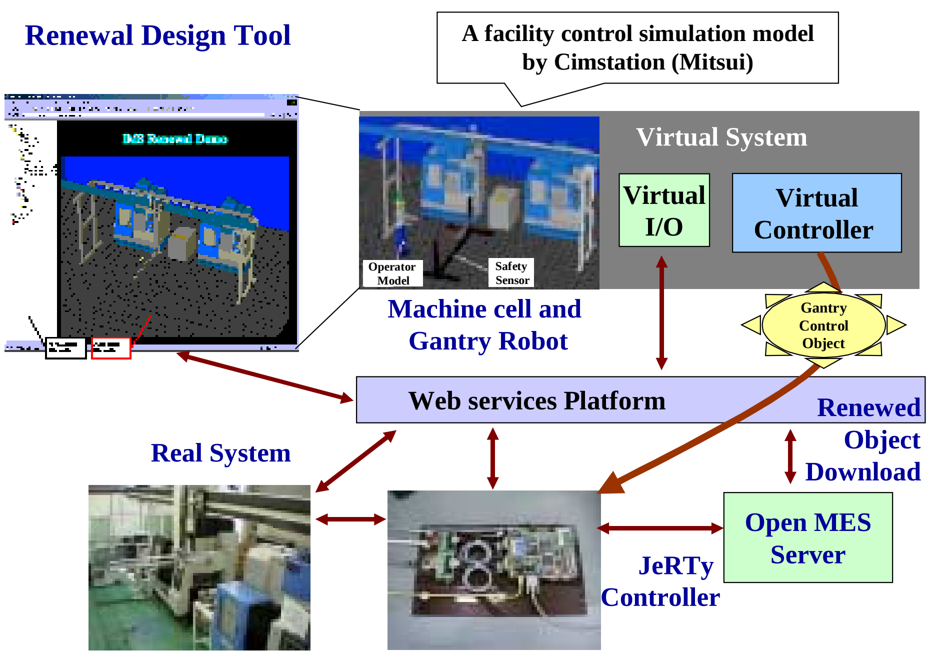


Figure 5. Prototype System Configuration.

4.2 Design tool functions

Figure 6 shows the Renewal Design Tool functions that realize the Renewal & Design Support demonstration. The functions include the UML editor, Component editor for programming, Compiler, Sensor/Actuator monitor, and Component browser of facility objects supported by the Internet.

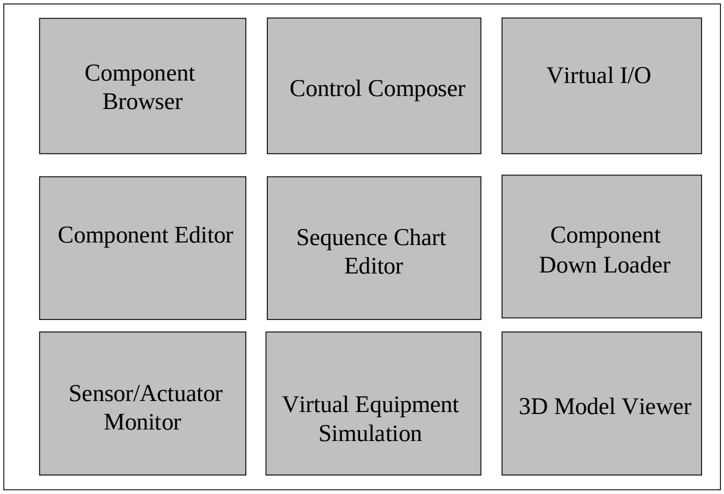


Figure 6. Renewal Design Tool.

4.3 Control object framework

The framework design of the prototype system is described as the following (Unified Model Langrage) use case, class chart and object sequence chart. Figure 7 indicates Transfer Control class as a part of the framework.

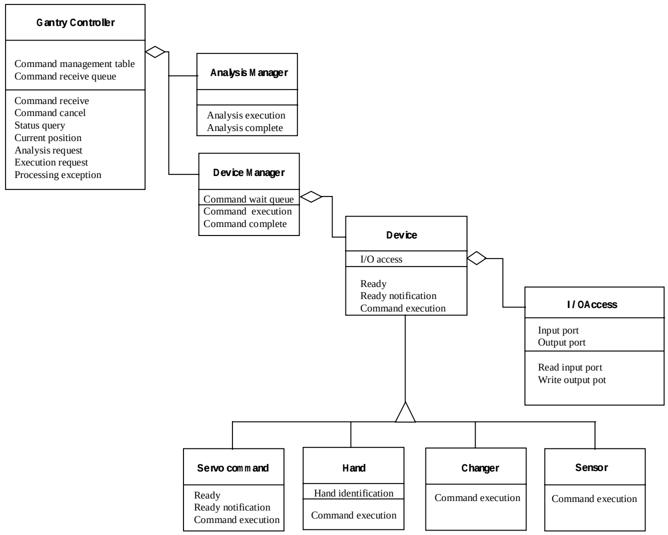


Figure 7. Control Object Framework.

4.4 Implementation of the system

The Renewal & Design Support System prototype was implemented and evaluated in a machining cell in JSPMI Test Bed system (Figure 8). The test bed system is a common manufacturing system for evaluation in the Globemen project. The machine cell has two NC machines and a gantry robot type transfer machine that transfers materials and products. The Renewal & design support

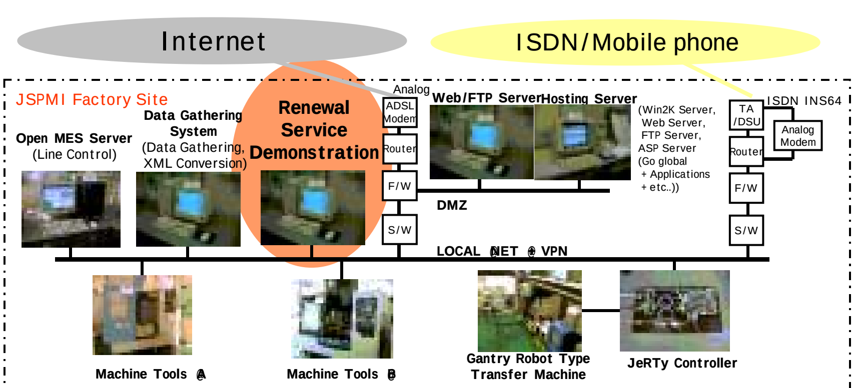


Figure 8. JSPMI Test Bed System.

service is provided by common infrastructure items like the Internet, ISDN and mobile phone.

The control framework was applied to the transfer facility that was controlled by an embedded type controller (Figure 9). The controller outputs position commands to the Servo Positioner through Parallel I/O and inputs the status of the gantry robot. Open MES server, Transfer Control Object and Cimstation communicate by ORB as distributed objects on Ethernet. JeRTy platform has real-time functions including real-time garbage collection and Parallel I/O API. Table 1 shows the system performance of the average time for CORBA ORB communication and the time of the transfer control and I/O Access processing on the JeRTy controller. The result indicates a good performance for the machining cell application.

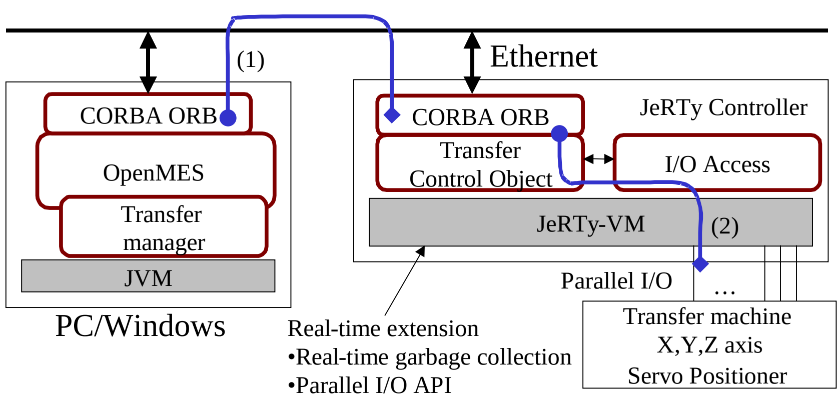


Figure 9. Implementation of the System.

Table 1. System Performance.

Prototype System Performance	Time
(1) Average time of CORBA ORB communication between JeRTy controller and PC	9msec
(2) Average time of Transfer Control & I/O Access processing on JeRTy controller	59msec

The virtual facility model was developed on Cimstation and the Controller object was renewed and evaluated in the Virtual Facility System (Figure 10). The Controller object was downloaded to the JeRTy controller and utilized in the real system. The lead-time was shortened in the Renewal & Design Support System.

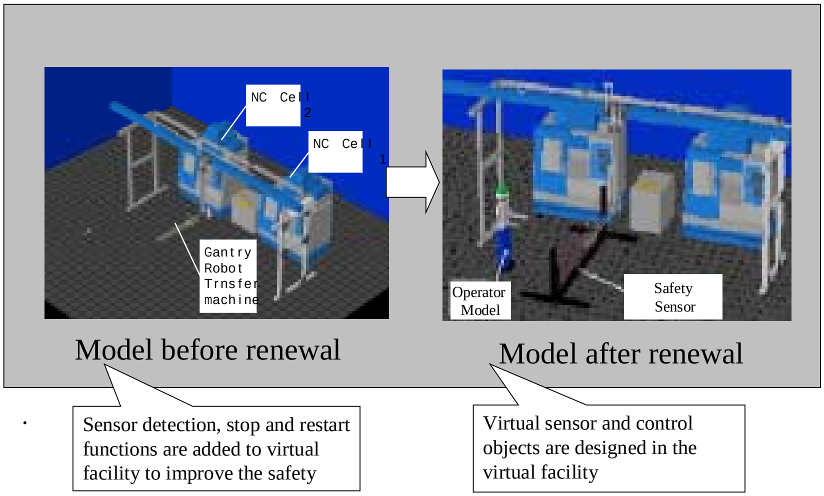


Figure 10. Case Study – Renewal & Design.

5. Conclusion

The Renewal & Design Support system is required in manufacturing systems. The system supports information sharing of facility objects, and collaborative design in a distributed environment between factories and facility vendors. We defined facility object interfaces and realized plug-in functions.

A case study was made of the process of improving the safety of a machining cell as a demonstration scenario. The prototype system showed that the implementation system of control objects had good performance and the ability to reduce lead-time of the renewal process. The web-top tools could display the all results of the design for collaborative review. We will try to apply the system to the other industrial cases and will provide Renewal & Design Support solutions in product lifecycle management business in future.

References

1. Goto, H. et al. 1997. Remote Renewal by Aggregating Real and Virtual Models in Manufacturing Systems. Proceedings of IMS’97. IFAC. Pp. 77–81.

2. Ollus, M. et al. 1998. Systems for Support of Process Operations. Proceedings of IiM98.

3. Mori, K. et al. 1998. Computer Aided Continuous Improvement (KAIZEN) System on Operating Manufacturing system. Proceedings of PTK98. IPK. Pp. 375–380.

4. Mori, K. et al. 2000. Neo-kaizen Applications on the Generic Operations Support and Renewal. Proceedings of DIISM2000, 15–17 November 2000, Melbourne, Australia. Kluwer Academic Publishers. Pp. 236–243.

5. http://www.jerty.com/jerty_e/index.html

6. Hori, M. et al. 1999. OpenMES: Scalable Manufacturing Execution Framework Based on Distributed Object Computing. Proceedings of the 1999 IEEE International Conference on Systems, Man, and Cybernetics, IEEE.

Development of an After-sales Support System for a Multi-vendor Manufacturing System Using Inter-enterprise Collaboration

Toshiaki Kimura
Japan Society for the Promotion of Machine Industry, Japan
(email: kimura@tri.jspmi.or.jp)
Fumio Kasai
Toyo Engineering Corporation, Japan (email: kasai@ims.toyo-eng.co.jp)
Yoichi Kamio
Toyo Engineering Corporation, Japan (email: kamio@ims.toyo-eng.co.jp)

Abstract

This research paper presents and discusses a manufacturing support system which supports not only maintenance services but also consulting services for manufacturing systems consisting of multi-vendor machine tools. In order to do this the system enables inter-enterprise collaboration between engineering companies and machine tool vendors. The manufacturing support system is called "After-Sales Support Inter-enterprise collaboration System using information Technologies" (ASSIST). This paper describes the concept behind the planned ASSIST system, the development of a prototype of the system, and the discusses test operation results of the system.

1. Introduction

Manufacturing support systems using information technologies such as remote maintenance systems and remote monitoring systems are available today [1, 2].

However, such manufacturing support systems are usually machine tool-specific and depend on individual machine tool vendors. A mechanism does not exist that supports an entire manufacturing system consisting of multi-vendor machine tools implying cooperation between different machine tool vendors.

Moreover, the usual scope of applications covering manufacturing support systems is often limited to the maintenance of machine tools and/or controllers, and does not include after-sales business consulting services.

This research paper discusses a manufacturing support system for a manufacturing system consisting of multi-vendor machine tools. The system not only supports maintenance services but also consulting services in both cases based on inter-enterprise collaboration between engineering companies and machine tool vendors. A hosting service environment is proposed for sharing data, information, and application systems among the collaborating engineering companies, machine tool vendors, and factories. A secure access control environment at factories for the exchange of maintenance information is also discussed. In this way, the manufacturing support system enables inter-enterprise collaboration for maintenance and consulting services using these environments. The manufacturing support system is called "After Sales Support Inter-enterprise collaboration System using information Technologies" (ASSIST) [3].

Section 2 describes the concept for the planned ASSIST project. Section 3 describes the development of a prototype for the system and also evaluates the operation results of the system.

2. Concept behind ASSIST

2.1 Background and objectives

Typically, maintenance of machine tools often depends on maintenance services for each individual machine tool vendor. Recently, however, machine tool vendors have developed remote maintenance systems using IT (information technologies) such as the internet [1, 2].

However, for maintenance of manufacturing systems consisting of multi-vendor machine tools, the overall condition of the manufacturing process has to be considered before specifying the maintenance areas. After assessment of maintenance areas, maintenance services by the machine tool vendors corresponding to the maintenance areas have to be procured. If engineering companies integrate multi-vendor manufacturing systems, the engineering companies are responsible for detecting maintenance areas. This means that it is the engineering companies that have to maintain the manufacturing system in collaboration with the machine tool vendors in question. For that reason, there is a need for a manufacturing support system that can handle maintenance of entire multi-vendor manufacturing facilities that can allow inter-enterprise collaboration between engineering companies and several different machine tool vendors.

On the other hand, in order to ensure improvement of manufacturing systems, it is necessary to collect the operational status information of these systems, analyse the data, track problems, and put together solutions for the problems including an evaluation of the solution plans [4]. For these activities, IT tools, such as TQC (Total Quality Control) tools and manufacturing system simulators, are useful. However, for smaller enterprises, it is difficult to deploy such IT tools because they are expensive and difficult to master. Therefore, ways are needed for engineering companies to contract these improvement activities as a consulting service and/or using IT tools providing service using ASPs (Application Service Providers).

The objective of this research is to develop ASSIST as a manufacturing support system for multi-vendor manufacturing systems, which supports not only maintenance services but also consulting services carried out as an inter-enterprise collaboration between engineering companies and machine tool vendors.

2.2 Overview of ASSIST

The organization, which uses the system, consists of more than one multi-vendor manufacturing system, more than one machine tool vendor and an engineering company.

The system consists of these distributed enterprises and the hosting server integrated over the internet as shown in Fig. 1. The hosting server is a data-accumulating, data-providing, and application-providing server for inter-

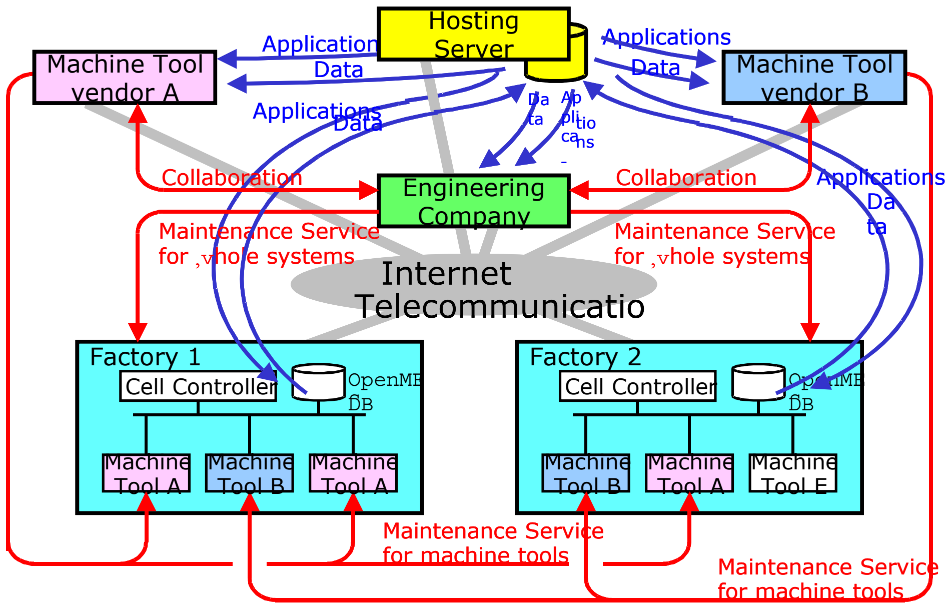


Figure 1. Concept of the ASSIST.

enterprise communication managed by the engineering company or a third party. Characteristics of the system are: managing information such as manufacturing system operational data in XML (eXtensible Mark-up Language [5]) format, and providing data exchange among distributed enterprises using the hosting server. Possible usage scenarios for maintenance and/or consulting services for improvement of manufacturing systems are as follows:

1. Operational data from the manufacturing system is gathered and accumulated in the factory. The data is sent to the hosting server over the internet when the factory needs maintenance service and/or consulting service

2. In the case of maintenance services, the engineering company provides support by finding trouble spots in the manufacturing system using the accumulated data from the hosting server.

3. Then, if the trouble area concerns a machine tool and therefore maintenance support performed by the corresponding machine tool vendor(s) is needed, the engineering company provides the accumulated data to the vendor(s) in question. After this, collaborative maintenance is carried out through

cooperation between the engineering company and the machine tool vendors.

4. In the other case of consulting services for improvement of the manufacturing system as ordered by the factory, the engineering company analyses the accumulated data from the hosting server using TQC tools and/or manufacturing system simulators. The engineering company then submits the results of the analysis, identifies problems, and proposes solutions for the problems to the factory.

5. Moreover, the engineering company can provide application systems such as TQC tools and manufacturing system simulators to the factory by using the ASP functionality of the hosting server.

3. Development of a prototype system

3.1 System configuration and functions of the system

A prototype system for ASSIST has been developed. This section describes the developed prototype system. An evaluation of the test results of the system is presented in the succeeding section.

The developed prototype system consists of a factory system, an engineering company system and a hosting server as shown in Fig. 2. Functions and configuration of these systems are as follows:

1. Factory system
   (Configuration)
   – Multi-vendor machine tools and robots integrated using OpenMES [6, 7], which is a middleware base on CORBA (Common Object Request Broker Architecture)
   – Data gathering server
   – Firewall with VPN (Virtual Private Network) server.

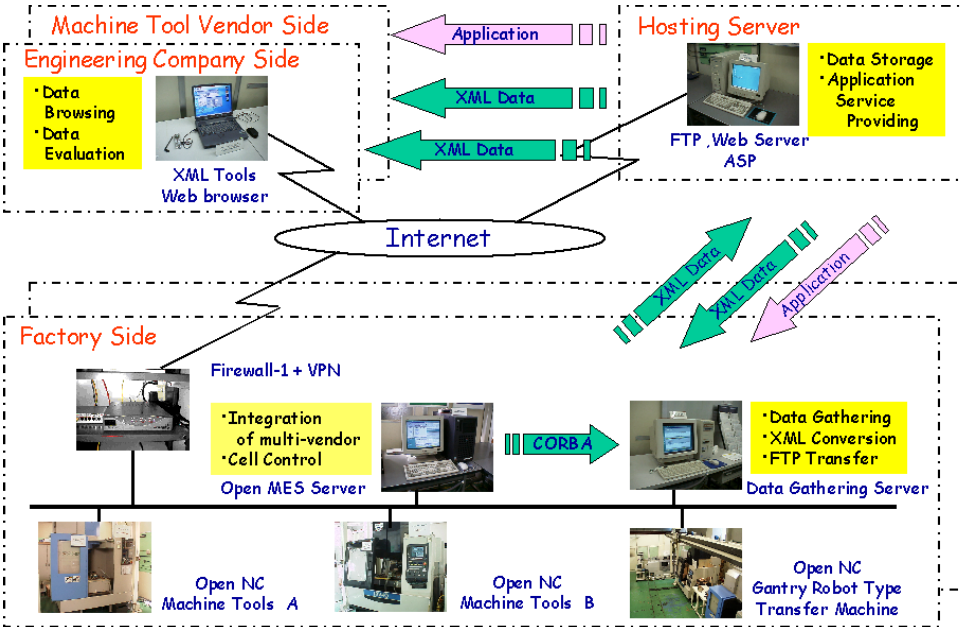


Figure 2. Configuration of the prototype system.

(Functions)

– Gathering of production log data for the manufacturing system, consisting of order information for production, product specification ID, scheduled production volume, scheduled earliest start date, scheduled start date, actual start date, scheduled completion date and actual completion date
– Conversion of the log data to an XML file
– Periodic transfer of the XML file to the hosting server
– Or transfer of the XML file to the hosting server by request of an operator
– The firewall with VPN (Virtual Private Network) server provides access permission control for machine tools of the factory for the machine tool vendors in question in order to allow maintenance of machine tools as shown in Fig. 3.

2. Hosting server

(Configuration)

– Web service and FTP service using Windows NT and IIS (Internet Information Server) by Microsoft Corporation.

				Facility of the factory (VPN Server side)				
			Vendor name	IKEGAI	TOYODA	TOSHIBA	IBM Japan	ARIES
			Facility name	TCR15	PV4-IIA	JRV40	OpenMES Server	Gantry Robot
	User name	User ID	Password / IP Address	192.168.224.150	192.168.224.154	192.168.224.155	192.168.224.156	192.168.224.159
Maintenance division of machine tool vendors and engineering companies (VPN Client side)	Factory User	AAAAAAAA	aaaaaaaa	permit	permit	permit	permit	permit
	Engineering Company A	BBBBBBBB	bbbbbbbb				permit	
	TOYODA	CCCCCCCC	cccccccc		permit			
	TOSHIBA	DDDDDDDD	dddddddd			permit		
	ARIES	EEEEEEEE	eeeeeeee					permit

Figure 3. Permission control of machine tools.

(Functions)

– Transmission and receipt of the XML file and XSL file using FTP services
– Web service of the XML files on a web server.

3. Engineering company system

(Configuration)

– Web browser
– Statistics and analysis tools such as TQC tools that have an XML file interface.

(Functions)

– Receipt of the XML files from the hosting server
– Analysis of production log data for the manufacturing system using the XML file
– Preparation of graphs using the results of the analysis.

3.2 Evaluation of test operation results

Test operation of the developed prototype system is performed. Consulting services by the engineering company through analysis of the operating conditions of the machine tools and usage time of the tools, using the production log data from the manufacturing system, are assumed for this test operation.

On the factory side, the manufacturing system worked for one week to manufacture five types of products: *MESPART1001, MESPART2001, MESPART3001, MESPART4001 and MESPART5001*. The production log data on the factory side is gathered and converted to an XML file as shown in Fig. 4 and sent to the hosting server once a day.

On the engineering company side, one week's worth of production log data for the manufacturing system is received from the hosting server. Machine tool operating conditions, including tool usage times, are analysed by use of statistics and, for instance TQC analysis tools. Graph charts for the results of the analysis are also produced. An example of a graph chart of tool usage times is shown in Fig. 5.

A prototype test operation was carried out, and the performance and functions of the prototype system consisting of the factory system, the engineering company system and the hosting server integrated over the internet were evaluated. All things considered, the test operations proved that the system performed quite well, showing promise for a future full implementation of the system.

However, the security system for the hosting server only uses a single user name and password. Therefore, the data sharing security system for the hosting server will have to be discussed in order to ensure dynamic sharing of data and information between several virtual enterprise partners. Also the ASP functionality of the hosting server will be discussed in this research. Moreover, test of operations that perform prevention, preservation, and maintenance of a multi-vendor manufacturing system are being considered.

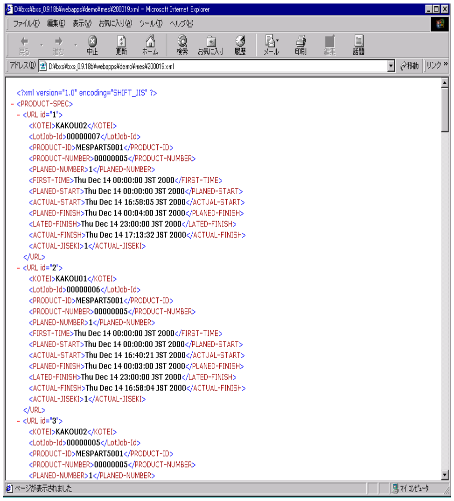


Figure 4. An example of XML file.

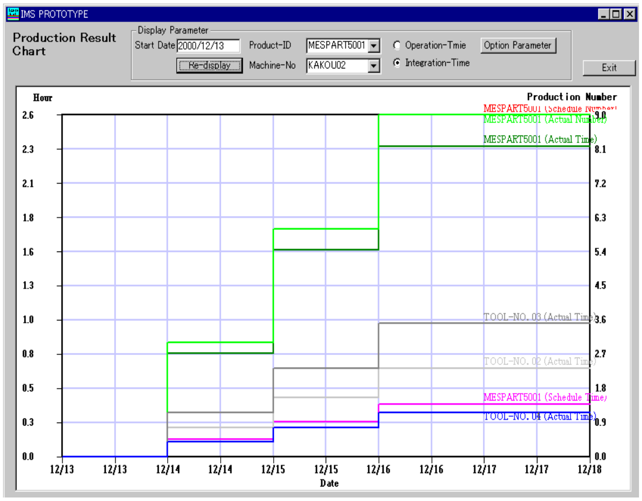


Figure 5. An example of graph chart.

4. Conclusion

The concept for a manufacturing support system named ASSIST has been proposed. ASSIST supports not only maintenance services but also consulting services for multi-vendor manufacturing systems carried out as an inter-enterprise collaboration between engineering companies and machine tool vendors.

A prototype system for ASSIST has been developed. A test operation using the prototype was successful. The test covered activities and functions of the prototype system consisting of a factory system, an engineering company system and the hosting server, all integrated over the internet.

According to the results of the test, the system performed quite well and the possibility that the ASSIST concept can be implemented has been confirmed.

The security system of the hosting server for dynamically sharing data and information among virtual enterprises consisting of more than one will be discussed. ASP functionality for the hosting server will be also discussed in this research.

References

1. Kimura, T. Proposal of the opening technology for the smaller enterprises. Tool Engineer, Feb. 2001, Vol. 45, No. 2, pp. 39–44.

2. NDE REPORT. Nikkei Digital Engineering, Jan. 2002. No. 49, pp. 30–31.

3. Kimura, T., Kasai, F., Kamio, Y. & Kanda, Y. Development of an after-sales support inter-enterprize collaboration system using information technologies. The 5th International Conference on Design of Information Infrastructure Systems for Manufacturing 2002.

4. Kimura, T., Goto, H., Fukuda, Y., Yoshikawa, N., Mori, K., Kawashima, K., Morita, K., Kamio, Y., Yamamoto, E. & Asamori, M. A study of information processing system for the improvement of the manufacturing system. Annual meeting 1999 of IMS project. Pp. 144–147.

5. http://www.w3.org/

6. http://mesa.org/

7. IBM Japan, Ltd. OpenMES Specification Ver. 1.0 Draft Alpha, May 25, 1999.

Knowledge Creation and Virtual Enterprises in Power Plant Construction

Pekka Välikangas
Fortum Engineering Ltd, Finland (email: pekka.valikangas@fortum.com)
Jari Puttonen,
Fortum Engineering Ltd, Finland (email: jari.puttonen@fortum.com)

Abstract

This article describes a procedure for knowledge creation in power plant engineering. Power plant construction typically involves virtual enterprises (VE), which are gathered from company-specific virtual networks (VN). With a focus on the inception phase of the construction project, the paper presents the principles that can be applied in collecting, creating and using standardised information. In Globemen Fortum Engineering (FE) has started the development of a knowledge creation environment (KCE) to support its VE concept. The tools available for collecting and classifying tacit knowledge are also presented. KCE is developed step by step through the implementation of advanced commercial tools in phase with the generation of document and data templates. The paper concentrates on the process of knowledge evolution from tacit information to explicit data, which can even be coded. The management of the total lifecycle information on the power plant is also introduced. The paper includes the data model by which the functionality of VE can be tested during its establishment. In practice the testing may mean, for example, the optimisation of delivery boundaries within VE. This information is classified and stored using the hierarchical system common for product models, making possible an organised collection of feedback information from finished VEs. The hierarchical structures also support product development and Internet-based data exchange between partners. The paper includes a description of a case study concentrating on the collection and use of a product's lifecycle data in VE. In the case study KCE is tested as an environment to offer modularly implemented support for VE.

1. Introduction

A cornerstone in knowledge creation is to collect information that is substantial for future activities. The quality, i.e. reusability, of the data available is often difficult to recognise when the connections between different pieces of information are not obvious. A lot of tacit knowledge may be lost unless the right context is discerned. The knowledge creation environment (KCE) has been developed for collecting and classifying tacit project-specific information and transforming it into explicit definitions. The role of KCE can also be seen as a way to artificially increase the amount and quality of data at the inception phase of the project, i.e. VE. This is done by combining the project-specific information with the hierarchically arranged experimental learning and product knowledge stored in KCE.

Managing power plant information is a complex activity covering the total lifecycle of the plant. Figure 1 shows the main phase in generating power plant-specific information during its lifecycle. In FE the target is to increase profitability by using experiments and product lifecycle knowledge in the inception or tender phase of the project. A tender-specific concept can be achieved by modifying the general concept to meet the requirements presented in the client's inception information. Optional O&M packages from the operator may be included in some power plant tenders. The KCE platform is intended to speed up this modification process and also to improve the quality. Specific concepts are stored in the same scope library as the general concepts. The scope library also includes a description of the partners' role in the delivery, offering the basic data to define tender-specific VE environments. Anticipated costs for entities of the information model are gathered from the resource library and used for cost estimation and pricing. The costs of the finalised projects are stored, as well as reliminary project budgets. The cost libraries are further used in cost control during the project delivery.

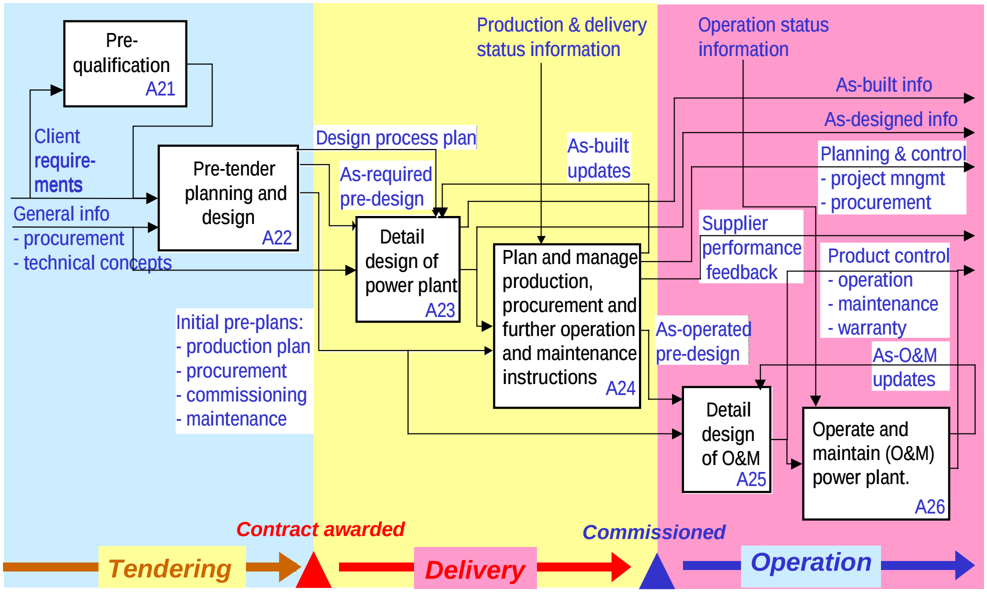


Figure 1. Management of product lifecycle information of power plant.

This paper describes the main features of KCE and the possibilities for its utilisation in VE or VN. The different models used to define product and workflow are also introduced. In VN one of the challenges is the communication and data exchange among organisations whose partnership may only last for a single project. This topic is also discussed in Chapter 4, which expands on the testing of KCE in the Globemen project.

2. Product and activity models

Figure 1 outlines the evolution of project information during the tender phase (A21 and A22). The search of optimal scope and network for project delivery is an iterative process. Different combinations of delivery packages and partnerships have to be analysed. The convergent iteration requires that the product and activities are modelled systematically. In FE the main models used are product, business and project models. Project simulation will be done in order to search and optimise the coherence of partners, limits of deliveries, labour resources and timetables. The models and their role in the VE simulation are described in Figure 2.

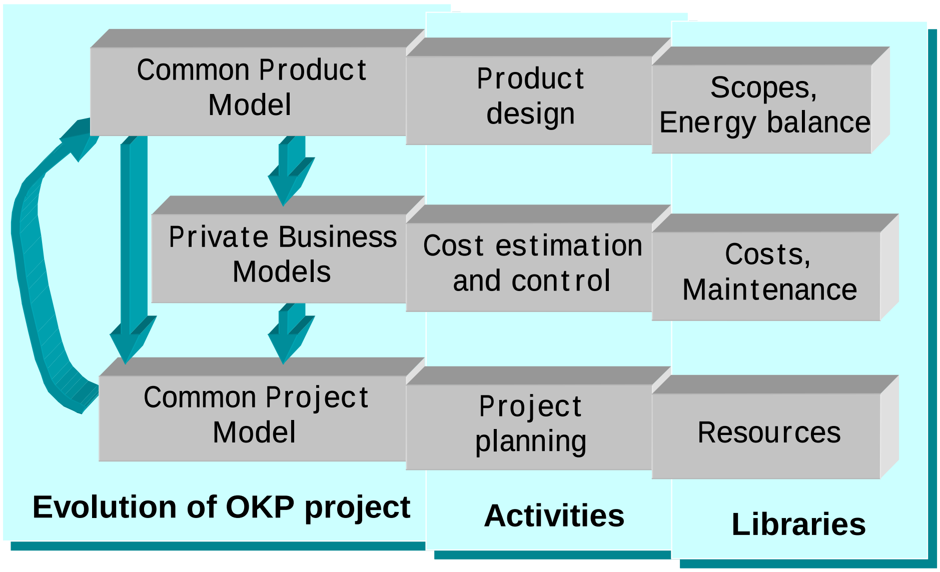


Figure 2. Data model for simulating VE of power plant production.

Common product model describes the parts (systems and equipment) of a standardised power plant from which a project-specific model is formed to meet the client's requirements. The product model includes documents and activities related to the parts or entities. Documents describe non-physical actions – for example, system descriptions, P&I diagrams and layout drawings. Operations describe, for example, the phases in which the parts are manufactured, constructed or transferred during the project.

Private business models consist of company-specific models and the activities of operations and documents. The VE concept should be described in the business model. The company model contains the company's facilities, the facilities' resources and the costs of the resources. Operations and documents are divided into activities. The activities describe more accurately the method of executing the operations or drafting of documents. The duration, resource (employee, machinery) and the method of using the resource will be given for each activity.

Common project models define the project's scope, timetable, delivery packages and other project-specific issues. The VE concept should be incorporated into the project level by a specific VE business model. The operations of VE are based on the product and business models. VE modelling often starts by selecting the principal contractors and main subcontractors. In turnkey projects the scope of the project is defined by pre-contracts among the main contractors. When the VE has signed the contract with the client, the project schedule is confirmed. Companies then allocate their resources to the operations and adjust their internal schedule to meet the deadlines fixed in the contracts.

Simulation and optimisation of the delivery – Delivery packages are optimised by investigating the different ways of allocating responsibilities within VE. A particular simulation tool can be used in the optimisation. The parameters used in the simulation are usually prices, delivery times and scopes of delivery. In FE the results of the simulations are examined with project planning and spreadsheet applications.

3. Knowledge Creation Environment

The basic role of KCE is connecting the product data of construction and operation to support the inception of new projects. The scope of the platform is to classify experiential information into a standardised information model. The input of tacit knowledge in the form received from practitioners is combined with pieces of data entries, thus assisting the creation of rules for decision making. Therefore, the KCE platform is required as a tool for transferring the collected tacit information into explicit form. Pekka Välikangas et. al. have described the principal idea of the KCE in article [1]. More useful information on the basic needs and correspondent enablers of organisational knowledge and networked business can be found from references [2–6].

The sequences between tacit knowledge and clear code for expert systems are described below. **Interviews** are discussions between experts in power plant techniques and knowledge engineers, where the reasoning between product/project thinking and correspondent documents is defined. **Documents** can be common textual, spreadsheet and CAD files in a document management system. **Forms** are graphical user interfaces (GUI) for the formatted data presented in the dialogues and databases. **Informal mapping** is a mind mapping to evaluate tacit knowledge with the logical structures of power plant techniques and to collect correspondent definitions in projects. **Structured mapping** is the formal use of LexiCon [7], XML and Unified Modelling Language (UML) for linking the logical structures of power plant techniques and the product model of an expert system. **Model solutions** are presented with CAD files and Databases, which are connected to the product model of the expert systems and are also presented in design guides. **Constraint of solution** is code (of Lisp, JAVA, etc.) and formulae for checkpoints in expert systems. **Rule for specification** is a code in expert systems for design, operation and maintenance rules. **New tacit knowledge** arises during the process of knowledge evolution as new data in databases, new documents and new descriptions for products.

3.1 Information collection process

Figure 3 illustrates the process of knowledge creation inside the network and the role of the different players in this process. Co-operation in the network is in three different layers, formed by marketing & sales personnel, technical personnel and the knowledge engineer. FE's company-specific part in the VE is the simulation of VE and design work carried out by expert applications.

The process of collecting knowledge is organised by a knowledge engineer, who deals with marketing and sales people. Support from technical personnel in the network is received in ordinary meetings or NetMeeting, so that engineering, procurement and construction (EPC) and O&M duties are properly defined. The iteration in steps 1 and 2 in Fig. 3 presents the capture of knowledge from potential VE structures and technical scopes. The iteration in steps 3 and 4 concentrates on getting partner-specific design documentation connected with the VE and project delivery descriptions. Step 5 is for publishing this information in the network and participating companies.

Based on the customer's inquiry in step 6, steps 1–5 are checked and the VE data is simulated from the project management and cost estimation point of view in steps 7 and 8. Step 9 is a company-specific action for getting this information into design tools and expert systems for the tender phase design.

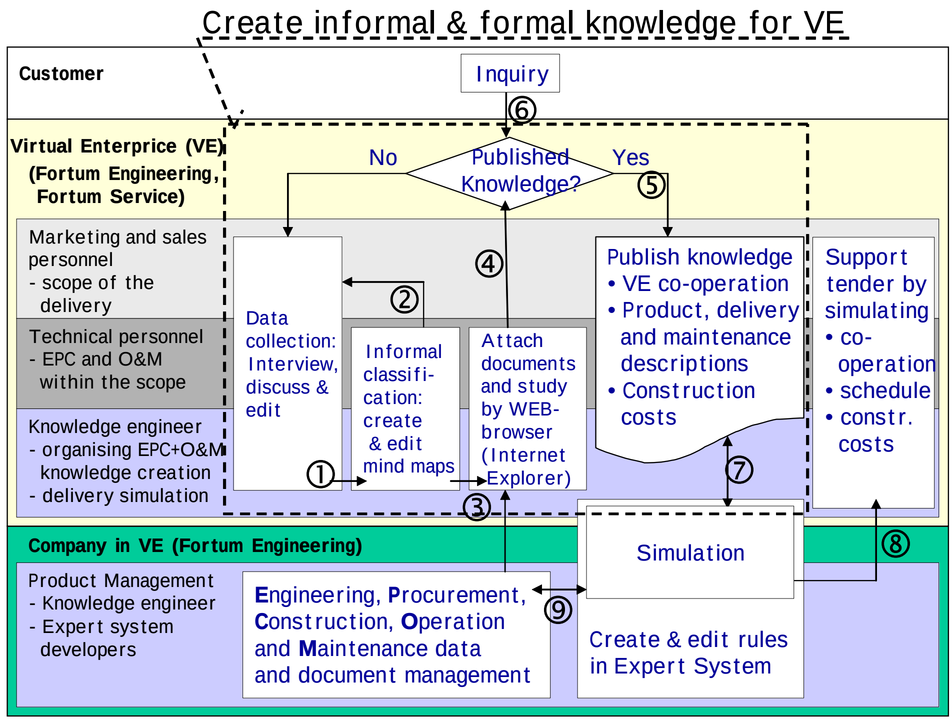


Figure 3. KCE in Virtual Enterprise.

3.2 Collection of tacit knowledge

Mind mapping is a method of collecting and structuring information into informal knowledge. An example of how the design knowledge of the equipment may be mapped is illustrated in Figure 4. Technical personnel and knowledge engineers are analysing knowledge so that they can describe the logical knowledge structures of product, design and project delivery. Knowledge engineers can also define the correspondent structure of the data warehouse and component structure in the expert system. "Active comments and questions" under Knowledge Creation are also structured.

It is possible to work concurrently with different experts and, at the same time, to have joint evaluations in meetings. Furthermore, the mind mapping applications may be used as a case tool for WEB application development. This may then be used for browsing, proposing, entering, modifying, verifying and validating knowledge with a larger number of participants.

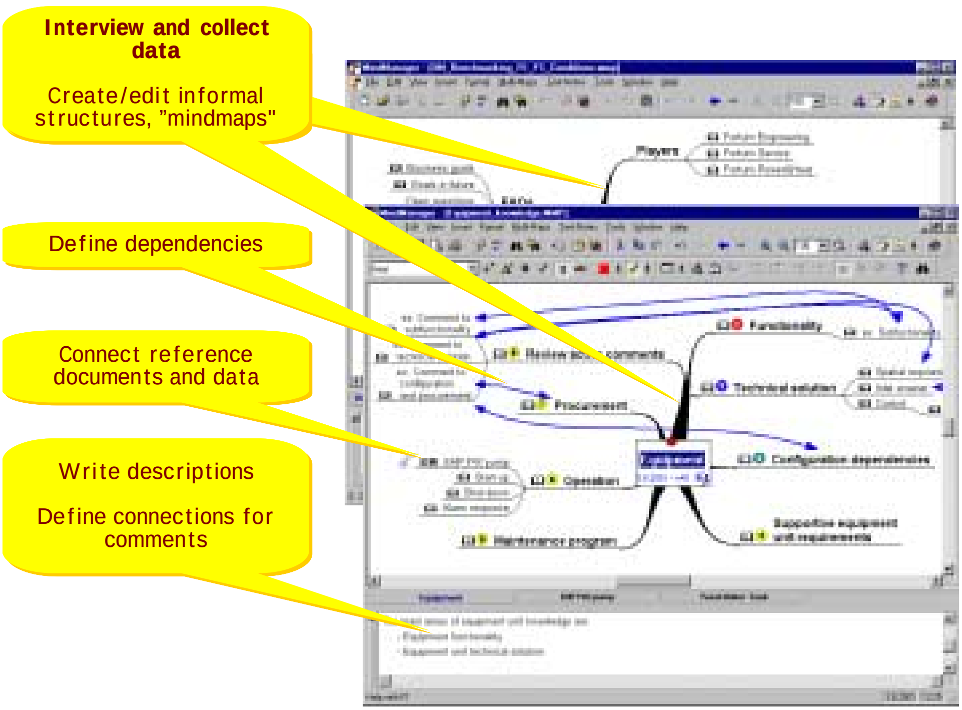


Figure 4. Informal mapping of knowledge by Mind Mapping.

3.3 Distribution of information in VE

Information is distributed in the intranet and document management systems by dynamically creating WEB pages from mind maps and XML exports from structured documents. Mind mapping software is available for key people like knowledge engineers, technical personnel and sales managers. Feedback is received throgh the user interface of the applications and Internet browser.

3.4 Use of product and activity models in KCE

In structured mapping the collected and created rules and associated structures are stored in a knowledge repository. Work between informal and structured mapping is manually defined using the LexiCon software from STABU [7]. The knowledge is connected with the same semantics as that of the informal mapping (Figure 5). An example of the support for formal mapping is shown in Figure 6. **The pane on the left-hand side** of the dialogue is for the subject, activity, property, unit and reference trees of components. The **right pane** is for showing detailed information on the component selected in the left pane, as well as for showing how the selected component is associated with other items.

The following mechanisms are available for making the network of associations: **component mechanism** for defining the structures of the equipment, systems and activities; **property mechanism** for defining the measurement of the subjects and activities; **reference mechanism** for pointing out the rules that are related to the described subjects and activities; **usage mechanism**, which is an automatically created summary of how the component is used by other components.

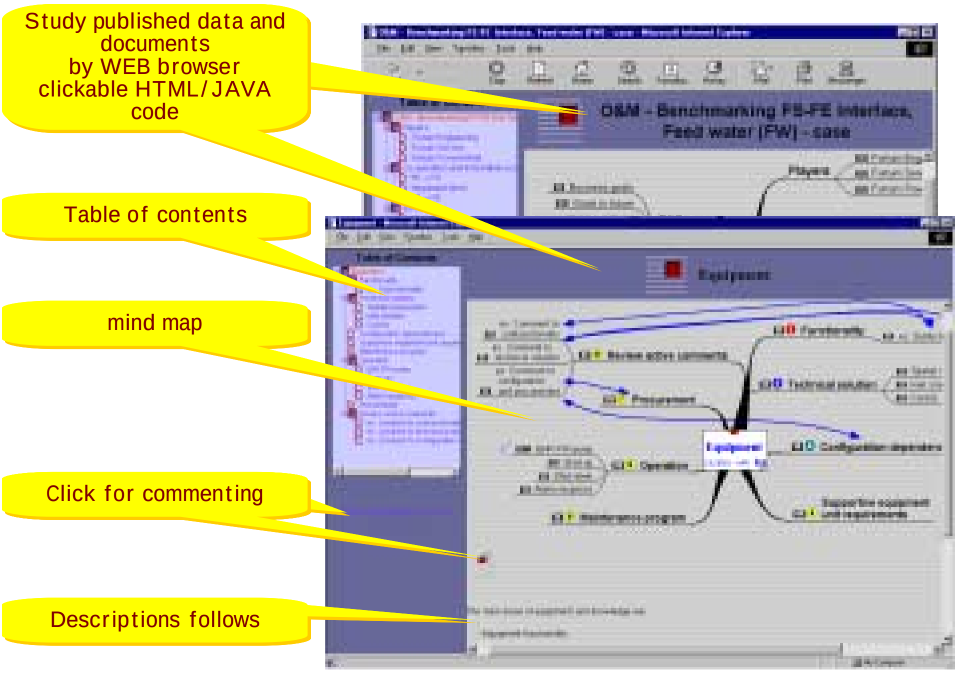


Figure 5. Dynamically created WEB pages from the informal mapping of knowledge.

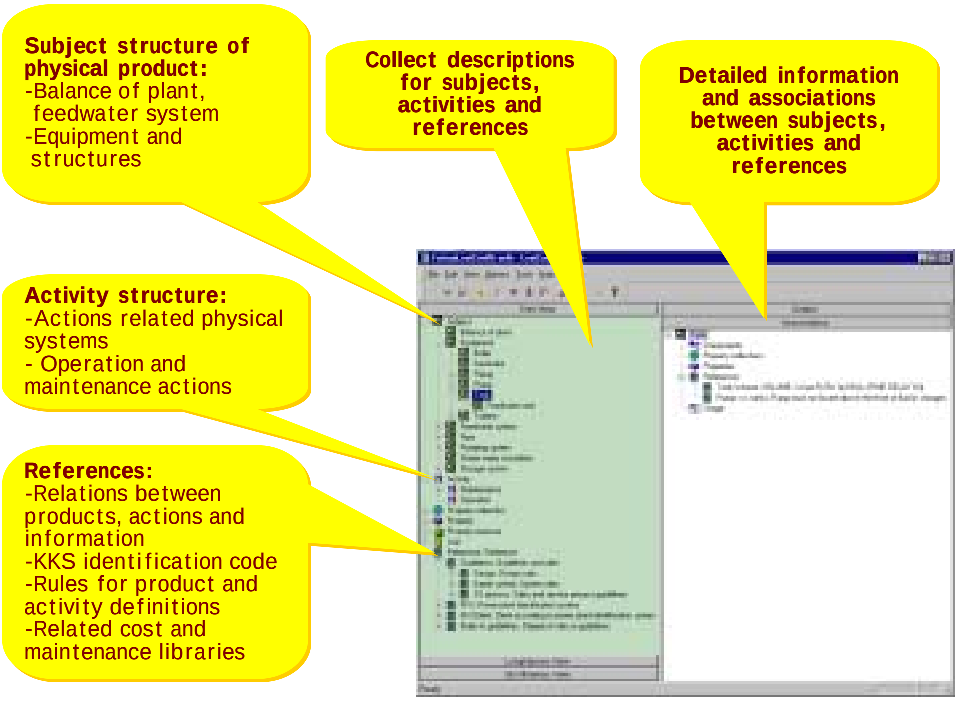


Figure 6. User interface of LexiCon to formal mapping of knowledge.

4. Use of KCE in power plant project

The system of initiating VE from VN in order to deliver a subsystem of a power plant is illustrated in Figure 7. The first step in establishing VE is to define the optimal combination of partners for the delivery. KCE makes it possible to gather information by simulating the function of VE in advance. The system helps to define the parties' shares, costs of shares and timetables of the total delivery. Sub-chapters present ways of using KCE for defining projects within the scope of the delivery and service requirements in order to establish a tender in VE.

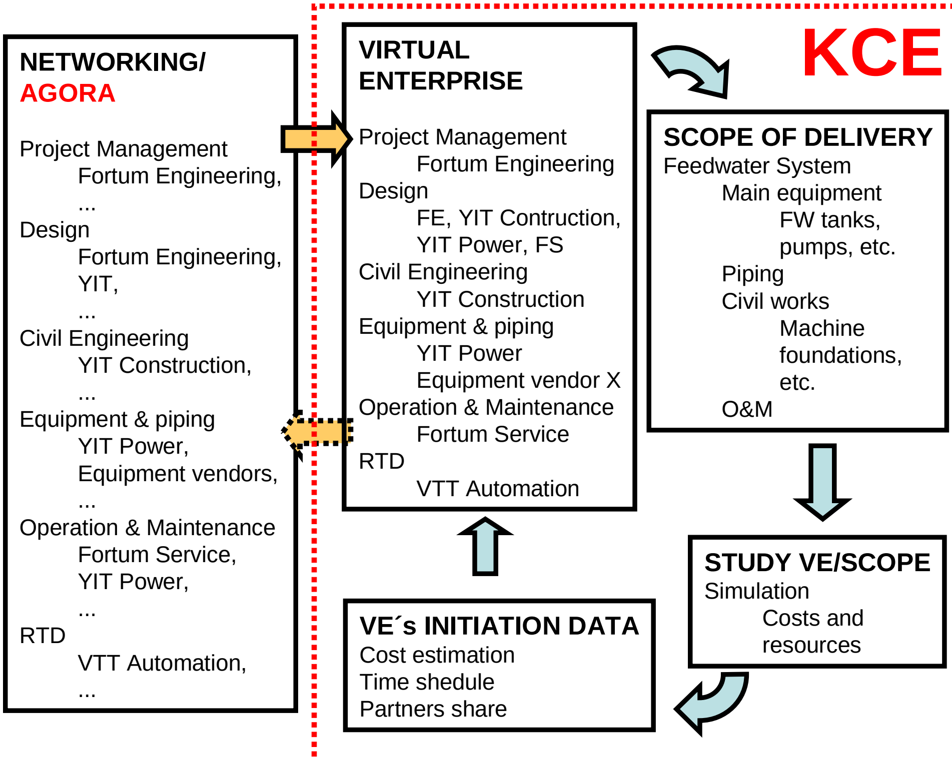


Figure 7. Tested generation of VE in GLOBEMEN project.

4.1 Description of VE

Figure 8 illustrates a way of collecting information during the formulation of VE. The partners' business goals are studied so that co-operation and information exchange are defined relative to the scope of the delivery and data requested for simulating the project delivery. Figure 9 shows how data and example material is collected and structured in order to understand partners' responsibilities and requested material in VE.

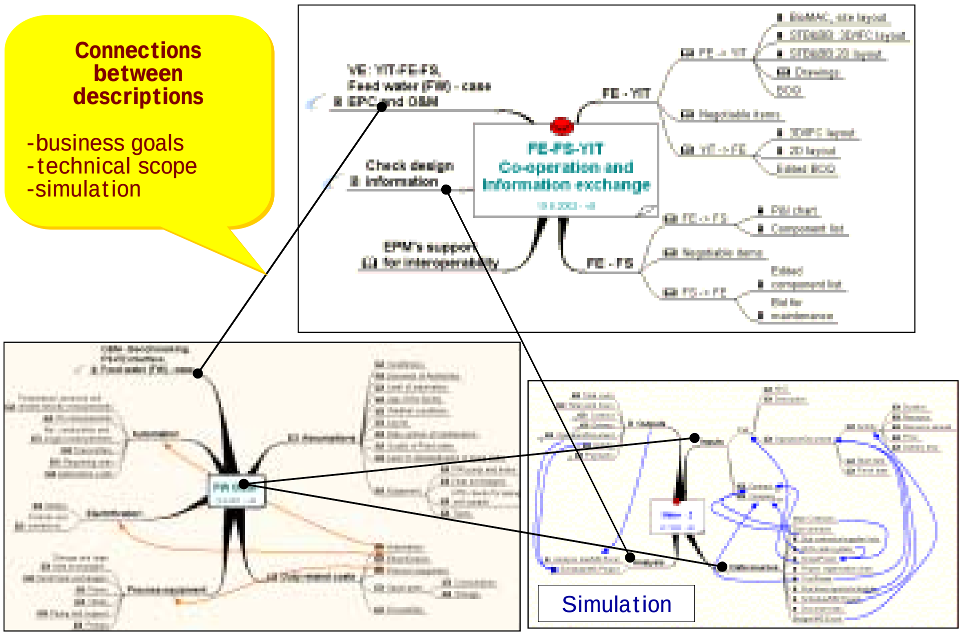
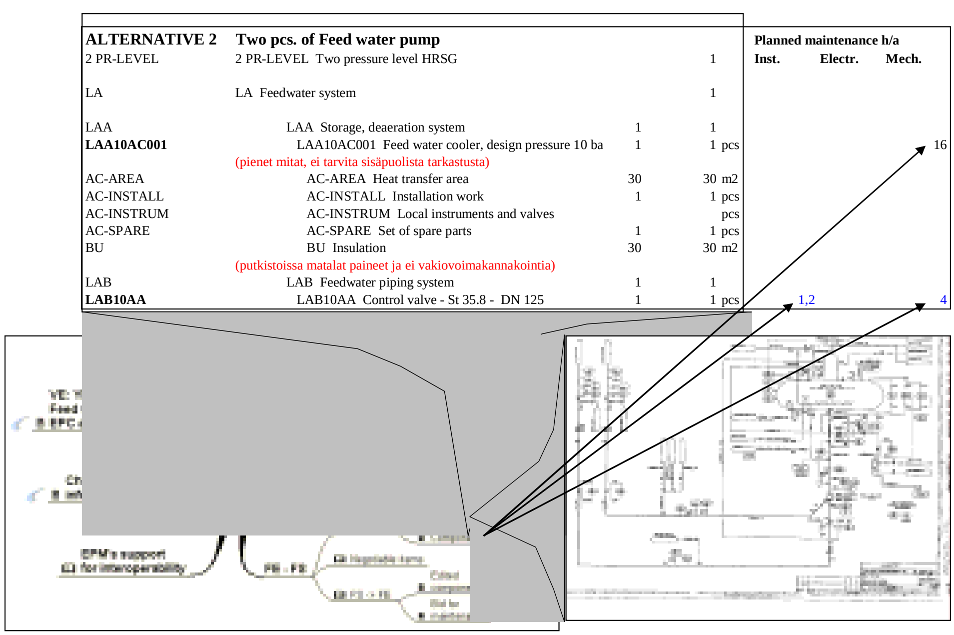


Figure 8. Combining mind maps of VE knowledge.



				Planned maintenance h/a		
ALTERNATIVE 2	**Two pcs. of Feed water pump**			**Inst.**	**Electr.**	**Mech.**
2 PR-LEVEL	2 PR-LEVEL Two pressure level HRSG		1			
LA	LA Feedwater system		1			
LAA	LAA Storage, deaeration system	1	1			
LAA10AC001	LAA10AC001 Feed water cooler, design pressure 10 ba	1	1 pcs			16
	(pienet mitat, ei tarvita sisäpuolista tarkastusta)					
AC-AREA	AC-AREA Heat transfer area	30	30 m2			
AC-INSTALL	AC-INSTALL Installation work	1	1 pcs			
AC-INSTRUM	AC-INSTRUM Local instruments and valves		pcs			
AC-SPARE	AC-SPARE Set of spare parts	1	1 pcs			
BU	BU Insulation	30	30 m2			
	(putkistoissa matalat paineet ja ei vakiovoimakannakointia)					
LAB	LAB Feedwater piping system	1	1			
LAB10AA	LAB10AA Control valve - St 35.8 - DN 125	1	1 pcs	1,2		4

Figure 9. Collecting data inside the knowledge in VE.

4.2 Knowledge exchange in VE

The data exchange within VE is illustrated in Figure 10. The data exchange concerns the defined informal and structured information of the product, delivery and O&M. The parties are using the VE platform in order to exchange and store the collected knowledge for cost estimation and time scheduling. The VE platform has been developed in the GLOBEMEN project and is based on the Product Model Server of EPM Technology. The information exchange is sequential, where the relevant VE knowledge is defined in three phases – numbered in Figure 10.

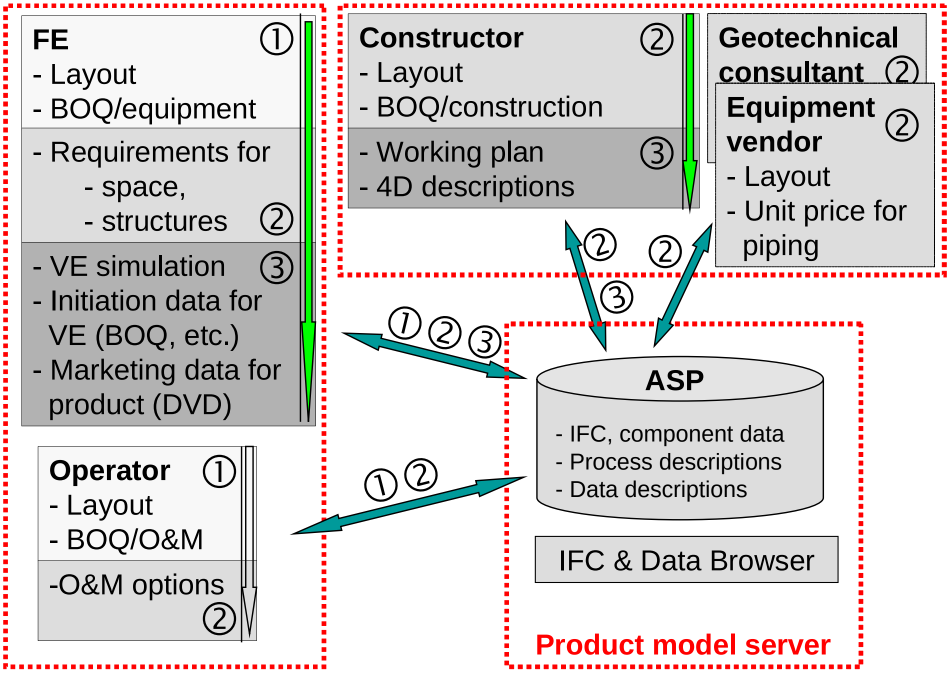


Figure 10. Data exchange within VE.

The leader partner (FE) has collected information about the **balance of the plant** in order to define the **power plant process and corresponding equipment**. **Space and site layout** definitions have been gathered for describing the **requirements for construction** – i.e. **fire zone**, **noise level** and **structural** requirements. **The operator of the power plant** (Fortum Service) has collected

O&M definitions to build a suitable **operation and maintenance option for tender**. **The constructor partner** (YIT Construction) has defined the **layout, BOQ and working plan for construction** so that the technical solutions of **facade** and **machine foundations** are optimal for the constructor. The **4D simulation**, which is a time schedule of the construction process presented in a 3D product model, is based on the product information collected from the different partners.

Finally, with all the data collected from the different partners, it is possible to **simulate VE** in order to establish the initiation of VE. The KCE has been used for gathering and structuring knowledge as fully explained and distributed data packages together with design tools, which were needed in the classic data creation and data exchange within VE. The correspondent CAD applications and cost libraries have been tested with XML/IFC-based advanced interoperability between the different parties in VE.

5. Conclusions

Based on the case tests, the KCE is a promising concept for defining VE and establishing advanced support for information exchange between different parties in VE. It is obvious that the XML/IFC-based exchange in the product model was not sufficient alone, because there are different ways of defining business and products in VE. Therefore, further structured explanative publishable descriptions were needed beside the actual data in order to understand the essence of the products and projects in VE. The KCE is seen as an enabler of VE, where the major role is to harmonise the data exchange between the different parties in VE.

References

1. Välikangas, P., Kazi, A. S., Puttonen, J., Sulkusalmi, M. & Hannus, M. 2000. Knowledge Creation at Fortum Engineering. The 4th International Conference on Design of Information Infrastructure Systems for Manufacturing 2000 (DIISM2000).

2. Cohan, P. S. 2001. e-Profit, High Payoff Strategies for Capturing the E-Commerce Edge. ISBN 0-8144-0544-4

3. von Krogh, G., Ichijo, K. & Nonaka, I. 2000. Enabling Knowledge Creation. ISBN 0-19-512616-5

4. Nonaka, I. & Takeuchi, H. 1994. The Knowledge-Creating Company. ISBN 0-19-509269-4

5. Davenport, T. H. & Prusak, L. 1992. Working Knowledge. ISBN 1-57851-301-4 (pbk)

6. Schierholt, K. 2001. Process Configuration. ISBN 3-7281-2780-9

7. Välikangas, P. 2001. Configure inception software. CONCURrent Engineering in Building and Civil Engineering, Brite EuRam BE96-3016, R2201.

An Object-oriented Application Framework for Construction of Manufacturing Execution System

Akira Okano
IBM Japan, Japan, (okano@jp.ibm.com)
Tateo Kawamura
IBM Japan, Japan, (tkawa@jp.ibm.com)
Shunichi Asaka
IBM Japan, Japan, (asaka@jp.ibm.com)
Satoru Koyama
IBM Japan, Japan, (E29523@jp.ibm.com)

Abstract

Abstract: This paper describes a framework for Manufacturing Execution System (MES), based on the concept of object orientation. The framework, OpenMES, supports an approach that reduces the complexity of constructing an MES, by supporting a step-by-step manner. The paper includes an evaluation of the framework based on experiences in a variety of applications that were developed with it. OpenMES is connected to a B2B framework and hence, agile global manufacturing such as sharing production data among sales division through the production division and rapid response over a supply chain can be realized.

1. Introduction

This paper describes a framework for Manufacturing Execution System (MES) in the assembly and machining industry. The framework, OpenMES, is developed on the basis of the concept of the object-oriented framework with considerations of issues in a system construction of MES.

This OpenMES framework in this paper is a MES framework for the discrete process developed by IBM Japan, and is based on “Open MES Application Framework” [KAWA99, HORI99, OKANO99] as a reference model which was developed and validated by Manufacturing Science and Technology Center (MSTC).

The framework allows a user to construct a target system with necessary customization and assembly of provided software components based on MES model, which is a template of the target system. It aims at constructing MES with shorter implementation time and lower const.

The framework was applied to some real systems. One of them is installed at the Japan Society for Promotion of Machine Industry as a middleware for the research prototype known as “ASIST” of GLOBEMEN Work Package 1 (Sales and Service). GLOBEMEN is an international research consortium focusing on the global manufacturing and conducted by Australia, EU, Switzerland, and Japan.

2. Issues in MES Development

Issues in the construction of MES are discussed here from the view point of a system development.

- Effective Response to Unique Requirement

Development of MES in machining and assembly process often becomes one-of-a-kind production for correspondence to characteristics of production site.

However, the resulting costs and long lead time in development are increasing becoming unacceptable to industry.

- Consolidation of Connection among Applications

MES is a complex system consisting of various applications, and it is often introduced as divided multiple systems by application area. These applications may be introduced in different timing. In such a system, connection among applications tends to be insufficient.

- Real-timeliness of Information

Recent production systems are required correspondence to complex production methodology such as various kind small production or variable kind variable production rather than small kind mass production. For this purpose, information of production site is required to be updated in minute order or second order. Traditional distribution of work orders and collection of work results based on paper sheet do not meet the requirements. Construction of an on-line system updating digitalized information in real time becomes indispensable.

- Information Sharing and Collaboration

In order to drive optimization of a whole production system by introduction of MES, collaborative environment for sharing various kinds of information accumulated in production site and for solving problem by related organization are required. For this purpose, easy access method to the information as well as digitalization of information in production site should be realized.

3. Overview of OpenMES Framework

OpenMES framework is developed as a platform software supporting construction of MES for discrete production system. It enables construction of a target system with necessary customization and assembly of provided software components based on MES model, which is a template of the target system.

3.1 Framework

OpenMES framework is developed on the basis of a technology called “object-oriented framework” (hereafter, framework). Framework is a mechanism for making and re-using components of software and is “A framework is a set of prefabricated software building blocks that programmers can use, extend, or customize for specific computing solutions.” [Taligent].

Framework defines elements of target software system. Each element is realized and provided as a software component. Construction of highly reliable system in short time and lower costs can be realized by assembling software components on the basis of proper framework.

3.2 Adoption of Java/CORBA

Runtime environment of MES should be covered broad area including controllers of production equipment to host computer running ERP or SCM. Therefore, we adopted CORBA (Common Object Request Broker Architecture) [OMG] as the platform for implementation of OpenMES. CORBA is one of promising platforms for construction of distributed system over multiple computer systems. As for implementation language, we selected Java whose language processor is independent on platforms. Both Java and CORBA are available on many platforms and the combination of these two technologies is considered large advantage as implementation platform of MES assuming distributed environment and multiple platforms.

3.3 Construction of FactoryWeb

In the latest system development, system development based on Web is indispensable for sharing information and collaboration. In this kind of system, software called application server becomes to take principal role in a server. It is a middleware integrating environment including Servlet, JSP (Java Server Pages), EJB (Enterprise Java Beans), CORBA as well as Web server.

Implementation platform of components of OpenMES framework is Java and CORBA and it makes easy to be embedded in an environment of application server. As a result, environment where appropriate person can share information of production site in real time and can collaborate with each other for production optimization can be constructed. We call this kind of environment as FactoryWeb.

3.4 SubSystem Model

During the development of “Open MES Application Framework” in MSTC, we analyzed various activities in shop floor, and identified application domains to be included in MES. We divided MES into 11 subsystems. The subsystems are modeled to ensure that they work as independent systems and have minimum overlaps each other. At the same time, cooperation between subsystems is also considered. The subsystem model clarifies relationship between subsystems, and defines information that are exchanged or shared by the subsystems.

This approach reduces the complexity of MES, and makes possible to construct MES step-by-step manner.

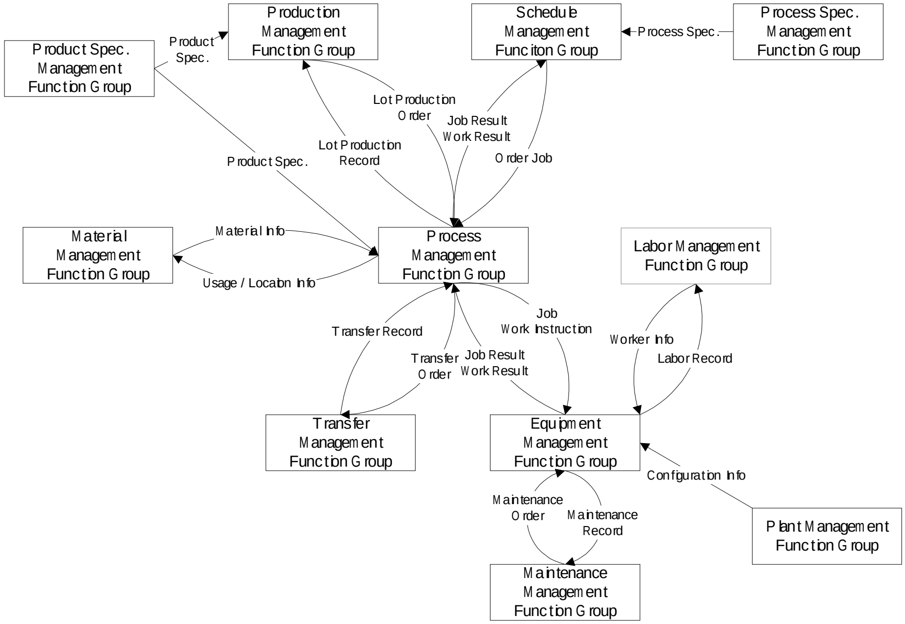


Figure 1. 11 MES Subsystem.

4. Supported Subsystems

OpenMES framework has employed the following three subsystems from MSTC's subsystem model.

- Process Management Subsystem
- Equipment Management Subsystem
- Schedule Management Subsystem.

5. Process Management Subsystem

Process Management subsystem is responsible for dispatching process jobs, monitoring progress of manufacturing process in real-time, and tracking the process results. The following functions are provided:

- order management
- job management
- job dispatching
- collection of job result
- collection of work result.

5.1 Order Manager Component

Order Manager component is an entity-manager that manages orders. It provides basic methods to manipulate an order object, which include add, remove, modify, and find method.

5.2 Job Manager Component

Job Manager component is an entity manager that manages jobs. It provides basic methods to manipulate a job object, which include add, remove, modify, and find method.

5.3 Dispatcher Component

Dispatcher component is responsible for dispatching a job to a resource, and sequencing jobs dispatched to a resource based on specific sequencing rule, and collecting job result and work result.

An assignment of job to resource is usually determined by the scheduler statically. However, there are cases that the assignment should be change dynamically at shop floor level. The following resource configurations require the dynamic assignment change. OpenMES framework has modeled these configurations and supports dynamic assignment change.

5.4 Production Controller Component

Production Controller component is responsible for operations that involve multiple components in Process Management subsystem. For instance, releasing process jobs to shop floor involves the following steps:

- ask Order Manager to set the released flag to the orders associated with the jobs being released.
- ask Job Manager to record release date/time into the jobs.
- ask Dispatcher to dispatch jobs.

Production Controller is responsible for executing above steps. The above steps should be executed as a single transaction. Production Controller ensures that they are committed / rollbacked in a single transaction.

6. Equipment Management Subsystem

Equipment Management subsystem provides interface functions between equipment controllers that control equipment devices and the MES management layer.

It provides following functions:

- manage information on configurations of equipments
- monitor status of equipments
- query Jobs and notify Job Results
- query Work Instructions
- notify Work Results.

6.1 Equipment Component / Process Equipment Component

Equipment component and Process Equipment component are connectors that connect an equipment controller to the MES management layer. Equipment component provides an interface between an equipment controller and an equipment monitoring system. Process Equipment component also provides an interface with a process management system on top of the interface provided by Equipment component.

- Equipment Component

Equipment component provides an equipment controller with interface to notify generic status of equipment for monitoring equipments. Equipment component handles following information of equipment's status.

Status	overall status of an equipment: active, down, standby, attention
Alarm	alarms which are defined for each equipment, such as parts jam
Property	properties that indicate additional status of an equipment
Event	events that occur in an equipment and that should be notified to a monitoring system

Above information that an equipment controller generates is notified to the equipment monitor component when an equipment controller calls a notification API provided by Equipment component.

- Process Equipment Component

Process Equipment component defines APIs to handle Jobs. By calling these APIs, an equipment controller can obtain Jobs dispatched to the equipment, and notify its progress to the MES management layer (i.e. Dispatcher component in Process Management subsystem). Process Equipment acts as just an interface; the equipment controller is responsible for keeping the status of the job being executed.

6.2 Equipment Monitor Component

Equipment Monitor component provides functions to monitor the status of equipments. The followings are major functions Equipment Monitor provides:

- receive notification of equipment's status and alarms from equipment components.
- store the latest equipment's status and history of the status into a database
- reply to query requests for equipment's status from equipment monitoring applications.

There are two options for monitoring equipment's status: the monitor inquires the status to each piece of equipment repeatedly (pull model); each piece of equipment notifies its status to the monitor repeatedly (push model). The OpenMES framework selects the later option. Each piece of equipment sends status information to Equipment Monitor component and monitoring applications get equipment status from the component.

6.3 Equipment Configuration Manager Component

Equipment Configuration Manager component provides functions to manage information of equipment configurations. Equipment components and Equipment Monitor component read the equipment configuration information from Equipment Configuration Manager component for their initialization.

While Equipment Monitor component manages equipment's attributes that dynamically change at runtime, Equipment Configuration Manager component manages static equipment's attributes that are defined at build time.

Since the equipment configuration information differs for every system, it is one of customization points. The default equipment configuration information has following properties:

- equipment id
- model and type text string
- location of equipment
- ids of Process Unit contained by the equipment.

6.4 Connection to the Equipment Controller

How to connect the MES to equipment control system layer is one of important subjects in building MES applications.

In the OpenMES framework, controller devices are connected to the MES by the equipment controller virtually. OpenMES framework does not define the substance of equipment controller, but it only defines abstract connector interface between Equipment component and the equipment controller. Supplier of controller devices or system integrator should implement this connector interface for each controller device.

Each controller device has unique interface. Therefore, equipment controllers are implemented for every controller devices.

Recently, many controller devices have network interfaces that support TCP/IP. In application programming interface, high level interfaces such as OPC (OLE for Process Control) are being provided. System integrator can develop equipment controllers efficiently by using such communication protocols and programming interfaces.

7. Schedule Management Subsystem

A scheduler is a tool for making daily schedule based on production order and process resource information. There are many scheduler products. Furthermore, some companies have unique scheduler as part of production planning system. Therefore, the OpenMES framework assumes the use of existing schedulers, and does not define the interface specification so far.

In current implementation of OpenMES based MES systems, the system integrators have to develop the interface module for each scheduler. However, the activity to standardize scheduler interface is making progress. Once such a standard interface becomes widely available and a common interface module is provided as a part of the framework, the system integrator will not need to develop new interface module for each system.

8. Evaluation of the Framework from System Integration Experience

8.1 Integration Variety

MES applications we developed using the OpenMES include variety of scale from small- scale validations systems to large-scale mission critical systems. The overview of developed applications is summarized in the following sections.

- Type of Process
  - flexible manufacturing system that consists of NC machines
  - assembly line in which manufacturing robots and workers exist
  - assembly job shop in which workers assemble parts manually.

We applied OpenMES framework to job shop type of systems in which work in process are routed freely from an equipment to other equipment, and also applied it to flow shop type of systems in which work in process are routed through fixed route such as belt conveyor.

Most of client applications use a Web browser as front end GUI. There are two types of client application. One is Java applet that directly communicates with components on the MES server. The other is CGI/Servlet that work on the server and that return results as HTML document. The former is used for applications that need complicated interactive operations, and the latter is used for the display of reports.

- Communication Methods between an equipment controller and an equipment device
  - TCP/IP: An equipment controller communicates with the equipment device that has a network interface by using the protocol defined by the device on TCP/IP.
  - JNI (Java Native Interface): An equipment controller calls APIs in control programming library provided for the equipment device by using JNI.

8.2 Evaluation in Applied Cases

The principal merit of using a framework is considered as high productivity of development by re-using software component. However, it is not easy to measure quantitatively the degree of the improvement of productivity by using the framework because there is no case that the same system is developed by different methods. Unfortunately, we have not measured quantitative data about OpenMES so far also.

On the other hand, firms that take interest in adoption of OpenMES framework are often large enterprises that have multiple factories or production lines. These enterprises have often invested in duplicate or triple development for multiple factories or production lines because of the reasons described in the section "Issues in MES Development." Therefore, OpenMES appeals to those enterprises because it enables set up or modification of production line in short time and can reduce investment of the development by a deployment of developed MES to other multiple factories and production lines.

Re-using of a framework is not limited only to re-using of the implementation. If anything, knowledge or know-how contained in the design are more important. OpenMES framework itself has been developed with feedback of the information of developed multiple MES in the past and receives many benefit from the knowledge and know-how in those MES. Furthermore, a user can extend it to a framework embedding knowledge and know-how that is specific to the enterprise and can deploy it to systems specific to each factory and production line. Actually, there are customers who are deploying a system to multiple factories with this approach.

9. Concluding Remarks

This paper studied construction of MES from the view point of system development and proposed a development methodology using a software framework for effective development.

Object-oriented technology, which is prerequisite of a framework, is rapidly spreading in software development domain. In accordance with it, the concept of framework will be spreading hereafter.

In the near future, this framework is connected to B2B framework and hence, agile global manufacturing such as sharing production data among sales division through production division and rapid response over a supply chain will be realized.

References

[Gamma95] Gamma et al. Design Pattern Elements of Reusable Object-Oriented Software. 1995, Addison–Wesley.

[HORI99] Hori, Masahiro, Kawamura, Tateo & Okano, Akira. OpenMES: Scalable Manufacturing Execution Framework Based on Distributed Object Computing. 1999 IEEE International Conference on System, Man, and Cybernetics (SMC'99).

[**KAWA99]** Kawamura et al. Manufacturing Execution System in Open Environment based on CORBA. Journal of the Japan Society of Precision Engineers. 1999, Vol. 65, No. 9, pp. 254–1258. In Japanese.

[KIMURA02] Kimura, Toshiaki & Kanda, Yuichi. Development of a remote monitoring system using a portable phone for manufacturing support systems. IFIP WG5.7 International Conference on Advanced Production Management Systems, APMS2002. Pre-print, Sept. 2002, pp. 225–233.

[**OKANO99]** Okano et al. Development and Trial on framework of open control systems for FA devices. http://www.ipa.go.jp/NBP/10seika/ec9_data/002/001.htm. In Japanese.

[OMG] OMG: "CORBA for Beginners. http://www.omg.org/corba/beginners.html

[OSEC98] Fujita et al. OSEC: Open System Environment for Controllers ---OSEC Architecture and OSEC-API ---. Open Architecture Control Systems. Itarian Institute for Industrial Technologies and Automation, 1998. ITIA Series, Vol. 2, pp. 157–186.

[Taligent] Taligent. Building Object-Oriented Frameworks. http://www-106.ibm.com/developerworks/library/oobuilding/index.html

Part III

Inter-enterprise Coordination

A Planning and Scheduling Integration Platform for Operational Virtual Enterprises

Yasuyuki Nishioka
Hosei University, Japan (email: nishioka@k.hosei.ac.jp)
Fumio Kasai and Yoichi Kamio
Toyo Engineering Corporation, Japan (email: kamio@ims.toyo-eng.co.jp)

Abstract

This paper deals with dynamic supply chain for OKP environment. SUPREME is a system architecture including web-based virtual enterprise design and collaborative planning system. The architecture contains an APS module, PSLX interfaces, web-service client-server modules and RDBMS. The system is located both on actual enterprise members in the network and a supply chain coordinator, who performs as an agent configuring a suitable supply chain dynamically. A prototype system is developed and demonstrated. In conclusion, SUPREME is one of the most fruitful systems in the next ICT infrastructure.

1. Introduction

Manufacturing is changing drastically in the ICT infrastructure. Since a manufacture takes more partial roll in hole manufacturing processes, global supply chain management should be more necessary. Moreover, to catch up customers' requirement just on time, the supply chain itself should be changed dynamically [1, 2]. This paper deals with an architecture in which dynamic supply chains are managed.

The prototype system for the proposed architecture is named SUPREME: SUPply chain integration by REconfigurable ModulEs. The architecture depends on the APS (Advanced Planning and Scheduling) framework and XML based communication protocols on Internet. In this case, APS systems are implemented not only in factories, but also logistic firms and supply chain coordinators offices. The interoperability of these systems and application integration are achieved by PSLX (Planning and Scheduling Language on XML specification) [3].

This paper shows architecture and a prototype system for it. Then we discuss its evaluation with the following business scenarios. First one is about a supply chain agent. A supply chain coordinator arranges the most effective supply chain considering the hole manufacturing processes given by a customer. Second scenario is integration of delivery and manufacturing. Here, a logistic processes and manufacturing processes are connected in the scheduling level. The final one is outsourcing management. Using APS collaboration, a master production schedule of a customer and its partial distributed schedule of a supplier are integrated.

The organization of this paper is as follows. First, in the section 2, the proposed system architecture is illustrated. Then PSLX interface that provides messaging service in the system is introduces in the section 3. Applications of the architecture to some business scenarios are explained in the section 4, some of which are demonstrated with a prototype system shown in section 5. Finally, the section 6 describes some concluding remarks.

2. SUPREME Architecture

The proposed architecture named SUPREME is used in a dynamic supply chain business models for OKP environment. In the target environment, each enterprise has to have function to reconfigure the relationship of its partners. In order to do this, they should be able to select suppliers quickly, and also manage them consistently until the production is finally completed. The proposed system architecture supports these business processes using ICT infrastructure and APS technologies.

In this framework, APS performs in planning and scheduling of each partner's activities, so that throughput of the dynamic supply chain will be maximized. Moreover, APS deals with unexpected changes in reality by adjusting their schedule consistently. Some times, the changes affect to other schedules in different enterprises. In that case, a system can maintain the relations of schedules by using APS and Internet technologies.

2.1 Main features

Features of the proposed framework are as follows. First, the target of the system is OKP environment. Although there are many supply chain management systems for repetitive production, supply chain management for OKP needs different methods and technologies. Since OKP has to make a supply chain network for each customer order, a partner selection process is required many times. To shorten production lead time, the system should flexibly support the configuration and re-configuration of the network.

Second feature is that the system supports collaboration of planning and scheduling processes of different enterprises. The selection of partners is evaluated not only by the quality of the products but also by delivery date. Depending on temporal relationship of delivery dates, total lead time of the supply chain is changed dramatically. Therefore, supply chain manager should concern delivery date in order to synchronize the network. APS in this framework provides re-configuration or re-scheduling functions. This is also a very important roll of the proposed system.

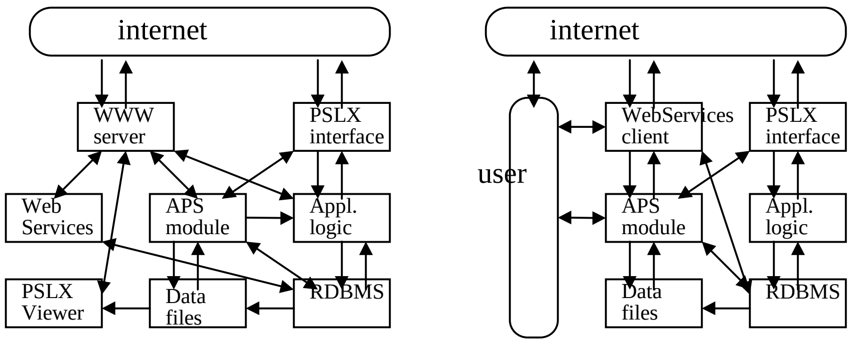
The final feature is openness of the communication protocols used in this framework. We use two communication protocols: One is so called web-services, and another is a PSLX interface communication protocol. Both two protocols are using XML-SOAP technologies, global standard of the next generation of Internet infrastructure [4]. Except of business processes in the application, every specifications of each access protocols are available to see. Web-services are discussed mainly in W3C, and SOAP specification is also there. On the other hand, PSLX interfaces and its specification are available to use on the Web [5]. The information of PSLX interface protocols are provided and maintained by PSLX consortium Japan.

2.2 System Components

The systems for each enterprise are divided into two types. One consists of web-based server side applications. This is for the supply chain coordinator that deals with synchronization of the business processes on the target supply chain. The other is a client side system that directory manages each supply chain member's business processes. The activities in the processes are supported by APSTOMIZER, APS system developed in HOSEI University.

Communications between partners are available in two ways. One is web-based client-server communications, in which an enterprise gets its partner's information via the server-side system. Once an enterprise puts information to the server, then, partners who know a federate key can connect to the information. The second type is peer-to-peer communications that the supply chain partners directly send their information each other. When federate processes are time constrained, it is better to make peer-to-peer communication in order to synchronize the business processes.

The important modules in the systems are illustrated in Figure 1. First, both systems have an APS module. The server side APS makes hole supply chain plan, whereas the client side module deals with the schedule inside of each partner. The scheduling viewer stored in the server side is used in the client side in order to show the production schedules of their supply chain. In the figure, modules on the Internet communication protocols are addressed, such as web-services and web-application programs. These business logic are available by WWW sever or PSLX interfaces.



(a) Server side system (b) Client side system

Figure 1. Main modules of the proposed systems.

2.3 Messaging Protocols

The proposed architecture supports two types of communications. One is server-client communications, and other is peer-to-peer communications. Both messaging processed are implemented by web-services interfaces or PSLX interfaces. Web services provided by the WWW server are used by client side application programs without WWW browsers. This is developed using XML-SOAP technologies.

On the other hand, the PSLX interface is also used XML and SOAP technologies, but the server side doesn't need a WWW server module. Furthermore, PSLX interface is used both as client programs and server programs. This means that the partners can communicate asynchronously. When an enterprise's process need federation in their business processes dynamically, the server-client communication is not enough. In that case, PSLX interface performs well in a peer-to-peer communication.

3. PSLX Interface

PSLX stands for a Planning and Scheduling Language on XML specification. The candidate of specification recommendation is now in progress by PSLX consortium Japan, and it will be completed in the spring 2003. PSLX interface is developed according to the draft version of the recommendation, and makes application programs easy to communicate their planning and scheduling information through Internet.

Since the interface is supported by SOAP technologies, application programs on each partner can immediately access and send XML data to each other. In order to make peer-to-peer communication, the interface module has both server and client capabilities. Using this interface module, collaborative planning and scheduling is available in virtual enterprises.

4. Business Scenarios

Considering OKP environment, there are many kinds of benefits if different enterprises share their information and make collaborative decisions on SUPREME. Especially, planning and scheduling problems are important to catch up to the changing market environment. This section shows some business scenarios suitable for using SUPREME. Actors of the scenarios include customers, manufacturing enterprises and a third party logistic (3PL) company. Since these actors have different decision-making systems, a supply chain coordinator, which is a part of the proposed system, is necessary to establish win-win partnership.

The following use cases represent typical benefits from the system, which dynamically suggests a best partnership of members in the network. Three simple use cases are listed. First, a customer orders OKP product that needs a new supply chain network because the product requires many unique manufacturing processes and the customer doesn’t know the best supplier for each (UC1). A manufacturer knows detail of a parts delivery schedule of the logistic company in order to maintain their production schedule more accurate (UC2). When a manufacturer asks their partial manufacturing processes from partners, the outsourcing processes are monitored, as same as they are internal processes (UC3). The rest of this section, these use cases are explained in detail.

4.1 Supply chain agent

The first use case scenario is that a user who requires OKP from scratch accesses SUPREME while making quotation and selecting a best supply chain recommended by the system. In a quotation process, the customer puts his/her request in a form of process plan. Then SUPREME ask the relative partners capability and availability to meet the schedule. Since suppliers registered their capability to carry on the process candidates, SUPREME can select partners for each process that is defined by the customer. After that, APS module calculates feasible plans, in which all temporal constraints are satisfactory.

In this case, SUPREME performs as an agent who arranges a best plan to produce the customer's order. One of the differences between the agent and a supply chain planning staff is that former can be automatically executed through Internet. Furthermore, after a supply chain is established, the members of the supply chain can be cooperated each other through Internet until the network is dismissed. This process chain is conducted by SUPREME. Figure 2 demonstrated this scenario by a collaboration chart.

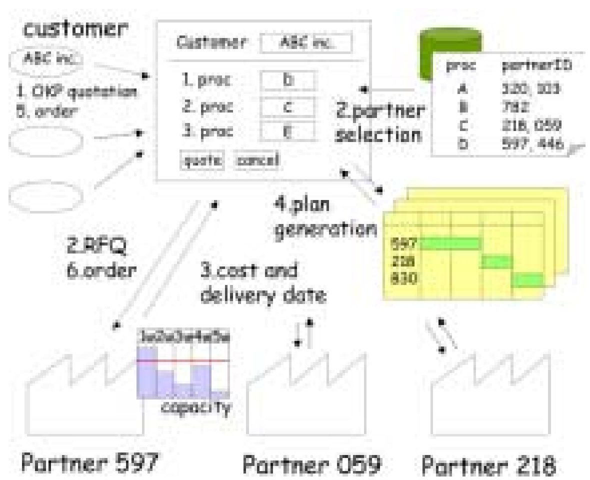


Figure 2. Supply chain configuration agent.

4.2 Delivery process integration

The second scenario is integration of manufacturing process and delivery process. For instance, while a 3PL partner manages delivery processes ordered by manufacturers, this is a very important roll to connect the customer's manufacturing processes with the supplier's manufacturing processes. This means process integration of a logistic enterprise and manufacturing enterprises. Suppose that a truck driver has an accident and the arrival time is behind the schedule, or a supplier's final process is delayed to the shipping time. In this situation, revised logistic schedule is sent to the 3PL manager and relative manufactures to request to rearrange the current schedule.

Detail of the collaboration is shown in Figure 3. A manufacturing user sends purchase order to a supplier, who then ask 3PL company to deliver the products. Since both the customer and the supplier have their production schedule, the delivery process schedule is uploaded to the SUPREME server in order to synchronize with the production schedule. The customer frequently checks the delivery process as well as the supplier's production process, so that SUPREME suggests to make reschedule the customer's plan when some serious outside changes are occurred.

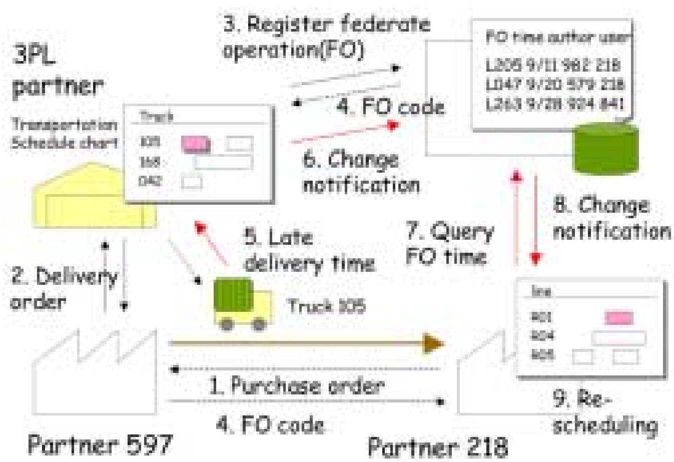


Figure 3. Delivery process integration.

4.3 Outsourcing management

The final scenario is addressed in outsourcing processes. When a manufacture makes production plan by loading resource capacities, a part of the orders would be asked to some suppliers that have capacity of resource usage for the corresponding production processes. In OKP, the selection of such supplier takes a lot of time, because most of the cases are the first time for the enterprise. Like the first scenario, this partner selection for outsourcing is supported by SUPREME.

Furthermore, SUPREME copes with the collaboration processes after the supplier selection. As the Figure 4 represents, the customer's production processes and supplier's production processes are synchronized by peer-to-peer communication. This communication process has an advantage that changes in one partner's manufacturing processes are immediately sent to the other. In this case, SUPREME is a kind of broker, who gives federation keys for the partners in order to the private communication.

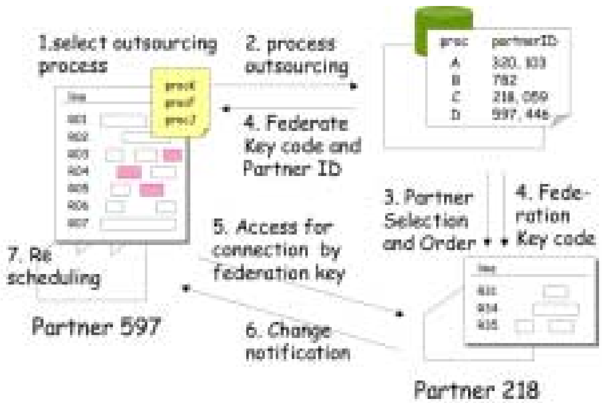


Figure 4. Outsourcing management.

5. Demonstration

Since SUPREME is a system architecture, actual systems implemented for each business scene would have different faces. In this time, a prototype system of SUPREME is developed for further discussions. The Figure 5 shows some graphical user interfaces of the system.

First of all, the partner registration form is used for new members who want to join the virtual enterprise network. In this form, each member has to register its information of the company profiles and also to describe its capability in terms of partial production processes in total virtual supply chain. Then the order entry form is shown for a customer to design and input any manufacturing processes to produce appropriate products.

This information is sent to the SUPREME agent who gathers corresponding partner's manufacturing capacity. After the APS modules calculate some supply chain configuration plans, the plan recommendation form gives them as candidates. If there is more than one plan, each plan is recommended with its cost, delivery date, and quality information. Furthermore, the Gantt chart that represents the supply chain production schedule can be shown for each alternative.

Forms in the figure are used in communication processes between a OKP customer and a supply chain coordinator in the first business scenario. The prototype of SUPREME also copes with the other scenarios including peer-to-peer communications.

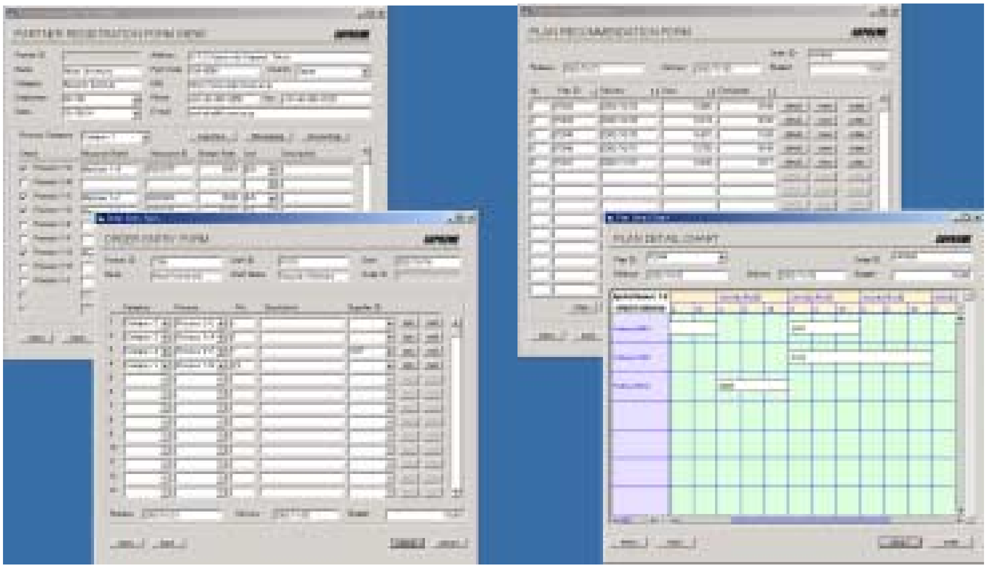


Figure 5. Prototype system for supply chain agent.

6. Conclusion

This paper deals with dynamic supply chain for OKP environment. ICT support is necessary for current economical situation, because the supply chain establishing time should be shorter and shorter. In the emerging supply chain, promises of collaboration also should be change in accordance with dynamics of reality.

SUPREME is a system architecture including web-based virtual enterprise design and collaborative planning system. The architecture contains an APS module, PSLX interfaces, web-service client-server modules and RDBMS. These components are located both on a supply chain coordinator and actual enterprise members in the network. Here, the supply chain coordinator performs as an agent who dynamically configures a suitable supply chain.

A prototype system is developed and demonstrated for evaluation of the architecture. We show three business scenarios, both of which represent typical scenes of strategic supply chain management in OKP, are addressed. And then, a prototype system is briefly demonstrated with these scenarios. In conclusion, SUPREME, which has a capability to re-configure supply chains dynamically, is one of the most fruitful systems in the next ICT infrastructure. Additionally, the communication and collaboration methods in such open network platform are necessary, so that PSLX interface and collaborative APS will be important research topics in the future.

References

1. Kamio, Y., Yamamoto, E., Morita, K., Fukuda, Y. & Nishioka, Y. 2001. Virtual Enterprise Architecture and its Supporting Methods/Tools for Managing Supply Chain System Life Cycle. *Global Engineering, Manufacturing and Enterprise Networks*, Kluwer Academic Publishers. Pp. 18–25.

2. Nishioka, Y., Kamio, Y., Kawashima, K. & Fukuda, Y. 2001. A Booking Type Production System as a Collaboration Method for Virtual Enterprises. *Global Engineering, Manufacturing and Enterprise Networks*, Kluwer Academic Publishers. Pp. 164–172.

3. Nishioka, Y. 2001. XML-based Standardization of Planning and Scheduling Problems for Virtual Enterprise Collaboration. *Proceedings of ICPR-16*, Czech, Prague.

4. W3C Working Draft 2002. SOAP Version 1.2 Part 1: Messaging Framework. http://www.w3.org/TR/soap12-part1/

5. PSLX Consortium Japan 2002. Planning and Scheduling Language on XML Specification Technical Documents. http://www.pslx.org/

Towards a Software Solution for Inter-enterprise Delivery Management

Roelof J. van den Berg
Baan Development B.V., The Netherlands (email: rvdberg@baan.nl)
Herbert Wubben
7B1 ICT Solutions, The Netherlands (email: hwubben@7b1.com)
Arian Zwegers
Baan Development B.V., The Netherlands (email: azwegers@baan.com)

Abstract

The concept of the virtual enterprise (VE) provides a good starting point to truly increase productivity in business operations, especially in domains for one-of-a-kind production. But tools to support many of the life cycle phases of the VE are not yet available. This paper describes the background of a tool, developed in the GLOBEMEN project, to coordinate the production and delivery phase of a VE. The paper gives some specifics of inter-enterprise delivery management, describes the architecture of the tool and illustrates its use in practice with a short case study.

1. Introduction

The “new economy” hype gave rise to quite a number of concepts that were used in pretentious and premature ways by those whose fate depended on a widespread belief in a productivity miracle that did not happen. At first glance, the notion of *the virtual enterprise* (VE) is one of the most suspect among them. Yet, while a significant part of the rhetoric of this most recent of ages of great expectations has already been drawn into the dark depths of oblivion, the concept of the VE stands a good chance of eventually becoming solidly established in management theory and the day-to-day practice of the business world. After all, the body of thought behind it, ranging from fields like computer science [1, 2] to management and economics [3–7] and sociology and cognitive psychology [8–10], convincingly outlines a novel way of organizing inter-enterprise co-operation. It shows how modern information and communication technology (ICT) can already leverage a superior match between a market opportunity and the provision of resources, especially in the business domains for one-of-a-kind production (OKP), e.g. shipbuilding, most parts of the aerospace and defense industry, and most types of construction. The canon concerning the VE provides a solid conceptual basis to truly enhance business productivity.

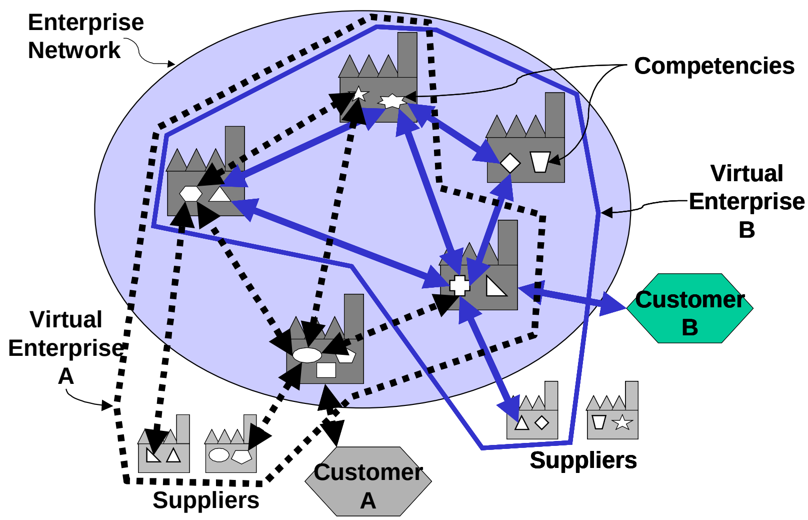


Figure 1. The Virtual Enterprise.

In a VE autonomous companies contribute distinct competencies to a temporary inter-organizational cooperation and tailor a value chain to meet the exact requirements of a specific business opportunity. Ideally, world-class competencies can be assembled for each market opportunity [4–7]. The VE is supposed to behave as one unified company although it is composed of competencies from various, geographically dispersed partners. Thus, business processes are not carried out in isolation by single companies, but must be dynamically configured and coordinated to serve the common mission of the VE partners [11]. Dynamic, collaborative relationships are thus at the heart of the VE. In addition, the quick acquisition of complementary competencies allows a highly agile response to changing market demands and pursuit of business opportunities with a short life-time. Clearly, successful implementation of the VE requires flexibility in terms of ICT infrastructure and advanced cognitive and social abilities of the people in the participating enterprises [12–14].

Not all agree that the ambitious technical requirements are inherent to the VE. They argue that the VE *avant la lettre* originated in times long before the recent hype that pushed it as a theoretical phenomenon. According to them already the Etemenanki of Babylon was built through a VE, somewhat along the same type of reasoning that makes Henry Ford the first business process reengineer. We consider modern ICT a *conditio sine qua non* to create a true VE [15]. The above description of the VE should have made clear that although in theory one could create one based on paper and telephone communication, modern ICT is crucial to make a VE efficient, competitive and thus feasible. In fact, even 'modern ICT' needs to be pushed to a higher level before it can support a full-fletched VE. In that sense, the above description of the VE with its emphasis on dynamic exploitation of market opportunities makes it first of all a lighthouse for ambitious ICT applications, a destination instead of a milestone already reached. After all, many important life cycle phases of the VE are not yet supported by commercial products. One of the areas that is hardly addressed by the currently available tools is inter-enterprise delivery management. This business area is the focus of this paper. The next section briefly describes what is meant by the term. The subsequent sections are devoted to the ICT support for inter-enterprise delivery management.

2. Inter-enterprise delivery management in a VE

In a VE, the scope of a delivery project is unique due to customer specific product requirements. As the VE is conceived in a context of (world-class) specialisation, fulfillment of the scope is typically achieved by distributing activities over multiple enterprises. This distribution of project activities is subject to the dynamics of required and available capabilities and capacities of each enterprise; trade-offs must be made for each individual project [11]. Delivery processes in such unique environment cannot be managed adequately by supply chain tools as used in repetitive industries, e.g. conventional interorganizational workflow management systems [16] or approaches assuming relatively stable supply chains as described for the high-tech industry in [17]. Traditional techniques to synchronize supply and demand [18] do not apply to this case, because production is not repetitive in a VE. Instead one needs to coordinate the cooperation of the enterprises in the VE as if one were building a completely new business from scratch, spanning the delivery process from customer contract to final handover of the delivery or even provision of after-sales services. In the GLOBEMEN project, the aim of workpackage 2 (inter-enterprise delivery management) was to facilitate the collaboration between enterprises in a VE along those lines. Workpackage 2 had to result in a prototype that could support business processes for collaborative project management. Research should lead to:

1. More reliable project plans
Via a shared model of project activities and requirements,

2. Better project monitoring
Via on-line access to project status, with real-time notification of events and "alert" conditions and with impact evaluation for deviations based on changes of downstream activities,

3. A decrease in project risk
Via clear visibility of the status of activities for all partners in the VE,

4. Higher flexibility and efficiency
Via a faster response to customer change requests, through better leveraging of partners from the network potential and accelerating and controlling the flow of information during the project lifecycle.

Based on these requirements, a detailed prototype specification was made.

3. Overview of the C-project architecture

One of the assumptions concerning the VE is that it can be activated in a short period of time. This implies that the VE is based on lean ICT, which can be implemented quickly. This means that from an architectural point of view only what needs to be shared should be shared. The specific, internal parts of the ICT provisions, e.g. an ERP system implemented at the site of one of the partners in the VE, should be left to the scrutiny of that individual enterprise. Such enterprise-internal systems are not dedicated to the VE. The lean application on top of it, dedicated to the VE, should maximize the exploitation of these generic ICT systems already available in enterprises and from it create an information flow specific for the VE. Based on this line of thought a prototype, *C(ollaborative)-Project*, has been designed to be accessible with an Internet browser. It also has the possibilities to be easily integrated with existing applications that execute the intra-company processes. C-Project will not replace the pre-existing applications, but will offer functionality to link up the different enterprises involved in project networks to support and enhance the inter-company processes. C-project is independent of any enterprise-internal back-end system and can even be used in a “stand alone” mode, without any link to e.g. ERP systems. Furthermore, C-Project is a multi-tiered application. This means that different enterprises in various levels in the project value chain can use the same application, thus creating maximum visibility to each other. While most of the current offerings for collaborative work are based on enterprise-centric applications, C-project is inherently network-centric. Enterprise-centric applications essentially can only distinguish between what is inside and outside the enterprise in terms of people, processes and products. Obviously this makes for difficult inter-enterprise applications, where the underlying systems should

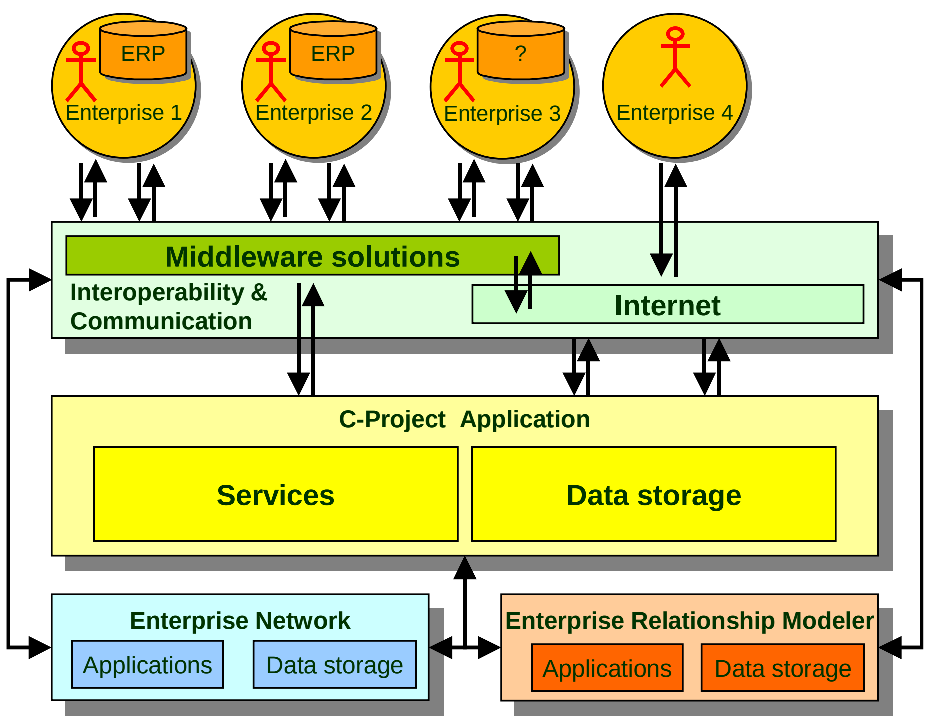


Figure 2. C-Project system modules.

be able to deal with entities that are outside the enterprise, but inside the extended enterprise (and thus “inside” to some extent). The powerful modelling engine that forms the basis of the C-project prototype is able to deal with the nuances of such business relationships and the corresponding needs to share some of the data available in the enterprise, but certainly not all. See [19] for more details on the modelling engine behind C-project. Based on the approach described above we can identify the following system components: the Enterprise Network, the Enterprise Relationship Modeler, the C-Project Application, individual partners’ enterprise systems, and an interoperability layer with the adapters to these latter systems.

The ***Enterprise Network*** component contains information about a group of enterprises (the network) with their individual capacity and competencies for any (potential) VE. See [12] to find out what information on competencies of other firms could typically be stored and [13, 20, 21] for various ways to assess the validity of claims about the quality of potential partners. Functionality in the prototype includes displaying competences of the members of the network and their availability at a given moment in time, as presupposed in the selection approach for VE partners [11]. In addition, documents such as general agreements, procedures and so on can be stored for later use during the setup and operation of a VE. The functionality of this component is not related to a specific VE.

The ***Enterprise Relationship Modeler*** is where all enterprises and their relationships in one or more VE are modeled based on Work Breakdown Structures, Organisation Breakdown Structures, Project Network Diagrams and Bills Of Materials (BOM). This model forms the basis for all other business process support and services provided by C-Project.

The core ***C-Project Application*** consists of a number of services offered to the enterprises with a specific task in one or more projects. Examples of these services are: document sharing, collaborative project scheduling and progress tracking. Which service will be available to whom depends on his role in a VE, as modelled with the use of the Enterprise Relationship Modeler.

The ***interoperability & communication*** part of C-Project consists of an interface to the Internet and possibly standard integration products. Via an Internet browser it will be possible to get basic access to the C-Project Services only. For more sophisticated use and high volume transactions, adapters could be made based on standard integration tools such as described in [22, 23].

4. Trial application

The case concerns the construction of a new office building ('building') for a company called ABC International (the customer). The main contractor for this project, SkyHigh Construction Plc., will design and construct the 'skeleton' of the building and subcontract the construction of its 'foundation' to RockSolid Building Company. This company will subcontract the 'design' of the foundation to Archimedes Engineering and the production and delivery of the 'concrete' to Kricon Supplies. The work breakdown structure for this project is illustrated in Figure 3.

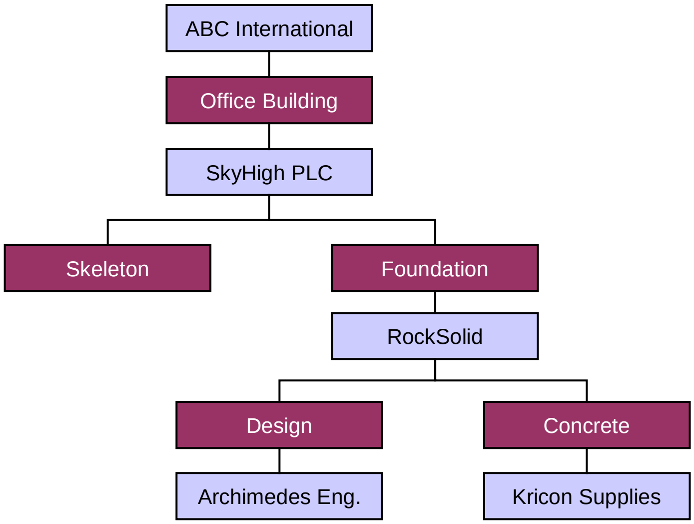


Figure 3. work break down structure.

The details concerning deliverables and agreements with regard to this work breakdown structure can be stored in C-project. An interface with MS project exists to simplify uploading of project details. In this example, the main contractor hosts the C-Project application. It is also possible to run C-project via an application service provider (ASP) and have each of the participants in the

VE concentrate on their core competence. In that case, each one of them is only user of the application against a certain fee. The host of the application controls the access rights for the other partners in the VE and the customer. For its immediate (the so called first tier) business partners this control is direct. For the others it is indirect, i.e. the direct partners of the host have the possibility to adjust access rights within the limitations set by the host. In this case, SkyHigh Construction could for instance give designated staff at ABC the possibility to check progress on the main deliverable 'building' and give certain people at RockSolid the possibility to update and/or check information concerning the 'foundation'. RockSolid in turn could provide its subcontractors with access rights to information about deliverables that are relevant for them. Of course it is possible that one person has several roles in the value chain of the VE, e.g. John Doe at RockSolid is main contact point for SkyHigh but also the project leader for the work with Archimedes Engineering. The application separates people/names from roles and can provide different views depending on the role perspective an individual user wants to take on the available information. During the course of the project, the status of the project will be updated. This could be done manually by authorized people in the VE or through a dedicated link with pre-existing systems in the participating enterprises. For instance, SkyHigh could get much of its information on the foundation from the ERP system of RockSolid. With each change in the available information in C-project, an automatic warning will be sent to those who need to know (and only to them). Unlike traditional supply chain applications, C-project will give SkyHigh visibility on status information beyond RockSolid. It could for instance show that the production of concrete is delayed due to quality problems. This multi-tier orientation of the application will make it much easier for the main contractor to notice exceptions anywhere in the project almost as they occur and react more swiftly to keep the project on track.

5. Conclusions

By definition, the VE needs ICT support that is open and easy to set up. One way to achieve this is by linking up existing intra-enterprise applications via modelling technology instead of hard coded integrations, and adding a minimal layer of functionality dedicated to the VE. The C-project prototype shows the feasibility of this approach in the domain of inter-enterprise delivery management. At this moment, the functionality of the application is quite limited, but on the basis of the powerful modelling engine below it, it can be easily extended with additional features. Feedback from the field shows how this type of application really addresses a need for network-centric, multi-tier delivery management.

References

1. Camarinha-Matos, L. M., Afsarmanesh, H., Garita, C. & Lima, C. 1998. Towards an architecture for virtual enterprises. Journal of Intelligent Manufacturing, **9**, pp. 189–199.

2. Zwegers, Arian, Hannus, Matti, Tølle, Martin, Gijsen, Jeroen & van den Berg, Roel 2001. An architectural framework for virtual enterprise engineering. In: *E-work and E-commerce; novel solutions and practices for a global networked economy*, Brian Stanford-Smith and Enrica Chiozza (eds.). IOS Press, Amsterdam. Pp. 1117–1123.

3. Williamson, O. E. 1979. Transaction-Cost Economics: The Governance of Contractual Relations. Journal of Law and Economics, pp. 233–261.

4. Hamel, G. & Heene, A. 1994. Competence-based Competition. John Wiley & Sons.

5. Davidow, W. H. & Malone, M. S. 1992. The virtual corporation. Edward Burlingame Books/Harper Business.

6. Prahalad, C. K. & Hamel, Gary 1990. The Core Competence of the Corporation. Harvard Business Review, Vol. 68, May/June, pp. 79–91.

7. Katzy, B. R. & Schuh, G. 1997. The Virtual Enterprise. In: Handbook of Life Cycle Engineering: Concepts, Methods and Tools, Molina, A., Sanchez J.M. & Kusiak, A. (eds.). New York, Chapmann & Hall.

8. Morley, David & Robins, Kevin 1995. Spaces of Identity; global media, electronic landscapes and cultural boundaries. Routledge, London.

9. Levy, Pierre 1997. Collective Intelligence; mankind's emerging world in cyberspace. Perseus Books, Cambridge, MA.

10. Berger, Peter L. & Luckmann, Thomas 1971. The Social Construction of Reality. Penguin University Books, Middlesex.

11. Rupprecht, C., Rose, T., Halm, van E. & Zwegers, A. 2001. Project-specific Process Configuration in Virtual Enterprises. In: Global Engineering, Manufacturing and Enterprise Networks, John P. T. Mo & Laszlo Nemes (eds.). Kluwer Academic Publishers, Norwell. Pp. 46–53.

12. Pedersen, Jens Dahl, & van den Berg, Roelof J. 2000. Supporting Partner Selection for Virtual Enterprises. In: *Global Engineering, Manufacturing and Enterprise Networks,* John P. T. Mo & Laszlo Nemes (eds.). Kluwer, Boston. Pp. 95–102.

13. Berg, Roelof J. van den & Tolle, Martin 2000. Assessing ability to execute in Virtual Enterprises. In: Global Engineering. Manufacturing and Enterprise Networks, John P. T. Mo & Laszlo Nemes (eds.). Kluwer, Boston. Pp. 38–45.

14. Senge, Peter 1990. The Fifth Discipline: The Art and Practice of the Learning Organization. Doubleday, New York.

15. Gijsen, Jeroen 2001. ICT for Supporting Collaboration in the One-of-a-Kind Industry. Thesis, Eindhoven University of Technology.

16. Aalst, van der, Wil 1998. Loosely Coupled Interorganizational Workflows. Working paper, Eindhoven University of Technology.

17. Moonen, Hans & Zwegers, Arian 2002. Collaborative Software Needs for Contract Manufacturers. Pre-prints of APMS '02, Hari Jagdev, Hans Wortmann, Henk-Jan Pels & Alexander Hirnschall (eds.). Eindhoven University of Technology, Eindhoven. Eindhoven, Netherlands. Pp. 392–403.

18. Lee, Hau 1997. Information distortion in a supply chain: the bullwhip effect. Management Science, Vol. 43, No. 4, pp. 546–558.

19. Zwegers, A., Wubben, H., Hartel, I. & Berg, van den, R. J. 2002. Managing Relations in Networks of Enterprises. This book

20. Berg, van den, Roelof J. & Lieshout, van, J. M. 2001. Finding symbolons for cyberspace; addressing the issues of trust in electronic commerce. *Production Planning & Control*, Vol. 12, No. 5, July–August 2001, pp. 514–524.

21. Sabherwal, R. 1999. The Role of Trust in Outsourced IS Development Projects. *Communications of the ACM*, 42, pp. 80–86.

22. Busschbach, van, E., Pieterse, B. & Zwegers, A. 2002. Support of Virtual Enterprises by an Integration Infrastructure. In: L. Camarinha-Matos (ed.). Proceedings of the PRO-VE ’02 Conference. Pp. 923–931.

23. Berg, van den, Roel & Zwegers, Arian 2002. Integration of Enterprise Systems to Facilitate Participative Decision Making. In: Intelligent manufacturing through participation, Frans M. van Eijnatten (ed.), TNO, The Netherlands.

Part IV

Distributed Engineering

Interaction Mechanisms and Functional Needs for One-of-a-kind Production in Inter-enterprise Settings [1]

Abdul Samad (Sami) Kazi
VTT Building and Transport (email: Sami.Kazi@vtt.fi)
Matti Hannus
VTT Building and Transport (email: Matti.Hannus@vtt.fi)

Abstract

In one-of-a-kind production industries, different entities join to share complementary competencies to deliver a unique product or service. This is typically through the modus operandi of the virtual enterprise (VE). Information exchange in VE settings has traditionally been through simple file exchange using a person-to-person exchange. This has naturally led to a significant degree of information redundancy and unawareness of as to whom possesses the latest version. A move towards project servers has been noticeable since quite some time. While this does resolve the redundancy issue, in essence one has to manually upload documents to a central location and that too done at a person level. As such, the organisation has no control as to whom is publishing what content. In the GLOBEMEN project, it is advocated that information exchange (upload and download) be done through links between enterprise systems and store in a central repository which also supports specific VE services. The paper presents an overview of different inter-enterprise mechanisms for one-of-a-kind production and discusses some basic functional requirements to be made available to participants engaged in a VE setting. The findings of this paper are primarily based on undertakings related to distributed engineering within the GLOBEMEN project.

[1] To be presented as, "Inter-enterprise Interaction Mechanisms and Functional Needs for One-of-a-kind Production", at eSM@RT 2002, November 19–21, University of Salford, UK.

1. The GLOBEMEN Project

1.1 Overview

Global Engineering and Manufacturing in Enterprise Networks, GLOBEMEN, is a three-year (January 2000 – January 2003) research project with an estimated effort of 1000 person-months. It is part of the global Intelligent Manufacturing Systems (IMS) program and the project consortium has 19 participant organisations dispersed across different IMS regions: Australia, EU, Japan, and Switzerland. The Information Society Technologies Programme (IST) supports EU participation in Globemen (IST-1999-60002).

The aim of GLOBEMEN is to create IT infrastructures and related methods, models, and tools to support globally distributed and dynamically networked operations in one-of-a-kind industries. Focus is on inter-enterprise integration and collaboration in a global setting in relation to the three main facets of manufacturing: sales and services, inter-enterprise delivery process management, and distributed engineering.

1.2 Industrial Relevance

The industrial relevance of the undertakings within Globemen and its contribution to the industry is envisioned as follows [1]:

- Radical decrease (50% or more) in lead-time of all phases in manufacturing is a must in the manufacturing industries. Efficient enterprise networking and distribution of functions is necessary for lead-time reductions of this magnitude.
- Businesses today are becoming more dynamic and multicultural. The relationships between companies in networks are changing with increasing speed.
- Dynamic global networking can not be efficient without tools allowing true concurrency for all partners in the network. The ultimate aim of Globemen is to equip the initially the project partners and eventually the industry at large with these tools.

– There is expected to be a major direct economic impact to the industrial end-user partners.

Different application systems can be developed based on the generic architecture developed in the project. This will magnify the global market potential for IT solution providers.

2. Inter-enterprise Collaboration

Changing needs of clients are putting pressure on organisations to collaborate with other organisations to deliver at times unique, one-of-a-kind products in response to client needs [3, 4]. The modus operandi of the virtual enterprise (VE) has established itself as a reality rather than a term only seen in scientific publications. Certain key differences exist between intra-enterprise and inter-enterprise settings (Table 1). When a shift towards operating in inter-enterprise settings is made, a change in priorities is noticed (Table 2) as reported by Kazi et al. [4].

Table 1. Comparison between some characteristics of intra-enterprise and inter-enterprise settings.

	Intra-enterprise	Inter-enterprise
Contractual coverage	No	Yes
Legal responsibility	No	Yes
Technology	Proprietary	Industry standard
Control of ICT solutions	High	Low/none
Set-up time	Long (~months … years)	Very short (~days)
Training	Yes	No
Application user interface	Yes (~"bells and whistles")	Hidden (~"Save as …")
Integration	Integrated applications and databases	Culture, ontology, standards, data warehouses, etc.
Target users	Own staff	Unknown future partners
Coordination	Resource and workflow management	Deliverable management
Information updating	Synchronous	Asynchronous

Table 2. Shift in priorotites from intra-enterprise to inter-enterprise collaboration.

From	To
Centralised planning	Transparency of information
Enterprise resource planning	Inter-enterprise coordination
Document management	Object management
In-house operative systems	Inter-enterprise collaborative systems
Supply chain management	Demand change management
Workflow management	Groupwork support
Scheduling	Schedule synchronisation
Management information systems	Decision and negotiation support
Reporting	Forecasting and coordination
Electronic commerce	Elimination of ordering
Access control	Knowledge sharing
Integrated systems	Flexible interfaces

3. Inter-enterprise Information Exchange

The sharing and exchange of relevant information from one entity to the next for continuation of work is of paramount importance in any environment, be it an intra-enterprise one or an inter-enterprise one. Different mechanisms have been used over the years to enable this sharing and exchange of information (Figure 1). We discuss below some of the main mechanisms and relevant characteristics.

3.1 File Exchange

The advent of email has been a powerful step towards electronic exchange of data and information. This however has not been without pitfalls, especially in inter-enterprise settings. When point-to-point information exchange takes place, data/information redundancy and loss of control of the physical source of the information in addition to its original user is inevitable unless specifics measures are put in place. At the same time, typically both information provider and recipient need to have access to similar applications software or viewers to be able to read/work on the same piece of information.

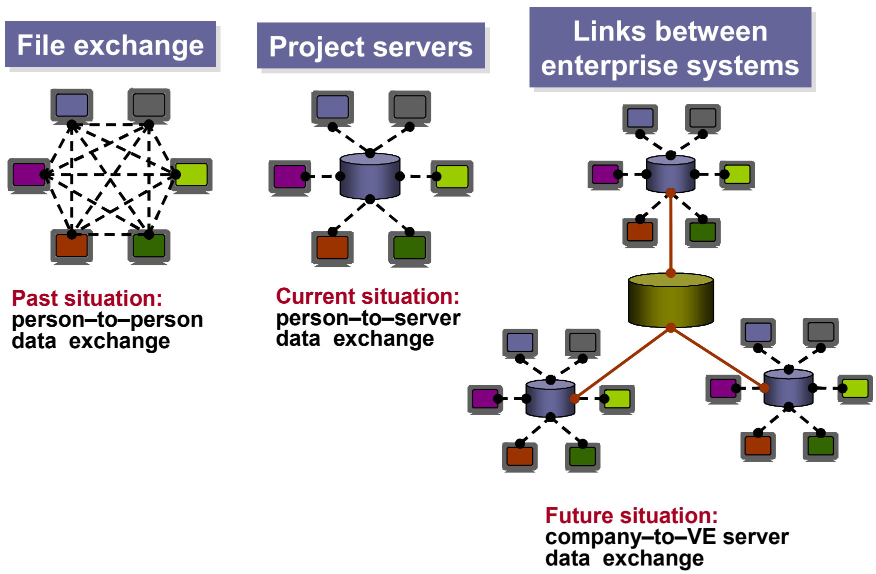


Figure 1. Data/information exchange mechanisms.

3.2 Project Servers

One solution to the problem of data/information redundancy has been through the introduction of project servers. Here, information is stared in a central information repository that is accessible by the relevant information providers and seekers. Version control is one of the many salient functions used in project servers.

The person-project server solution, while resolving the data/information redundancy problem and maintaining information centralisation as opposed to decentralisation in the file exchange approach, is still individual user centric. In simple terms, the interaction is through a user and not the enterprise which in fact is the legal entity involved. As such, when information is released by an individual, legal endorsement of the same by the enterprise is assumed.

Organisations prefer to at times only release “partial” information, whereas keeping and maintaining the whole “internally” [2]. This functionality is not available in the person-project server approach.

3.3 Links between Enterprise Systems

The way forward as described by Kazi and Hannus [2] would be through flexible links between enterprise systems (refer to Figure 1). Here, an individual would communicate with the central repository of the enterprise for which they are working, this would then release the relevant portion of this information to a shared project server. As such, enterprise specific systems/repositories would transfer and receive information packages on a periodic or per request basis to/from the VE specific project server. At the same time, this complies with legal requirements that information is released by an enterprise and not an individual.

It is advocated in GLOBEMEN that links between enterprise systems hooked through flexible interfaces to a central VE repository is the means for inter-enterprise information exchange. As such, an enterprise would simply need to "plug-and-communicate" to the VE repository. Both enterprise and VE specific systems would communicate through *interfaces* based on established standards and thereby eliminating/minimising the need for "compliance" between the two systems other than through the interface [4]. A typical environment (Figure 2) supporting the above advocation was presented by Hannus and Kazi [2].

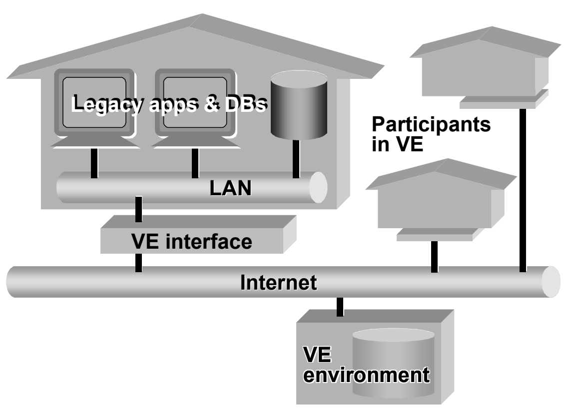


Figure 2. A typical VE environment supporting links between enterprose systems.

This environment (Figure 2) consists of two main components of interest:

- VE environment: This constitutes the common data and information repository, and sharing environment for enterprises participating in the inter-enterprise setting. Typical services provided should include distributed groupwork and sharing of information based upon available (or agreed upon) standards.
- VE interface: This constitutes the main interface and front-end through which organisation specific legacy systems would interact with the VE environment. As such, this interface acts as a communication bridge between the two systems and furthermore, as a control agent for the transfer and management of released information from organisation specific systems to the shared VE (inter-enterprise) environment.

4. ICT Support for Distributed Engineering in VEs

A VE environment should not be limited to a central repository where information is stored. Key functionalities need to be provided to enable distributed teamwork in inter-enterprise settings. Such functionalities were studied in GLOBEMEN both through an assessment of current software offerings and through an analysis of user needs. The results of this exercise revealed that most software only provided a subset of these needs. This was not entirely surprising as certain needs do vary from one VE to the next. Some of the common requirements for ICT supported for distributed teamwork in VE environments as identified in GLOBEMEN are listed (these rely on a combination of the project server and links between enterprise systems approaches for data exchange in VE environments):

- Role specific access control for Virtual Environments at person level
- Licence costs that are affordable and predictable over the total project duration
- Archiving of all contents and provide a non-specific means of navigation and viewing
- Means of comprehensively logging all events
- Assuring that the identity of each user accessing the system is verified

- Assuring that each system user has the authority to perform specific transactions within the system
- Configurable back up procedures with automated logging
- Means for users to post events into a project calendar
- A standard method of acquiring, recording and displaying photographs, roles, tasks and contact info for each person
- On-line availability of project contract
- Templates and toolkits available for preparation and publication of web presentations / demonstrations
- Automated project schedules, lists of deliverables and to-do reminder tools
- Standardised facilities to upload, search and download of files
- Automatic customisable management and recording of all email communication
- Answers to frequently asked questions about software tools/packages
- Feedback forms
- Threaded discussion forums
- User administered glossary of terms and acronyms
- Unique identifier system for all information items
- Allow the Virtual Environment to be accessed via participating companies
- Hints and FAQ on how to use the Virtual Environment
- Flexible licensing conditions to fit the specific Virtual Environment conditions
- Allows links to related topics to be uploaded by all partners
- Specific document folders related to meetings
- Mechanism to define metadata for the system administrator's use
- Customisable/automatic default navigation mechanism
- Instructions on how to use email and other e-communication within a project
- Means of posting of news
- Automatic notification system
- Means of viewing the project plan on line

- Ballot system for digital voting
- Replication system
- Definition of project procedures and automatic configuration of the VE environment accordingly
- Replication of contents(partial) between distributed locations with automatic synchronisation
- Standardised definitions of typical actor roles in Virtual Enterprises
- Standard method for maintenance of project schedules and reporting deviations.
- Means of searching of all information in the Virtual Enterprise environment based on date, metadata, all contents etc
- Physical separation of data of different Virtual Environments
- Quick system set up (1–3 days) based on templates and Virtual Enterprise specific parameters
- Open system architecture, PDM & document mgt standards, API, SQL database, XML interface
- Versatile statistics and query interface for all communication & transaction events
- Support for streamed media e.g. video viewable with RealPlayer
- Support for a configurable telepresence
- Models for configuring the Information Communication Technology environment for all types of Virtual Enterprises
- Automatically maintained lists of to-do items allocated to persons and organisations
- Configurable trust levels between VE members
- Bulk uploading of many files with metadata
- On-line communication between persons supported by audio, video, shared application, whiteboard etc.
- Different views depending on a user's profile
- Webcast facility, usable anywhere
- Management system for deliverables and information flows between organisations

- Facility that shows the local time at all Virtual Enterprise member locations
- All viewing and administration is done using a web browser
- System for the coordination and follow-up of agreed contributions and deliveries
- System whereby the shared Virtual Environment is hidden in the members' internal working environment
- Automated follow up of minuted action items.

Some of the above functionalities have been used in GLOBEMEN (which in itself is a VE) and some missing ones developed.

5. Conclusions

Operation under the modus operandi of the virtual enterprise to deliver a one-of-a-kind product is fast becoming the norm than the exception. This norm has been researched in detailed in the GLOBEMEN project based on an analysis of three main facets of manufacturing and production: sales and services, inter-enterprise delivery process management and distributed engineering. The results have been a set of requirements, specifications, prototypes, guidelines, demonstrators, generic architectures, etc. A consolidated version of some of the findings in terms of inter-enterprise interaction mechanisms and needs for distributed teamwork was presented in this paper.

In inter-enterprise settings there is a need to share and exchange relevant information between project participants. Three such mechanisms were identified: file exchange, project servers, and links between enterprise systems. The focus of research in GLOBEMEN has been on the identification of key requirements for and development of the same through a combination of both project servers and links between enterprise systems. A main means being through the use of flexible interfaces and compliance to relevant data/information exchange standards. Some basic requirements for ICT support for distributed teamwork in VE settings were furthermore identified. It is believed that these will be beneficial to ICT vendors and service providers developing/hosting solutions to support one-of-a-kind-product delivery in inter-enterprise settings.

References and Selected Bibliography

1. GLOBEMEN 2002. Public website, http://globemen.vtt.fi

2. Hannus, M. & Kazi, A. S. 2000. Requirements for distributed engineering. Proceedings of 3rd European conference on product and process modelling in the building and related industries: Product and process modelling in construction. Ed. by Gonçalves, P. et al. 25–27 September 2000, Lisbon, Portugal. Balkema. Pp. 41–47.

3. Kazi, A. S. & Hannus, M. 2001. Functional requirements for inter-enterprise intranet services. Proceedings of IFIP 4th international conference on the design of information infrastructure systems for manufacturing: Global engineering, manufacturing and enterprise networks. Ed. by Mo, J. P. T. & Nemes, L. 15–17 November 2000, Melbourne, Australia. Kluwer Academic Publishers. Pp. 54–60.

4. Kazi, A. S. et al. 2001. Distributed engineering in construction: findings from the IMS GLOBEMEN project. ITcon 6. Pp. 129–148. (Available online at: http://www.itcon.org/2001/10/)

5. Afsarmanesh, H. et al. 1997. Management of Distributed Information in Virtual Enterprises – The Prodnet Approach. Proceedings of the 4th international conference on concurrent engineering, Nottingham, UK. Pp. 241–255.

6. Browne, J., Sackett, P. J. & Wortmann, J. C. 1994. The System of Manufacturing: A Perspective Study, Report to the DG XII of the CEC.

7. Byrne, J. A. 1993. The Virtual Corporation. Business Week, February 8, pp. 37–41.

8. Camarinha-Matos, L. M., Afsarmanesh, H., Garita, C. & Lima, C. 1998. Towards an Architecture for Virtual Enterprises. Journal of Intelligent Manufacturing, Vol. 9, No. 2, pp. 189–199.

9. Charbuck, D. & Young, J. S. 1992. The Virtual Workplace. Forbes, Vol. 150, No. 12, pp. 184–190.

10. Filos, E. & Banahan, E. 2001. Towards The Smart Organization: An Emerging Organizational Paradigm And The Contribution Of The European RTD Programs. Journal of Intelligent Manufacturing, Vol. 12, No. 2, pp. 101–119.

11. NIIP 1996. The NIIP Reference Architecture (http://www.niiip.org/public/public-forum.html)

12. Rabelo, R. & Camarinha-Matos, L. M. 1996. Towards Agile Scheduling in Extended Enterprise. Proceedings of BASYS'96: Balanced Automation Systems II – Implementation Challenges for Anthropocentric Manufacturing (Camarinha-Matos, L. M. & Afsarmanesh, H., eds.). Chapman & Hall. Pp. 413–422.

13. Walton, J. & Whicker, L. 1996. Virtual Enterprise: Myth and Reality. Journal of Control, Vol. 22, No. 8, pp. 22–25.

14. Zwegers, A. et al. 2001. An Architectural Framework for Virtual Enterprise Engineering. E-work and E-commerce: Novel solutions and practices for a global network economy (Stanford-Smith, B. & Chiozza, E. eds.). IOS Press. Pp. 1117–1123.

Document-based Knowledge Management in Global Engineering and Manufacturing Projects

William P. Hall and Martin Jones
Tenix Defence Systems, Australia
(email: bill.hall@tenix.com)

Mingwei Zhou, Julia Anticev, Jeffrey Zheng, John Mo and Laszlo Nemes
CSIRO Manufacturing & Infrastructure Technology, Australia

Abstract

The core competence of a global engineering and manufacturing enterprise increasingly depends on the quality of its intellectual resources and how these resources are used. This paper presents an approach to document-based knowledge management in a typical global engineering and manufacturing application, the ANZAC Ship Project.

1. Document-based Knowledge Management

1.1 Documents in the Project Life Cycle

With the globalisation of business activities, the core competence of a manufacturing enterprise increasingly depends on the quality of its intellectual capital and how this capital is used [1]. Intellectual capital is usually presented in the form of various kinds of documents.

This paper discusses an approach towards the document-based knowledge management in the global engineering and manufacturing projects [2]. As shown in Figure 1, knowledge can be captured into documents at many stages in the project lifecycle and the nature and value of the reusable content and contextual knowledge varies with the project stage [3, 4].

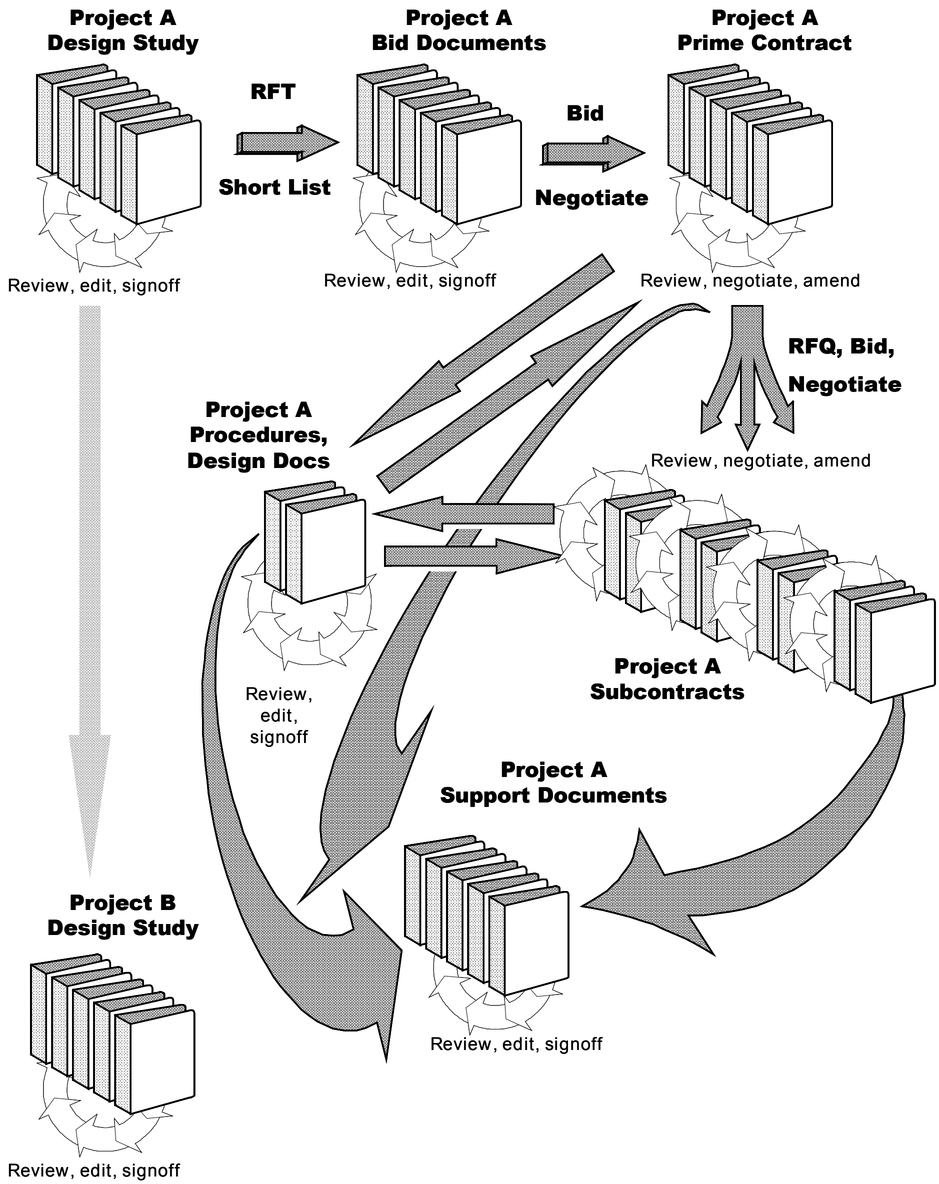


Figure 1. A simplified view of documentation stages and knowledge flow in a typical global engineering and manufacturing project.

In a global engineering and manufacturing project involving many different systems, document content is highly redundant within each project stage, in that the same kind of information is required for each of the systems, and the same components may be used in many different systems. Also, document content is often reused as it flows from one stage of the project to the next, and documents developed for one project serve as the basis for later projects having similar requirements. Management of this redundancy through re-use is a major goal for document based knowledge management architecture. On the other hand, different kinds of contextual knowledge need to be captured at each stage.

The design stage of a project normally begins with a client's Request for Proposals (RFP) outlining the capabilities sought from the project. The essential contexts are knowledge relating to the client's statement of capabilities, engineering decisions, notes, standards, correspondence, and a variety of documentation from lower tier suppliers. Suppliers distil this kind contextual information into design proposals and bids. Based on information provided by design studies, the client normally issues a Request for Tender (RFT) to a short list of suppliers. Suppliers then rework and extend the documentation developed in their proposals and include a detailed commercial response to the RFT. Design proposals and RFT responses are required to be completed within very limited time periods, such that if documentation is not delivered by the specified due date the proposal or bid will not be considered. Development of proposals and bids is highly competitive and places major pressure on bidders to minimise document production cycle times and to maximise the quality of information/knowledge the documents contain [5].

After assessing bids, the client negotiates a contract with one or more of the tenders. Contract negotiations with preferred bidder(s) can be protracted as the parties work to maximise their respective commercial advantages – but this is at the expense of delaying start of production. Contexts (e.g., notes, memos, correspondence, etc.) relating to the contract negotiations can be extremely important to explain details of the agreement to minimise scope slippage, but can be easily lost as personnel changes in the client and supplier organisations.

Subcontract and partner negotiations are normally completed after the prime contract is finalised and agreed. These represent all of the problems encountered in the negotiation between the client and supplier.

Internal design and procedural documentation (which may also involve client reviews) must then be developed to give effect to the contractual agreements. Here, the contextual knowledge represents an understanding of the linkages between contractual requirements and conditions and what is being done to give effect to them.

The final stage of the project documentation cycle involves the production of product support and maintenance documentation. The process is driven by contractual requirements, and information is assimilated from supplier document, and a variety of internal and external resources. This information can then be assimilated into maintenance documentation.

1.2 Knowledge Models

Knowledge is the internal state of an agent following the acquisition and processing of information, here the agent could be a human being or a computer system. To categorize human knowledge, many knowledge models have been proposed. Polanyi [6, 7] identified that human knowledge has two major components: the tacit and explicit knowledge. Following Polanyi's concept, Nonaka [8, 9] further proposed his theory that tacit knowledge consists of personal relationships, practical experience, shared values and explicit knowledge consists of formal policies and procedures.

Nickols [10] further clarified the intrinsic meanings of various knowledge terms by proposing a testable knowledge model that includes: explicit, tacit, implicit, declaration, and procedural knowledge. As shown in Figure 2, Nickols' model also depicted a testable procedure to distinguish the relationship among different classes of knowledge.

In our approach, we classified the knowledge involved in the engineering and manufacturing project into three categories based on Nickols' framework.

The first category is the "direct knowledge" or facts, which are the explicit or declarative knowledge. This category of knowledge is visible, written, transferable, sharable and reusable. It is usually documented and stored and transmitted externally to a human brain. In the bidding process, engineers assimilate their information and turn it into bidding documents conveying distilled knowledge. A knowledge management system should help the engineers capture, validate, and preserve knowledge; and assist discovery, reuse, retrieval and transmission of that knowledge.

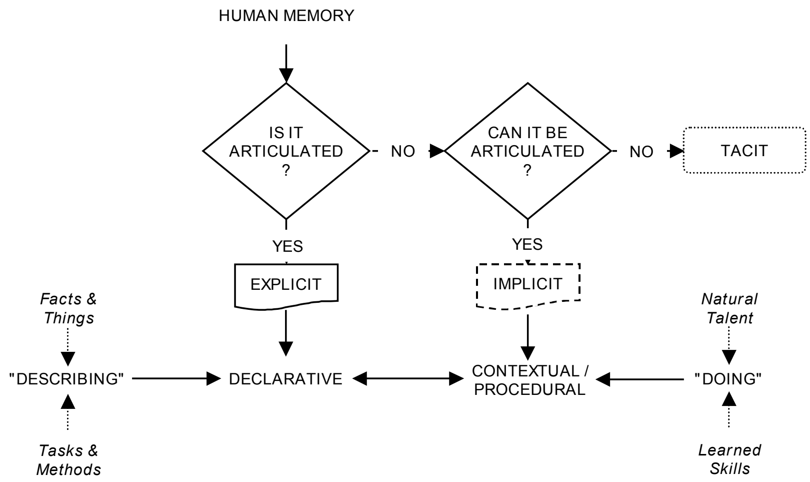


Figure 2. Nickols' Knowledge Model.

The second category of implicit knowledge includes "procedural knowledge" or the best practices, which are usually implicit, and context sensitive. This category of knowledge is related to processes, methods, practices in groups and professions. This type of knowledge needs to be identified, captured and made explicit in the way that can be shared. However, it is not always well documented. A second form of implicit knowledge includes "contextual knowledge", which relates to sources of information, background knowledge and the like that was available to the author at the time of writing, but that has no place in the formal, explicit document. This knowledge is easily lost with time as authors forget or change positions in the organisation. Benefits can be achieved if this contextual knowledge can be captured and made explicit.

The third category is the "tacit knowledge", which is the most difficult to understand and represent. It is indirect, embedded in experience, owned by individuals and cannot be articulated in words.

Our research presented in this paper focuses on the first two categories of knowledge, aiming to capture and make available for preservation, management, discovery and reuse as much direct and procedural knowledge as possible, and attempt to interpret and convert the contextual tacit knowledge surrounding the documents into direct and procedural knowledge and contextual information that can be preserved, managed, discovered and reused.

1.3 Project Information Architecture

Essentially all activities in a large engineering organisation are related either to winning contracts or fulfilling the requirements of existing contracts. Aside from the contractual documentation that states the requirements that drive the project, there are three major bodies of information and knowledge that must be managed: design, production and documentation.

Design information encompasses the engineering knowledge and structural model required to describe and build the physical product from its components. This knowledge is hierarchically structured, with the product logically broken down into smaller components. Components of the design that must be managed include catalogue items that are purchased or manufactured and drawings that provide 2D or 3D models for what must be assembled. A product data management (PDM) environment provides tools for relating all kinds of data, drawings and documentation to particular components in the product structure. Careful management of Engineering Changes (ECs) to components and related data, drawings and documents is crucial to building a successful project.

The design process culminates in the production of an Engineering Bill of Materials (EBOM) describing all of the components that must be assembled into the product. The engineering bill of materials is changed into a Manufacturing Bill of Materials that describes how to build a particular instance of the product. Production information is managed in an Enterprise Resource Management environment to ensure that the knowledge embodied in the MBOM is reflected in the actual production of the products. This involves resource management, production planning and scheduling, procurement and warehousing of materials and components, and the management of work orders. Production also interfaces with a number of subsidiary systems including human resources management (HRM), Accounting and Cost and Schedule Control System (CS^2).

Ideally, the knowledge in documents should be managed in the same way that the engineering knowledge is managed in a PDM environment. Documentation products include a number of document types, where each type generally has a well-defined content model. When document content is encoded in SGML or XML, rather than defining formatting styles, the document type description (DTD) defines elements that are allowed/required to occur in a document validly conforming to the type, and rules for the allowed/required sequence and hierarchy of in the document. Tags defined by the DTD can be used to label the kind of content enclosed by the tags, which can in turn be used to infer semantic relationships or contexts.

Requirements that are common to both the Product Data and Document Content management environments are configuration control and change management. Changes to elements of content in the documentation must be managed coherently with engineering changes to the product as designed and as built. The documentation must manage applicability and effectivity of elements that document changes are released in synchrony with engineering changes. Management of the engineering and documentation change processes can be most effectively managed and tracked using an electronic workflow system.

The following sections discuss the systems and information architecture adopted by Tenix for managing support knowledge and documentation for the ANZAC Ships.

2. Documentation for the ANZAC Ships Project

2.1 The ANZAC Ship Project

ANZAC Ship Project is one of the largest defence contracts in Australian history. It aims to design, build, and support 8 ANZAC Class frigates for the Australian Navy and 2 for the New Zealand Navy. The A$ 6 billion ANZAC Ship Project contract was signed with Tenix Defence in November 1999 after several years' project development, bidding and contract negotiation activities, and will run through 2006 when the last ship is delivered. Following completion of the production contract, ships will have to be supported in service for at least another 27 years (the design life) or longer if work is done to extend their lives. In-service support is provided by the ANZAC Ship Alliance (ASA) comprised of Tenix, Saab, and the Royal Australian Navy's ANZAC Systems Program Office.

Defence projects are knowledge intensive, capturing much of the required knowledge in various kinds of documentation, both within the project and as deliverables to the client. Many document types are required to be maintained for several decades. For example, the authoring of ANZAC Ship maintenance procedures began more than three years before the first ship was delivered. Documents will have to be maintained up to date with ship configuration changes until the last ship goes out of service sometime around 2033, representing a total document lifespan of some 40 years. Based on Tenix's experience, the cost to produce, manage and deliver project-related data and documentation is several percent of total project acquisition costs.

2.2 Fleet Support Documentation

An area that caused considerable difficulty has been the collecting knowledge for, authoring and maintaining support documents for ANZAC ship systems and equipment. Figure 3 summarises the process by which information is assembled from a variety of different sources to produce this documentation. Requirements for the support documentation are given in the contract and supporting documents. These are consolidated and extended in the Integrated Logistic Support Plan. System and equipment technical manuals and other supplier documents provide factual information about systems and equipment. Details of the systems hierarchy, materials, parts, tools, fluids and lubricants and other miscellaneous and test equipment are assembled and managed in the Integrated Logistic Support (ILS) Database.

Logistics and maintenance engineers digest the input documentation and produce a draft Technical Maintenance Plans (TMP) for ship systems, which establish basic maintenance philosophies for each system. TMPs describe two kinds of maintenance, Technical Repair Specifications (TRSs) – describing equipment overhaul type tasks normally done by external repair agents, and maintenance procedures (Maintenance Requirement Cards or MRCs) – detailing periodic or conditional maintenance tasks to be done by naval personnel on-board or using shore-based facilities. On completion of the detailed analysis required to draft the TRSs and MRCs, TMPs are finalised to reflect the TRSs and MRCs as written.

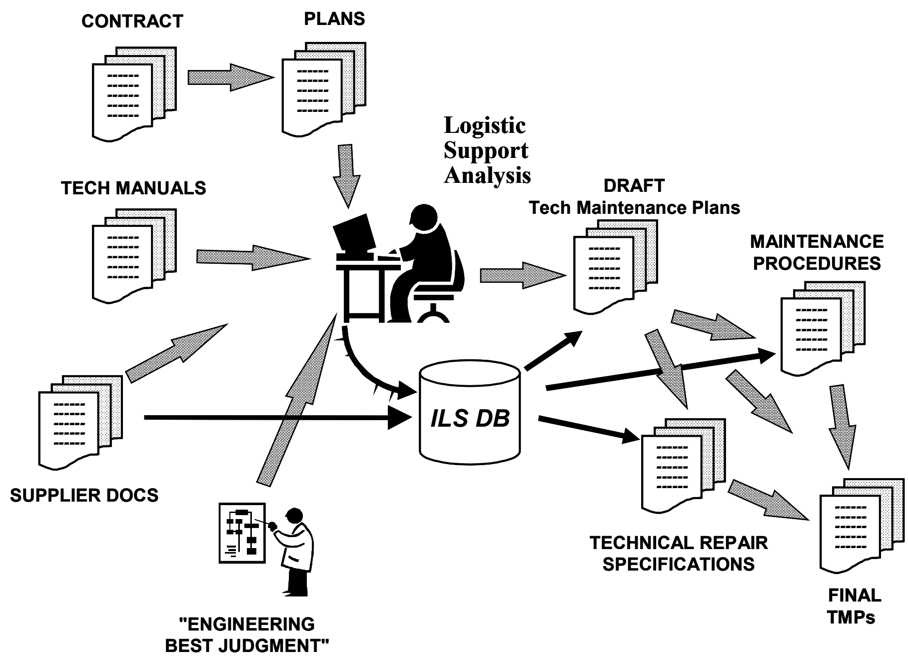


Figure 3. Information flow in the production of maintenance documentation.

2.3 Requirements

Obviously, authors apply "engineering best judgement" based on their own experience, and a large amount of implicit contextual understanding is developed regarding the many different sources of information condensed into the deliverable documents. However, the documents themselves only offer limited capabilities for explicitly capturing the contexts. Much of the knowledge about the sources of information behind the documents is lost when the authors go on to other things.

There is only a single TMP for each of the ~160 systems comprising a ship, and a single TRS for each kind of equipment to be overhauled. However, due to configuration and language differences between the ships, MRCs need to be ship-specific. Also, there may be many MRCs for each equipment requiring maintenance.

The requirements for authoring and managing the MRCs are onerous:

- ~ 2000 different MRCs per ship, times 10 ships,
- coherent management of commonly used information affected by engineering changes across the fleet documentation,
- language differences between Australian vs New Zealand ships,
- major health and safety implications if the wrong information is provided or essential safety warnings omitted,
- requirement to include scheduling and resource requirement information in procedures (maintenance "metadata") and deliver this data electronically into the client's relationally-based computerised maintenance management system (AMPS), and
- Ship-specific information in the MRCs needs to be maintained concurrently with changes to ship configurations throughout the ships' anticipated in-service life of 27 years.

Innovative solutions are needed to meet these requirements. Documents were initially authored in WordPerfect merge table formats. More than 20 different deliverables could be sourced from a database comprising a single "record" corresponding to each maintenance procedure and its associated metadata. Merge/macro processes were also developed to validate critical data items in the records against master data held in the ILS DB. This solution sufficed for the first ship, but as soon as work began on MRCs for the second ship, it was clear our authors would face substantial difficulties maintaining complete consistency of key data items across many thousands of independently maintained documents. These had to work without error when loaded into the client's relationally based AMPS maintenance management system. By the time MRCs were completed in 1999 for Ship 04, client complaints about inconsistencies in common information used throughout the ~8,000 MRCs for the first four ships had escalated to the point that Tenix faced a threat that Ship 05 would not be accepted.

Implementing the system provided us with a platform for an architecture that by October 2000 more than successfully resolved all of the outstanding issues with MRCs for our Ship 05 delivery, both internally and for the client.

3. Knowledge Management Systems Architecture for In-service Support

3.1 System Architecture

The stringently fixed-price contract for the ANZAC Ship Project has a number of relatively unique features that have forced the company to focus not only on managing the flow of knowledge into maintenance routines, but on supporting and maintaining this knowledge after delivery of the ships into service. The fixed price contract terms included delivering logistic support requirements for the ships' in-service operational requirements.

Figure 4 illustrates the information flow for the maintenance of logistic support knowledge in the in-service support portion of the project lifecycle [11]. The shaded arrows indicate the feedback loop between the operational knowledge about performance of the logistic support package (including documentation) in service, and making adaptive modifications to the various forms of support and maintenance documentation. This knowledge that has been refined with in-service experience is also available to be flowed down into other projects using similar systems. However, as is the case for other kinds of documentation, in a word processing environment much of the author knowledge used to assemble the deliverable documents remains implicit, and is readily lost through staff movements.

Figure 5 illustrates a generic systems architecture developed for managing the information and knowledge flows for the in-service phase for major projects. Supplier-based systems are shown in the black boxes, client-based systems are shown in the white boxes. Heavy arrows represent the flow of operational knowledge through the support optimisation loop.

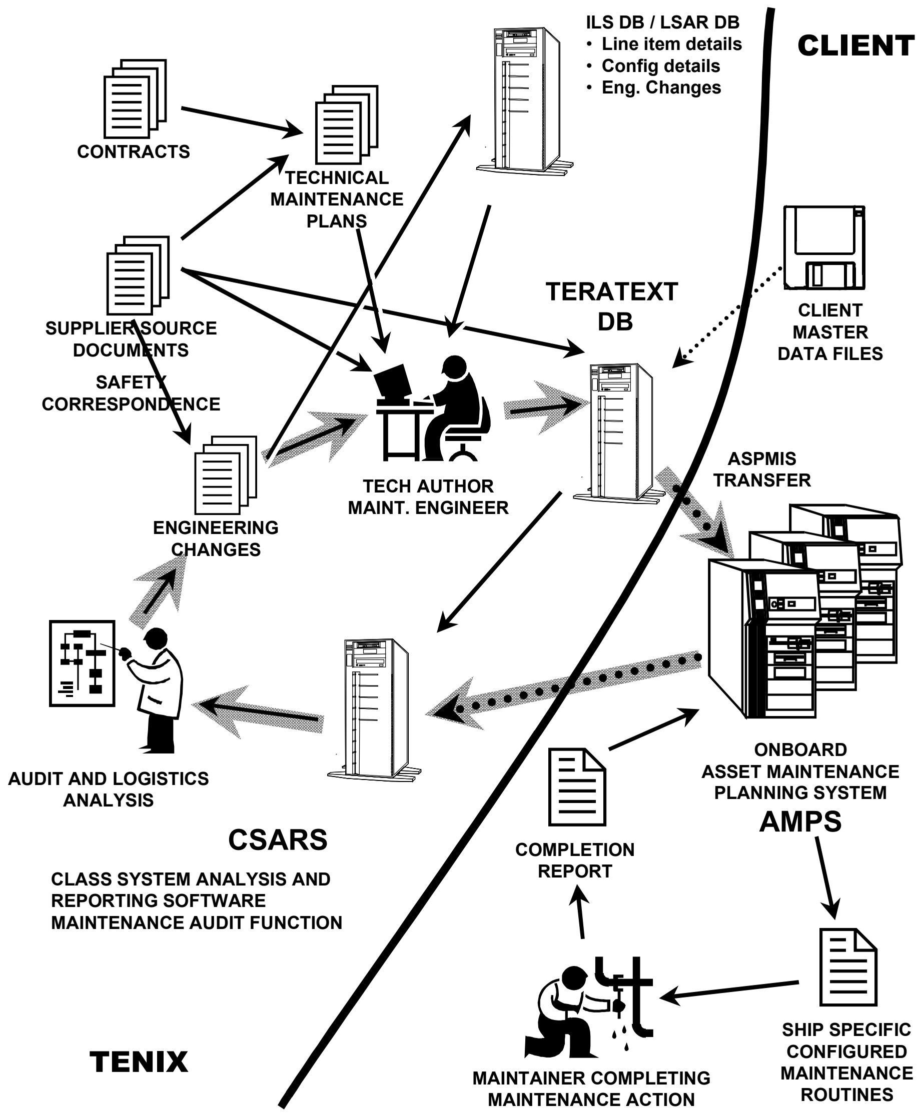


Figure 4. Closing the circle with operational knowledge to optimise in-service support.

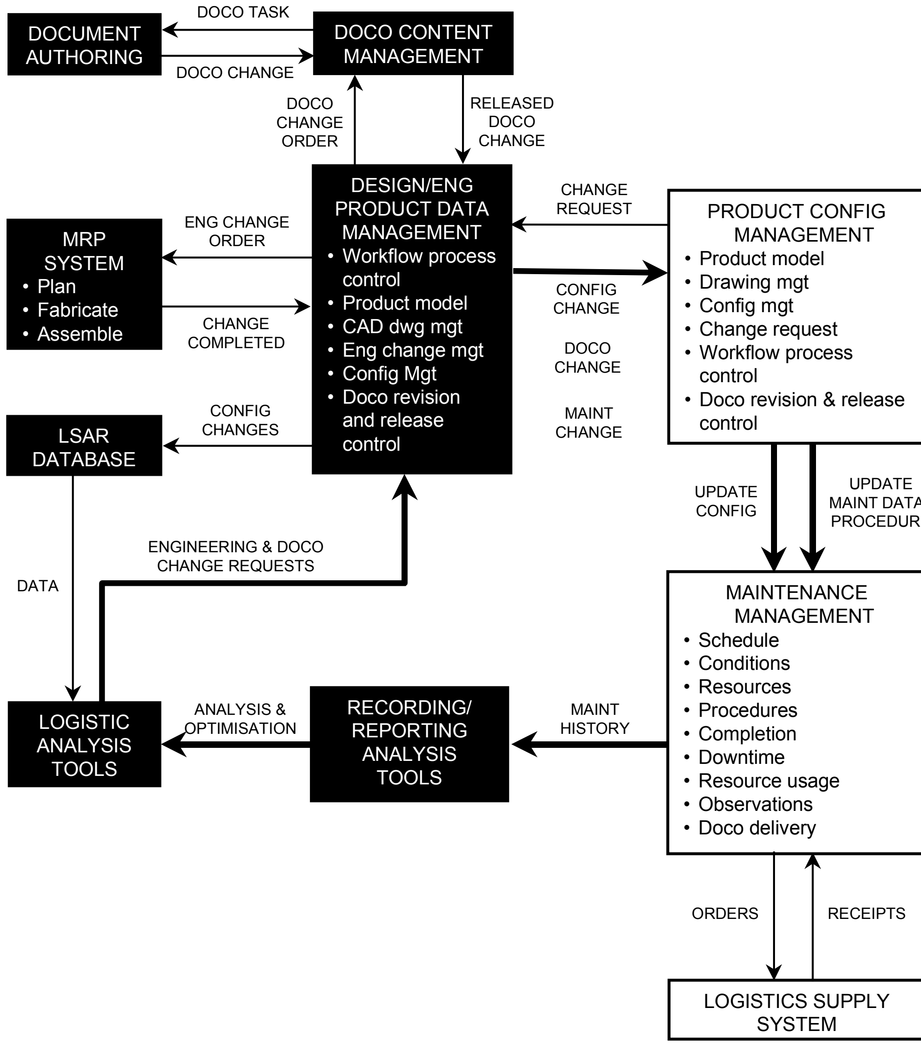


Figure 5. Systems architecture for project in-service maintenance management and support.

The central system on the supplier side is the engineering/product data management environment, which ideally includes workflow responsibilities to co-ordinate all engineering and all engineering-related documentation changes. Document content is either managed at the file level within the PDM system and for distribution to the client, or within a document and content management system (DCMS) for management of the authoring process.

As will be discussed below, the DCMS system provides a key for capturing authors' implicit contextual knowledge. Tenix currently uses the Web-based TeraText platform. Authoring and editing can be done in any SGML or XML compliant editing tool. Bespoke tools were developed in the TeraText platform to automatically validate all key MRC metadata items against master copies of the information held in the ILS DB or as supplied by the client.

On the supplier side, all engineering changes to the manufacturing environment (i.e., MRP) and to the master logistics data should be controlled and tracked by the central PDM system.

In the case of the ANZAC Ship Project, configuration information and maintenance documentation is delivered electronically from the Tenix PDM environment to the client's PDM environment via an agreed interface standard. For the MRCs, the deliverable consists of a single master document containing configuration and language specific information for all the ships, comprising an HTML file describing the procedure to the human maintainer, plus a set of relational table records (delivered as ascii comma delimited files) comprising the MRC metadata the maintenance management system requires in order to properly schedule the maintenance activity and associated human and material resources required for its completion.

The client's PDM/AMPS central maintenance management system then resolves the master MRC for a particular kind of equipment (including information for all ships using the particular routine) into ship-specific MRCs that are delivered electronically to the ship-board AMPS systems. Ship-board AMPS systems then automatically trigger maintenance jobs based on calendar periodicity or the existence of certain system conditions (e.g., engine running hours) as captured into the AMPS system. When a human scheduler selects a job for action, AMPS prints a job card (on flimsy paper) for the human maintainers that includes the procedural document, portions of the metadata (e.g., the job's requirements for tools, spares, and other supplies), and forms as required for reporting any observational information back into the AMPS environment.

Maintainers complete the job and enter required observations and other relevant information onto the job card. These returned details are then entered into the AMPS system together with a number of job related parameters that AMPS collects automatically.

As part of the requirement to measure and prove the effectiveness of the logistic support and documentation package for the ANZAC Ships, Tenix developed a Class Systems Analysis and Reporting Software (CSARS). Tenix periodically downloads selected data items relating to the performance of corrective and planned maintenance tasks from AMPS into the CSARS application for calculation of measures of effectiveness for each ship system and analysis of factors contributing to the poor performance of systems falling below their effectiveness targets. Logistics engineers try to identify and find engineering solutions for components that prove to be inherently faulty and/or any issues in maintenance or operating procedures that may have caused abnormal failures.

Engineering change requests to correct system components or documents are then fed back into the engineering PDM environment for management and execution – to close the circle with corrective feedback to the project engineering and maintenance knowledge base [11].

3.2 Managing Content within Documents

If the only concern was to manage and distribute document files, any of many different document management systems could have met their requirements. However, Tenix decided that only an SGML (or XML)-based content management system had the appropriate capabilities to provide the full functionality required for the ANZAC Ship maintenance documentation.

Authoring in SGML or XML offers many advantages where it is useful to automate or intelligently index identifiable elements of content within the documents [12, 13]. Appropriately named element tags identify to the computer system the location of particular kinds of content. Also, SGML or XML authoring tools and SGML/XML content management systems validate documents against document type DTDs to ensure that content is structured according to the rules of the DTD. Where the content management system is able to parse the DTD, content can be indexed in semantically useful ways to assist human or automated retrieval of particular kinds of content. Also, the tagging systems make it easy to identify particular elements of content within documents that require validation against master data repositories.

Some of the immediate benefits that were derived from this system are significant. For example, by implementing "single source" content management after completing the documentation for Ship 04, four ship sets of WordPerfect merge data files were collapsed to one class-set of SGML instances for the delivery of Ship 05. This immediately reduced text under management by 80% and once the class set was delivered, further delivery requirements were reduced by more than 95%. The documentation change cycle time was reduced from a year to delivering only net changes within a matter of days.

Since the initial implementation of the DCMS, the ANZAC Ship Project has added functionality to annotate documents and include the client in the pre-release document review and signoff workflow.

3.3 Integrating Documentation with Engineering/Product Data Management

A major goal for integrating document content management with engineering/product data management is to provide hard links between configuration related information in the documents and master data as held in the engineering tools. Two kinds of connections ensure this linkage.

- Integration of documentation changes and engineering changes into a single Engineering Change (EC) workflow process, where both engineering tools and authoring processes are under command of the one workflow engine, to ensure that changes are made in concert.

- Automatic validation of relevant document content against master engineering data. This is facilitated in a structured authoring environment where the element tag and associated attribute data can uniquely identify an element of document content with a particular configuration item in the engineering data.

In the ANZAC Ship Project's DCMS implementation, the EC process still involves a paper-based workflow – but one that is strictly controlled by the Engineering/PDM system. To minimise response times in the documentation system, the DCMS system automatically downloads a configuration master file every night, and then automatically validates all configuration specific information in a document against this master file, whenever the document is checked in or out. Any changes or mismatches in the configuration-related information are immediately alerted to the author/user for attention in a formal document change process.

3.4 Capturing Implicit Knowledge with Annotations

From a knowledge management point of view, the ability to apply annotations to elements of content within documents is one of the most powerful tools that can be applied in a content management architecture.

As implemented in Tenix (Figure 6), the content management architecture contains two logically separate repositories; one for managed content and one for "source" documents that are preserved for reference purposes as binary objects. Each annotation is managed as a separate structured document. Content managed documents and annotations are managed within the content management repository. Any kind of object (physical or electronic) can be referenced as a "source". The critical thing is to enter metadata describing the source object and its revision status in the Source Registry. If the object is available in an electronic format it can be preserved for reference and archival purposes in the Source Repository linked to the Registry.

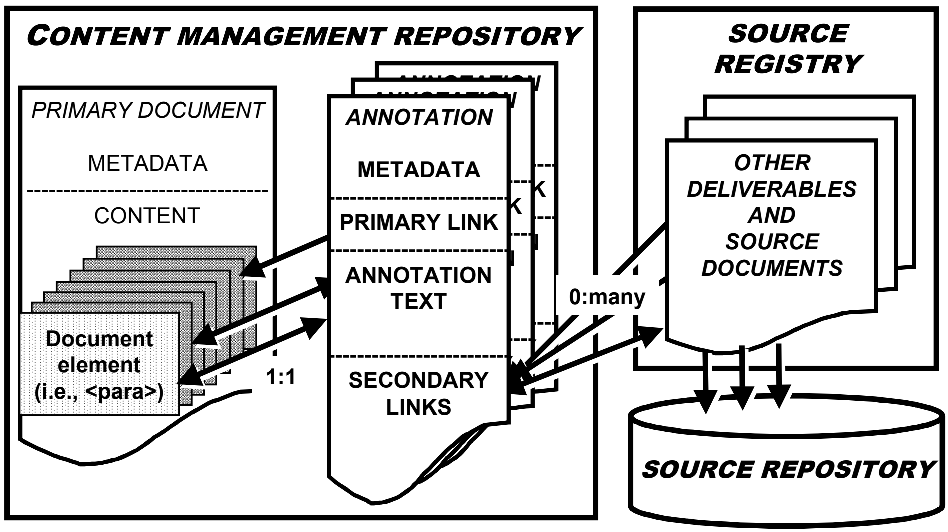


Figure 6. Annotation architecture.

Within this architectural framework, an annotation consists of:

- metadata describing the annotation itself (author, date, version),
- a primary link associating the annotation with a particular element of content in a managed document version – where zero to many annotations can be linked to the one element of content,
- free text entered by the annotation's author that provides contextual information relating to the link that cannot appropriately be entered into the primary document's text, and
- zero to many secondary link associating the particular annotation with the source registry entries for particular source(s) relevant to the annotation.

The annotation function as implemented in SIM/TeraText provides an easily used capability for capturing contextual information relating to the primary link.

Three types of annotation functions are provided:

- *Author annotations.* These persist for the lifetime of the linked element of content in the managed primary document, and may include any number of secondary references. Author annotations are visible to other internal staff. They are used primarily to capture authors' implicit knowledge of the circumstances and contextual information surrounding the authoring process.

- *Internal review annotations.* These persist only for the life of a major version, and are dropped from the document when it is released for publication. Internal review annotations are only visible to authors and internal reviewers. Review annotations are primarily used to communicate reviewer comments and requests for corrections to authors and supervisors. Because all versions of a document are archived, the reviewer comments remain available if required for change tracking or audit purposes.

- *External (client) review annotations.* Except that the client can only see their own annotations, external review annotations are managed the same way that internal review annotations are managed.

In the ANZAC Ship Project, author annotations explicitly significant sources of information authors use in creating or changing each paragraph of text, e.g., references to supplier and client documentation including correspondence, standards, third party procedures, change requests and the like. For each reference, the author is required not only to provide the link to the referenced object, but details of why the source was referenced and the location(s) of the referenced information within the source. This information is of great value to Tenix in managing document changes.

In the past, when a lower-tier supplier changed a part in an assembly, or a specification or determined that some aspect of maintenance processes should be changed, this is normally notified by correspondence – or perhaps only a new version of an existing document is received. To determine the potential impact of the change, when the original authors of the documents were no longer available, experts first had to compare the new document with the prior version to identify source changes, and then had to guess which systems and documents would be affected by the change, and finally had laboriously study Tenix's deliverable documents to see if these had to be changed. The process often took person days of work over several weeks to complete a single impact analysis.

With the implementation of annotation, impact analyses can be completed in a few minutes. When a change is received to a registered source (as determined by its metadata), the system will print a "Where Used" report, identifying all deliverable documents linked to the source by annotations. The text of the annotation identifies particular locations in the source that have been used. If these are unchanged between the original and new version of the source, there is no impact. If there are relevant changes in the source, the linked deliverables can be opened to the paragraph(s) referencing the source. A quick read of the deliverable text, the text of the annotation, and the text referenced in the source will reveal any need to change the deliverable to reflect the change. In other words, impact analyses that often took an author familiar with a the particular system weeks to complete – leaving a significant risk that some impacts may have been missed, can be completed by any author in a few minutes with more confidence that no impacts had been missed.

Although in the ANZAC Ship environment the direct exchange of deliverable documentation is only between Tenix as the prime contractor and its client, the TeraText-based content management architecture and workflow environment is fully Web based and could readily be deployed to include all members of the supply chain contributing directly to the documentation package. Also, the annotation function was expressly developed to provide a means for quickly and accurately determining the impacts of changing supplier documentation or client requirements on the content of deliverable documents by comparison to a documentation environment based on paper formats where much of the necessary information required for impact analysis remains implicit, and was lost through time when the original authors of the deliverable documents were no longer available.

3.5 Minimisation of Redundancy

As noted in the introductory material, a major issue with project documentation can be the requirement to separately maintain common information that is used in many different places. There are three strategies akin to "normalisation" in a relational database [14] that can be used in the architecture described here to minimise the requirement to manage redundant content.

- *Variant documents from a single source master file*. All variant information is held in a single master file, with the variant information held in parallel elements within the overall document structure. Attributes on the variant elements determine which element at any point in the document structure should be included in a particular output variant. This requires a significant processing task to resolve the content for the particular output type, but once the process is developed it allows one document to satisfy a number of different outputs. In this case, the single master document contains components for all the documents that can be delivered from the single version managed container. The strategy is particularly appropriate for a limited number of language or configuration-specific texts within an overall consistent document structure. Tenix gained all of the benefits it required to resolve the MRC documentation issues for the ANZAC Ship Project using this approach. However, single sourcing is much less appropriate where documents share texts but have significantly different structures where it is not possible to maintain a 1:1 co-ordination between corresponding elements in the different output documents.

- *Virtual documents from shared content.* Each deliverable document has its unique version managed container, and includes all content that is unique to that particular container. However, where content to be included in the deliverable already exists somewhere else in the content management system, the container for the specific deliverable will simply point to the location where the shared content already exists. For this architecture to work, content elements need to be maintained within the content management repository as individually indexed items, and the output process must be able to assemble the referenced elements together with unique elements to produce a deliverable document. Tenix is currently working to implement this methodology in a generic version of its DCMS based on functionality provided in later versions of the TeraText application. The virtual document approach is particularly suited to reducing redundancy in the less rigidly structured documents such as technical manuals and the range of document types found in the earlier stages of the project documentation cycle.

- *Managed entities.* SGML and XML include the concept of named entities in their DTD languages, where an entity is an object defined in the DTD that can be included in a document instance simply by invoking its name. Entity references are used to invoke graphics (where a single identified graphic may be used in many different documents) or sufficiently standardised and commonly used texts that it pays to define them separately from ordinary elements of text that may be subject to casual reuse. For example, in some systems standard health and safety warnings and cautions are treated as entities, which can be invoked wherever required in deliverable documents by entering the entity number.

The major benefits from virtual documents and managed entities that a block of content needs to be written only once but can be used many times. In highly redundant bodies of documentation such as are often encountered in engineering project documentation, this can reduce authoring and document maintenance costs by 50% or more by comparison to standard file management systems where each document has to be separately maintained. To safely manage content for reuse requires the ability to track and manage versioning at the level of reusable elements as well as at the file level. It also requires the development of change management workflow to identify all documents using the changed element, so users can determine whether the effected documents should include the new version of the element or should preserve the original version.

4. Conclusions

This paper presented an approach towards a document-based knowledge management system for the ANZAC Ship Project. Their benefits have been proven in a real-world engineering environment.

This system and architecture described in this paper serves as a prototype and proof of concept for what will in time become a generic capability. Our aim is to "package" the system and make it easily deployed for arbitrary document types across all divisions and the whole supply chain.

References

1. Mo, J. & Zhou, M. 2002. Tools and Methods for Managing Intangible Assets of Virtual Enterprise. To appear in Computers in Industry.

2. Zheng, J., Zhou, M., Mo, J. P. T. & Tharumarajah, A. 2000. Background and Foreground Knowledge in Knowledge Management, Global Engineering, Manufacturing and Enterprise Networks. Proceedings of 4th International Conference on Design of Information Infrastructure Systems for Manufacturing. 15–17 November, Melbourne, Australia. Pp. 332–339.

3. Hall, W. P. 2000. Structured Management of Maintenance Documentation. XML Asia-Pacific 2000, Sydney, Australia.

4. Hall, W. P. 2001. Maintenance Procedures for a Class of Warships: Structured Authoring and Content Management. Technical Communication 38:3, pp. 235–247. http://www.tenix.com/PDFLibrary/91.pdf

5. Zhou, M., Mo, J., Nemes, L. & Hall, W. 2002. Knowledge Management in Bid Preparation for Global Engineering and Manufacturing Projects. DIISM2002, Japan.

6. Polanyi, M. 1958. Personal Knowledge: Towards a Post-Critical Philosophy. [Corrected Ed., 1962.] University of Chicago Press. 428 p.

7. Polanyi, M. 1966. The Tacit Dimension. Routledge & Kegan Paul.

8. Nonaka, I. & Takeuchi, H. 1995. The Knowledge Creating Company: How Japanese companies create the dynasties of innovation. New York: Oxford University Press.

9. Nonaka, I. 1996. Knowledge Has to Do with Truth, Goodness, and Beauty. In: Dialog on Leadership: Conversation with Professor Ikujiro Nonaka, Tokyo, Japan, February 23, 1996 and with Claus Otto Scharmer.

10. Nickols, F. 2000. The Knowledge in Knowledge Management (KM). In: J. W. Cortada & J. A. Woods, eds. The Knowledge Management Yearbook 2001–2002. Butterworth–Heinemann.

11. Hall, W. P., McFie, K. & Beer, J. 2002. Managing Maintenance to Reduce Life-Cycle Costs for a Multi-National Fleet of Warships. Proceedings. 2002 International Maintenance Management Conference, Gold Coast, Australia.

12. Berners-Lee, T., Handler, J. & LaSalle, O. 2001. The semantic Web: A new form of Web content that is meaningful to computers will unleash a revolution of new possibilities. Scientific American. May 2001.

13. W3C 2002. Extensible Markup Language (XML). W3C Architecture Domain. World Wide Web Consortium.

14. Kent, W. 1982. A Simple Guide to Five Normal Forms in Relational Database Theory. Communications of the ACM 26(2), Feb. 1983, pp. 120–125.

Collaborative Engineering in Inter-enterprise Networks

The prototype system GAIA-DEE

Koji Kawashima and Koichi Kasahara
Mitsui Engineering & Shipbuilding Co., Ltd., Japan (email: kkawashi@mes.co.jp)
Yasuyuki Nishioka
Hosei University, Japan (email: nishioka@k.hosei.ac.jp)

Abstract

This paper describes a GLOBEMEN solution of Distributed Engineering Environment (DEE) for collaborative engineering environment in Virtual Manufacturing Enterprise (VME). The goal of this study is to construct the Web-based application platform for sharing and integration of the engineering information among enterprises worldwide. The prototype system is called GAIA-DEE (Global Advanced Information Application for Distributed Engineering Environment). The system is built with Web markup languages and Web browsing technologies.

In this paper, the requirement, framework and models of DEE are proposed in order to share and integrate the engineering information among enterprises worldwide. And also, the prototype system GAIA-DEE for the engineering collaboration is introduced in order to evaluate the feasibility.

1. Introduction

By the development of the global Information and Communication Technologies (ICT), the importance of information sharing has been increasing among related companies, companies having core competence technologies and customers worldwide.

The target of the research is the development of methodologies and tools necessary to carry out and manage the lifecycle business activities sharing the information that change dynamically in VME.

At first, an engineering knowledge-based model is introduced for the requirement of DEE models. Subsequently the information framework and methodology to execute engineering are described. Next, the GAIA-DEE model to realize the environment of the information sharing in VME is shown. Finally, the prototype system is introduced in order to evaluate the feasibility.

Figure 1 shows the target system to be developed in inter-enterprise networks. DEE has integrated information models and Simulation Based Engineering (SBE) tools on the Web. The form of information is reusable through the PLC.

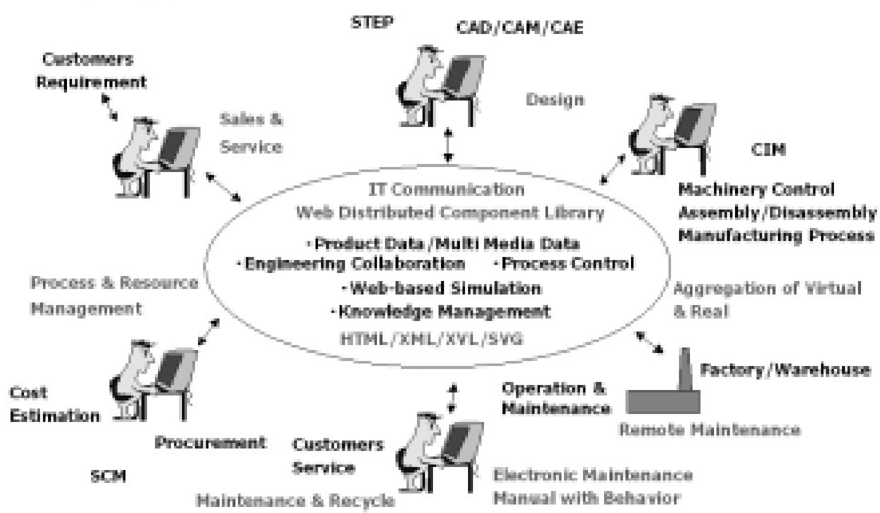


Figure 1. Distributed Engineering Environment in Inter-Enterprise Networks.

In GAIA-DEE, Web markup languages are used. XML (eXtensible Markup Language) technology prescribes the communication data form that contains a hierarchical functional data structure. PSLX (Planning and Scheduling Language for XML) technology [1] prescribes the dynamic processes and the controls of the connection among the distributed business activities for creating the engineering information that is product data and documents. The GAIA-DEE information management system is composed of three components: Document, Process, and Product Data including multimedia data all reusable in the PLC.

The information necessary in each phase of PLC is constructed by these components.

2. Requirement for DEE

At first, the background of DEE, from the viewpoint of Knowledge, is described. The requirement based on Knowledge is important in DEE in order to share/understand the information among engineers who have individual role in VME. This consideration is the basis of GAIA-DEE information structure and execution of work.

For example, **Meister** is an engineer working in a section of a company. He has long experiences and is capable of reliable judgments, and he works accurately and swiftly. In Japan, there is the popular **5W1H** method. The method is the KAIZEN technique to improve the work by considering “who, what, when, why, where and how”. 5W1H method suggests that a person understands business and/or his job by the following compound effects.

- To know business function and its elementary functions composing the business
- To know flow/process of the work elements to execute the business function
- To know I/O information and executable resources to attain the business function.

Generally, function, information and process have the forms as shown in Figure 2. In the engineering, these are complicated/nested to the mutuality.

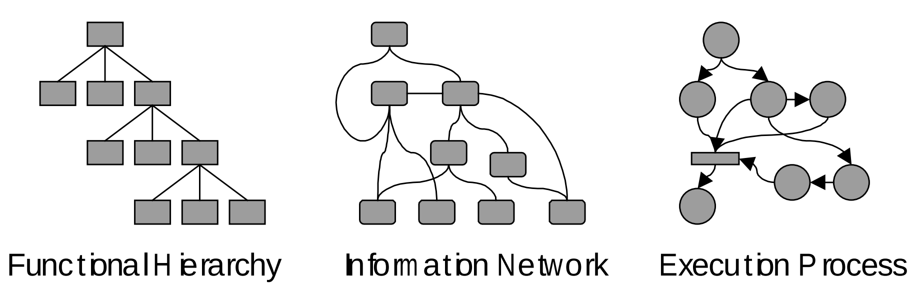


Figure 2. Form of Function, Information and Process.

The example of the plastic molding simulation with interactive operation is shown in Figure 3. The simulation shows the most suitable “Function, Information and Process” of each machine by visualization. Everybody can know the mechanism/**5W1H** of the molding from the simulation. And also, the simulation is able to execute the parametric-survey from HTML (Hypertext Markup Language) I/O fields by the decision on human intention. The type of this HTML based document is called **Active Document** [2].

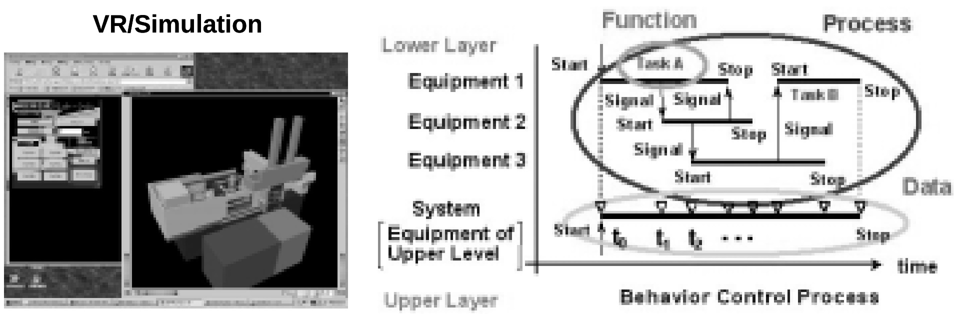


Figure 3. Function, Information and Process in Molding Simulation.

This model has 2 types of constraints. In order to have the outcome of the molding mission, both restrictions have to be controlled.

- **Constraints on layered structure**

The upper layer gives constraints to lower layer and the lower layer gives constraints to upper layer. That is the so-called top-down and bottom-up constraints propagation. This is the layer of **Decision Making** that is whether the outcome is suitable or not, in each level.

- **Constraints on process**

Time-dependent process of upper stream gives constraints to down-stream processes. And also, down-streams give constraints to up-stream processes. That is the so-called time-dependent constraints propagation in **Time Scheduling**.

We presume that **Meister** knows the form of “Function, Information and Process” for executing engineering activities as Knowledge.

And also, the simulation shows that one of the most effective requirements, to understand easily the business/engineering activity, is to know the function, information and process by visualization and interactive operations.

Furthermore, Figure 4 shows the consideration of progression from data to wisdom.

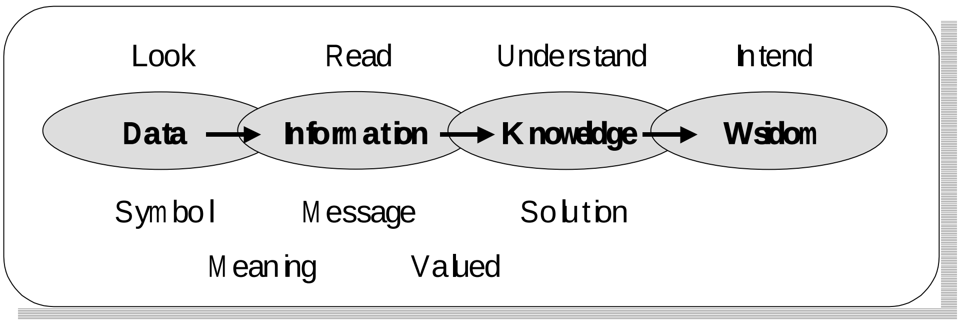


Figure 4. From Data to Wisdom.

Data is Symbol that has no Meaning itself. Information is Message that gives Meaning to Data. Knowledge is Solution that gives Value to Information/Message. Wisdom is not for computer. **Meister** applies Wisdom to various scenes, by using his solutions/Knowledge(s) based on his intention.

We suppose that no engineer except **Meister** can understand the stability, performance, productivity, etc. by looking at CAD geometry data of the product. What give the value to Information is "definition by rule", "proof by analysis" and "trust by experiences or sensibility of human". The data is shared to give it value according to each functional role of engineering in VME. The value is described in engineering document.

Knowledge has the layered structure of Knowledge. Which layer of Knowledge is taken out, it is Knowledge, too. Knowledge is autonomous and reusable in each layer. Document has layered structure. The document describes the outcome/solution of the required function. When document is made of Knowledge, each layer becomes reusable in all phases of the PLC.

3. GAIA-DEE

In order to share the information, the requirement for DEE where various engineers take roles is to have models of the above described, from the viewpoint of the structure and communication form in DEE. For the purpose, the four models that are Function Model, Information Model, Process Model and Document Model are defined. On the basis of DEE framework, the models are described from four views: Function, Process, Information and Document.

3.1 DEE Framework

To deal with the connection of such information integration, the framework [3] of the requirement description and the function description is proposed as shown in Figure 5.

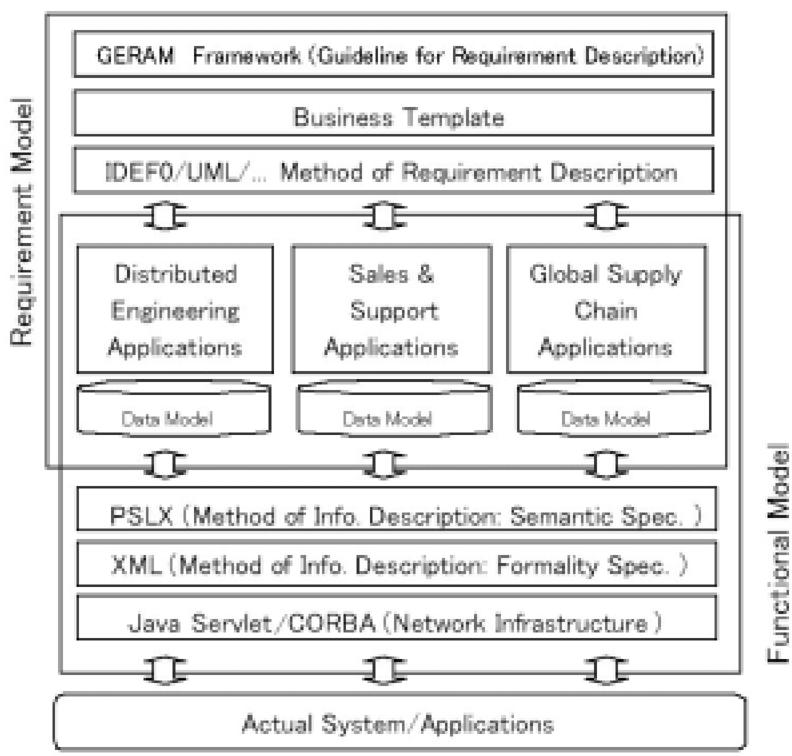


Figure 5. Framework of Requirement and Functional Description.

In Figure 5, **Requirement Model** describes the present condition (as-is) and a goal (to-be) in each business. **Functional Model** shows the executable forms in order to realize the requirement. **Requirement Model**, from the viewpoint of function, in the whole business model of VME, makes “equivalent parts”, “mutual relationships” and “roles in VME” clear.

The framework satisfies the above requirement condition well (see Figure 2). GAIA-DEE integrates the engineering information and manages the activities in the distributed VME environment based on the framework.

- The requirement is reified into hierarchy to satisfy the required mission in each business by the modeling tool such as IDEF0 or UML. By the reification, abstract requirement, for design and production, is divided into functional executable level. The form is hierarchical layered structure of executable functions from the abstraction to the concrete engineering activities having information relationships mutually.
- The execution of the engineering is the flow of process components that has the unit role of engineering function. The process of the business is constructed by the dynamic connections that contain the time-dependent information flow mutually.
- The product data and document are created in the process component that has the role of elementary engineering function.
- XML technology prescribes the communication data and information form that contains a hierarchical functional structure.
- PSLX technology prescribes the dynamic processes and the controls of the connection among the distributed business activities together creating the engineering information and documents.

3.2 GAIA-DEE Models

GAIA-DEE models: Function, Process, Information and Document, are described. These compose the GAIA-DEE system with close mutual relationships. GAIA-DEE becomes the development and optimisation system environment for the information in VME by managing the relationships among work process, product data and document.

3.2.1 Function View

The function view of GAIA-DEE is a functional reification structure of the mission requirement with constraints propagation of top-down/bottom-up. The structure of the function becomes VME structure of the individual roles of engineering. For example, as shown in Figure 6, the first layer is composed of artistic/styling design, structural design, system design, parts design, production design and maintenance design. The second layer of structural design is composed of thermal design, mechanical design, dynamic design seismic design, etc.

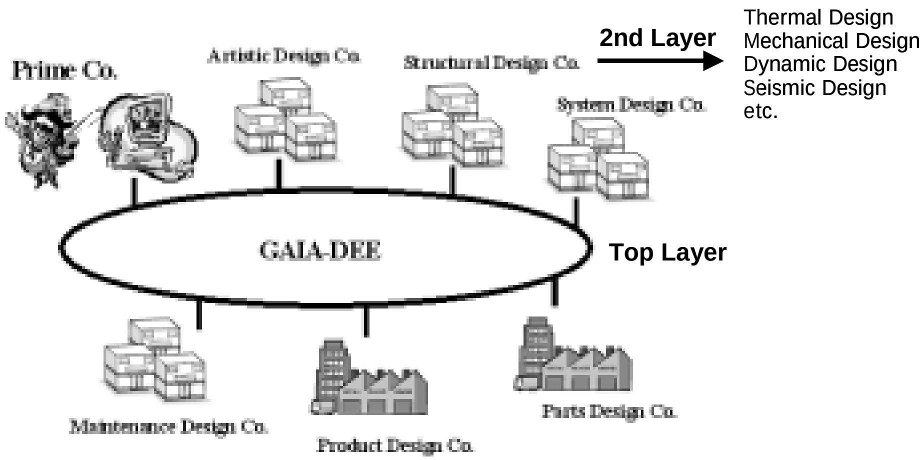


Figure 6. DEE Functional Work Model in Inter-enterprise Networks.

3.2.2 Process View

The work flow shows the dynamic connection of engineering business activities with constraints propagation of up/downstream. The process has the form of time-schedule that is nested in **Function** hierarchical relationships in VME. The whole flow is integrated from the individual VME flows of each executable activity/process component.

In the beginning of a project, engineering process is closed and static because there is a mission but no Input/Output information from each other. This static view of the process is the same as **Function View**. The next phase is the construction of information networks including dynamic information feedback. The process flow considering only lowest business activities is not sufficient enough. Because the dynamic process has 2 types of constraints; top-down/bottom-up and up/down-stream.

The process model is illustrated in Figure 7. The process model has the form to control the 2 types of constraints.

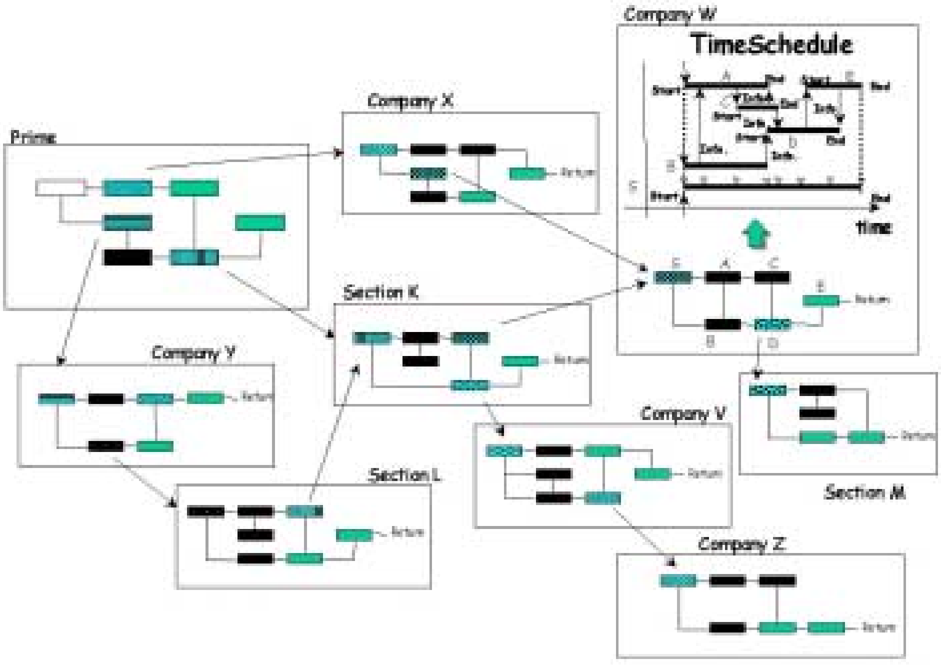


Figure 7. DEE Process Integration in VME.

The process component is the unit of creating the product data and document shown in Figure 8. The input is documents and the output is document(s).

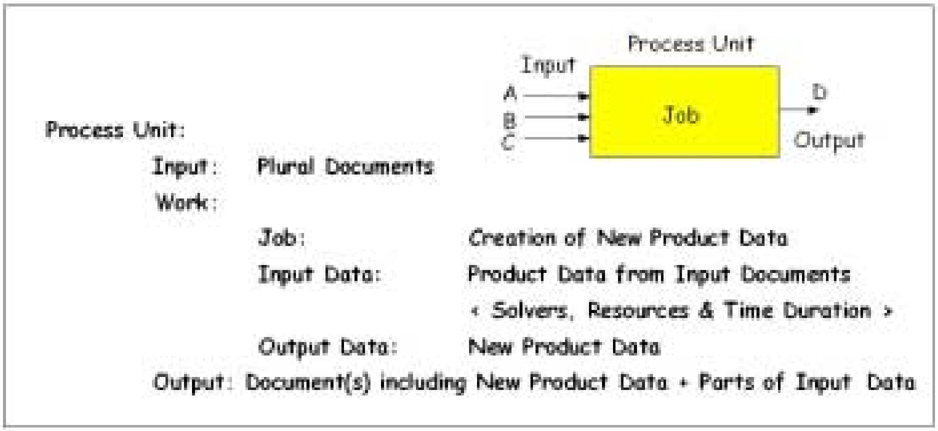


Figure 8. Process Component/Unit.

3.2.3 Information View

The form of the information for communication is represented by documents including product data. The product data is quoted by URL (Uniform Resource Locater), written in documents, from Web warehouse. In order to give another functional value to the data, the data can be referred from other documents. Accordingly, document and product data have to be managed separately to secure the uniqueness of the data. The Intercommunication form that is constructed by each component and their combination in VME, is defined as shown in Figure 9. In the case of using the international standard protocol such as STEP, the data has to be managed separately from multimedia data.

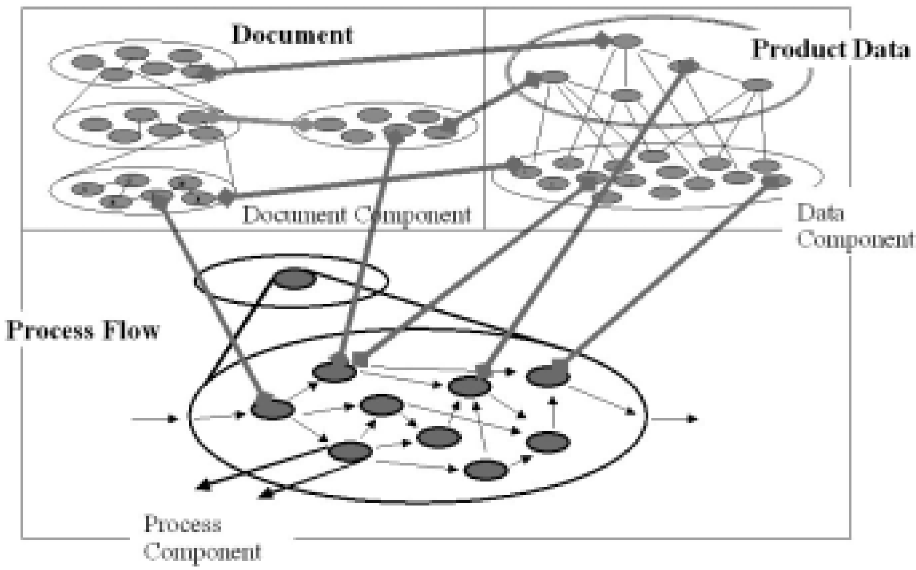


Figure 9. Intercommunication in VME.

3.2.4 Document View

The whole document is integrated by all the document components. The document component is created in the process component as shown in the figure 8. The input to the process component is document components. The product data components are created in the process component using product data components that are quoted in the input document components both with their URL on the Web. The document integration is the combination of each document component using XML.

The form of the document component that is **Active document** as shown in Figure 3 is illustrated in Figure 10. The **Active Document** is constructed on Peer-to-Peer (P2P) computing environment of ICT browsing space. The available ICT are XML based markup languages and their communication infrastructures.

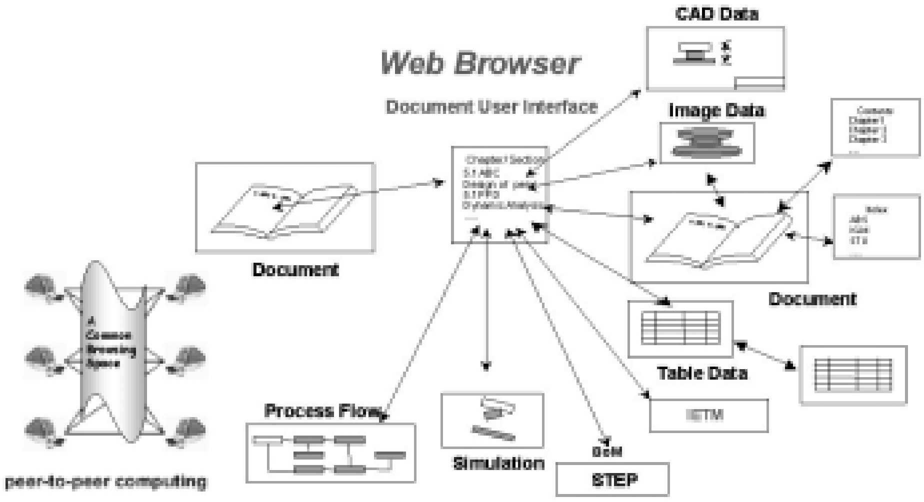


Figure 10. DEE Document Integration in P2P Computing.

According to the above models, GAIA-DEE conceptual image of the information browser is shown in Figure11. The common Web browsing space is named **4D Virtual Space**.

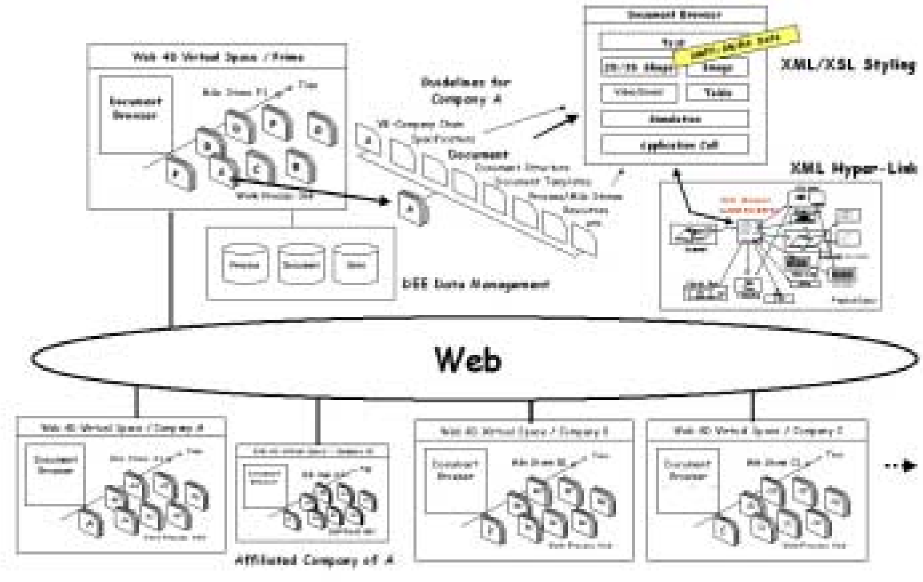


Figure 11. Conceptual Image of GAIA-DEE.

4. GAIA-DEE Prototype

The prototype GAIA-DEE system platform has been developed to evaluate the models. This environment has a common 4D virtual space of P2P in VME on the Web browser. 4D virtual space displays business functions, individual/integrated documents and multimedia product data. 4D virtual space is closed browsing space in VME and every member can browse the documents that are displayed hierarchically on the space. The document includes HTML and word processing document, product data such as SVG drawing and XVL (eXtensible Virtual world description Language) [4] simulation. These are called and transmitted from Web data warehouse directly by the URL. XVL is the compression technology of 3D model transmission on the Web and has animation execution capability.

The developed 4D virtual space is shown in Figure 12.

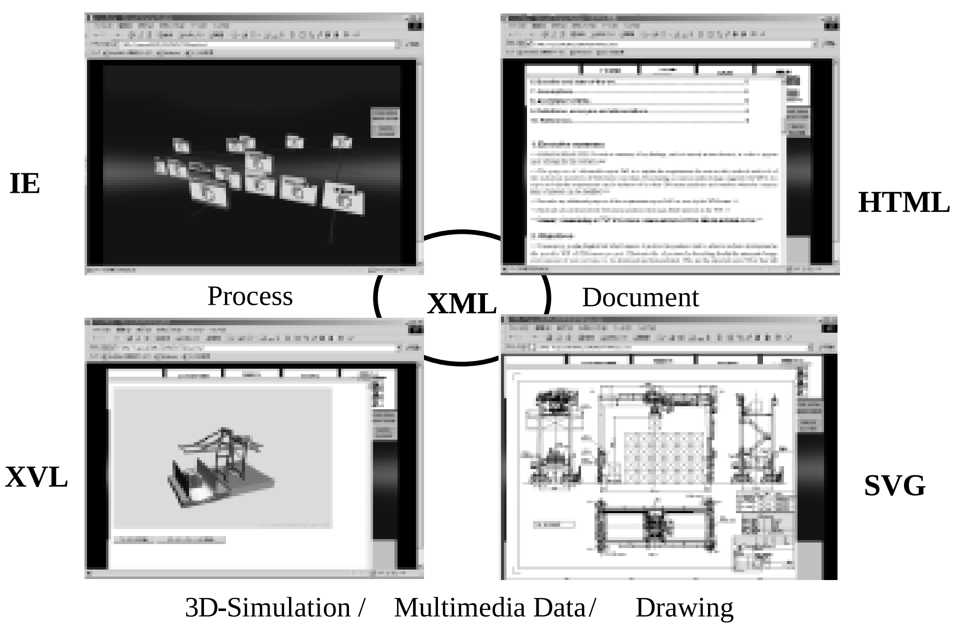


Figure 12. 4D Virtual Space in GAIA-DEE.

The information description is independent from hardware and its OS. The document is an encapsulated executable document component, the active document, with the following four elements of HTML document, input/output menus, programs and product data. The document components that are produced in the design phase are reusable through the PLC, respectively. And also, these components are managed in each enterprise as one of the knowledge base in engineering respectively.

5. Conclusions

This paper describes the knowledge based DEE collaborative engineering environment in VME for the lifecycle information integration. The prototype is the Web-based application platform for sharing and integration of the engineering information among enterprises worldwide. The prototype shows that such a distributed engineering environment is implemented by elementary parts of process, product data and document for the business and their dynamic integration by the active document. The environment has Web P2P browsing space that is closed in VME. GLOBEMEN prototype system: “SUPREME” describes the details of the process-scheduling using PSLX [5].

It is very effective that the components of document, process and data are managed separate and independent with the links from each other because each component is usable to the other purposes. These contents are managed as the knowledge base. The functional document component is re-usable to each phase of the PLC such as design, manufacturing, maintenance and customer services.

The prototype needs full Web addresses by URL. However, in order to obtain the necessary contents, the search engine is indispensable. The search engine will be the target of the next research. In this consideration, Semantic Web concept proposed by W3C [6] is expected. That is RDF/OWL (Resource Description Framework/Web Ontology Language). The DEE background of Knowledge will be applicable to Semantic Web.

References

1. Nishioka, Y. 2001. XML-based Standardization of Planning and Scheduling Problems for Virtual Enterprise Collaboration. Proceedings of ICPR-16, Czech Prague.

2. Morita, K. et al. Web-based maintenance manual with three-dimensional simulation model. DIISM2000, Nov. 15–17, 2000, Melbourne, Australia.

3. Nishioka, Y., Kamio, Y., Kawashima, K. & Fukuda, Y. 2001. A Booking Type Production System as a Collaboration Method for Virtual Enterprises. Global Engineering, Manufacturing and Enterprise Networks, Kluwer Academic Publishers, pp. 164–172.

4. XVL Web site: http://www.web3d.org/TaskGroups/x3dIndex.html

5. Nishioka, Y. et al. SUPREME: Supply Chain Integration by Reconfigurable Models. GLOBEMEN BOOK.

6. W3C Web site: http://www.w3c.org/

Web-based Simulation Environment through Product Life Cycle – WISE

Koichi Kasahara, Kazuo Morita and Koji Kawashima
Mitsui Engineering & Shipbuilding Co., Ltd., Japan (email: kkasahar@mes.co.jp)
Yoshinori Fukuda
Hosei University, Japan (email: fukuda@k.hosei.ac.jp)

Abstract

In the engineering, Simulation Based Design (SBD) has been generalizing. This paper proposes a new Web communication form of knowledge-based contents for collaborative Virtual Engineering in worldwide Distributed Engineering Environment (DEE). This paper describes the architecture and example demonstrations of Web-based World Wide Simulation Environment (WISE) using engineering information and resources for Product Life Cycle (PLC) such as design, manufacturing, material handling and after-sales service. The purpose of WISE is to construct and to reuse Web document (Active Document) in PLC. The active document is WISE component of executable documents and has hierarchical structures. Each active document of hierarchical level is also the active document in engineering. The engineering resources/tools are constructed and executed by assembling/collecting the WISE components for the required mission through global communication networks. In the engineering, a typical use of WISE active document becomes documents of design, analysis, manuals for operation, maintenance and diagnosis etc., by using reusable WISE components build in the engineering and design.

1. Introduction

In manufacturing industry, innovative improvement has been required through product life cycle such as the forms of resource, design, manufacturing and customer service by applying the ICT infrastructure effectively. As one of those solutions, Simulation Based Design (SBD) has been generalizing. The SBD supports creation, operation and evaluation of virtual products for increasing the values of the real products and reducing the total PLC cost.

The simulation technologies are very effective to realize the internationalisation and decentralization of the Web business. However, the simulation technologies are not still good enough to apply to ICT environment. Therefore, to construct the next generation engineering environment on the Web, the followings are the requirements for a Web-based World Wide Simulation Environment (WISE):

- To use computer resources, product data and multimedia data distributed worldwide.
- To share and visualize all necessary information with Web browser.
- To have simulation abilities through PLC.
- To be independent from information description forms of hardware and OS.
- To reuse the information for all phases in the PLC.

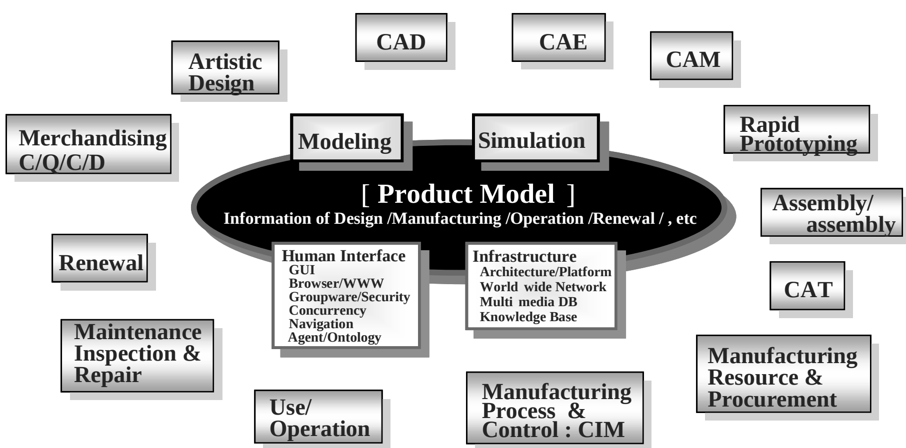


Figure 1. Application Fields of WISE for the PLC.

The final goal of this study is to construct the reusable active documents and their assembly including SBD environment that simulates the virtual design, manufacturing and customer services on global communication networks.

2. WISE Architecture

Figure 2 shows the proposed WISE architecture. The WISE model will be transferred by the HTTP protocol from the designated URL address to the client side. The model is an encapsulated executable document component, the active document, with the following four elements of HTML document: Input/output menus, programs and product data. The description form of the contents is XML based markup languages with no dependence on the hardware and its operating system. The substances of resources and data are transmitted from their Web warehouses by the designated URL address.

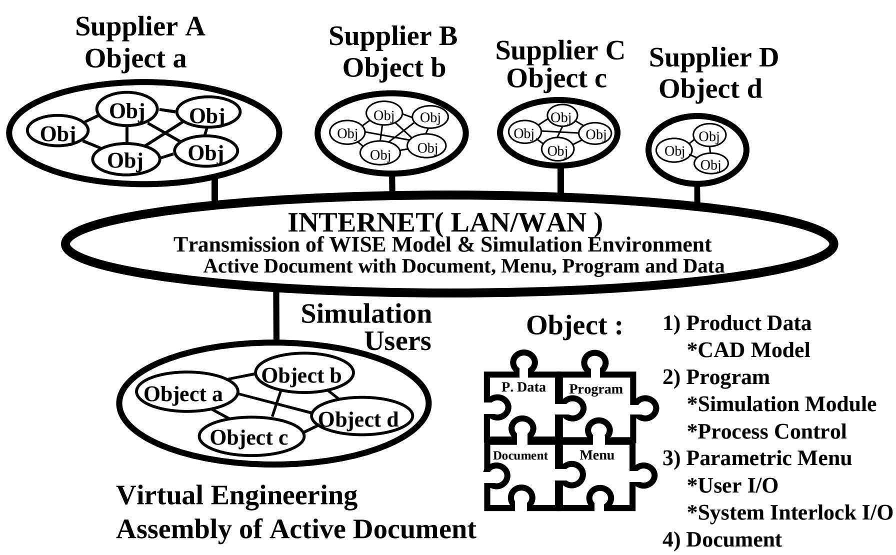


Figure 2. World Wide Simulation Environment (WISE) Architecture.

The WISE active document is an executable document component. The architecture constructs the active document of upper level that can execute assembled function to apply the compound activities. The method of the assembly and execution is illustrated as follows (see Figure 3).

On the point of view of knowledge management, the most effective requirement, to understand easily the business activity, is to know the function, information and process by visualization and interactive operations. For example, the design by analysis using some tools/solvers is executed automatically by the definition of functional hierarchy, I/O data communication and execution process of each tool/solver. In WISE, the form of each tool/solver is also the executable active document.

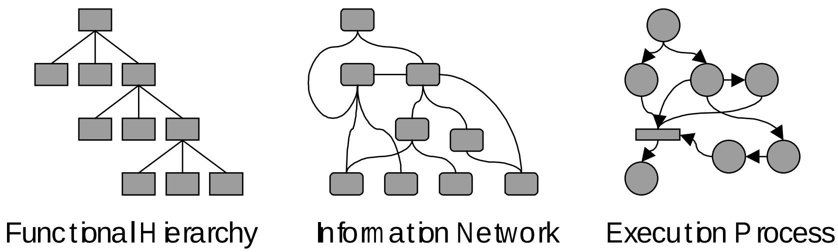


Figure 3. WISE Execution Model.

The WISE can also have physically meaningful models or product models with behaviours for Virtual Reality (VR) simulation activities. The models are built on the Web and distributed throughout networks. The models are made to represent the function, behaviour and performance of real equipment and human beings by giving behaviours programs to three-dimensional CAD models that is operated by interactive way on the HTML active document of Web browser.

Users can thereby collect the active document through worldwide networks, and confirm and evaluate these behavioural activities. The virtual environment gives easy and effective information to understand for engineers. The Web-based simulation environment drastically improves the engineering environment among distributed companies and virtual enterprises.

3. Web-based Demonstration System

The Web-based demonstration system for VR activity is developed in order to evaluate the proposed WISE architecture and the possibility of usage to VR simulation field. Three demonstration systems are shown below.

3.1 Electronic Catalogue of Virtual Factory

Robot, NC machine and AGV are constructed by the WISE active document as the electronic catalogue for examples of typical factory equipment. This electronic catalogue is able to simulate the behaviours by setting up input parameters on HTML. The electronic catalogues of the factory equipment are shown in Figure 4.

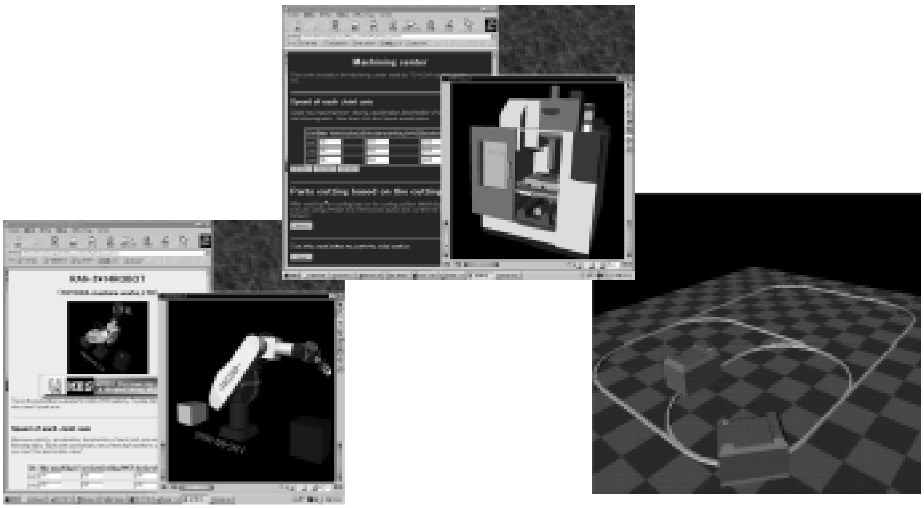


Figure 4. Electronic Catalogue of Robot, NC and AGV.

The input data of the Robot example on the Web browser are as follows:

- Acceleration, velocity and deceleration of each servomotor.
- Coordinate of points where to grip and release the target part.

Figure 5 shows the electronic catalogue of the Factory Automation (FA) Virtual Factory. The electronic catalogues of Robot, NC and AGV construct the factory.

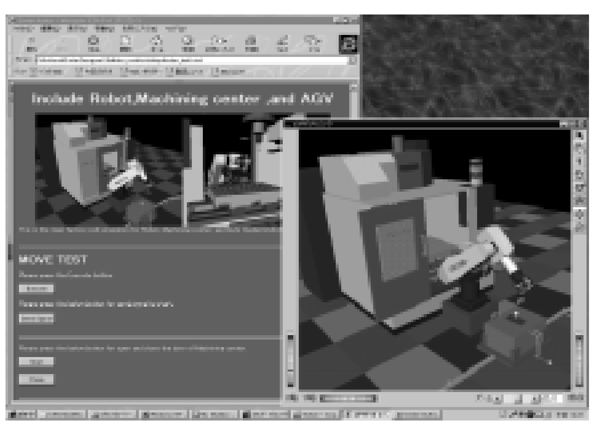


Figure 5. Electronic Catalogue of Virtual Factory.

AGV delivers a work piece, the robot handles the piece from AGV to NC machine and NC machine processes the piece. After finishing NC process, the robot handles the piece from NC to AGV and AGV carries out the work piece. In this process, a product engineer constructs an FA cell after evaluating the performance of each machine using the electronic catalogue for each piece of equipment. Not only evaluating the performance of the whole system by assembling partial models, but also evaluating compatibility of behaviour of equipment and actual operation mode is confirmed. These electronic catalogues are constructed and registered on the Web as reusable master models.

3.2 Adjustment Manual of AGV

The AGV for heavy cargos is operated in the steel manufacture fields and container terminal marine ports. It has dozens of adjustment items at the delivery test. The developed Web-manual is one of the adjustment instructions for the AGV and is shown in Figure 6. The instruction processes of adjustment activities are written in HTML. The active document instructs users, step-by-step and in visible way from any point of view of three-dimensional animation.

Figure 6. Manual of AGV Adjustment.

3.3 Maintenance Manual of DE Turbo-Charger

The diesel engine is the main machine for the vessel. They require the periodical maintenance. Therefore, these training processes are important for the technical crews. To operate effectively the maintenance activities by crews, the manual has to be more serviceable. Figure 7 is the example of Web-manual for turbo-charger of diesel engine. The figure shows the disassembling process of the turbo-charger for overhaul.

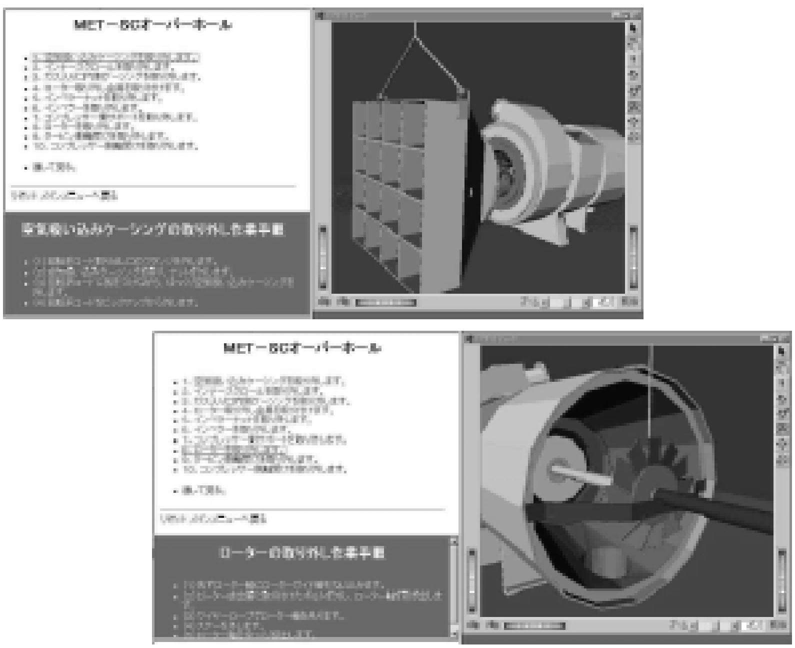


Figure 7. Manual of Overhaul Process for Turbo-charger.

4. Conclusion

This study clarifies the basic foundation of usability of the WISE model through INTERNET by the electronic active documents concerning simulation based engineering and also clarifies the availability of the WISE model applying in the PLC, such as the Virtual Factory under the distributed environment, manual for adjustment of AGV and maintenance manual of turbo-charger for vessel diesel engine.

This Web-based multimedia manual shows that it is very effective for the service engineer and/or customers to understand the maintenance process by the interactive way on HTML and three-dimensional model with motion.

We propose a new form of Web contents in this paper. The contents have the form of no dependence on computer hardware. The URI addresses of computer resources, such as application tools/product data, are written in the contents. The contents are travelling on the Web. The content becomes an intelligent document that contains all the elements for a person easy to understand and to intend the information. The components of the active document created in the design are reusable through the PLC and becomes knowledge base.

The WISE will be the information model to support a human creative idea. The business intention becomes the basis of design and engineering. The database that manages knowledge, shares the “business information“, “business process” and “decision on intention”, and it is made to have an idea as a new knowledge by the connection of the knowledge. It becomes possible that WISE constructs the business model of the knowledge sharing type of virtual environment. The INTERNET will become the huge warehouses of the intellectual property as to the data, information and knowledge by the intelligent contents as shown in WISE.

WISE model makes the simulation of the complicated system possible. That case is shown in Figure 8. The whole model has the parameters of behavior beyond ten thousands. The combination of these parameters is astronomical. However, the simulation execution without scenarios becomes possible by the master models of equipment.

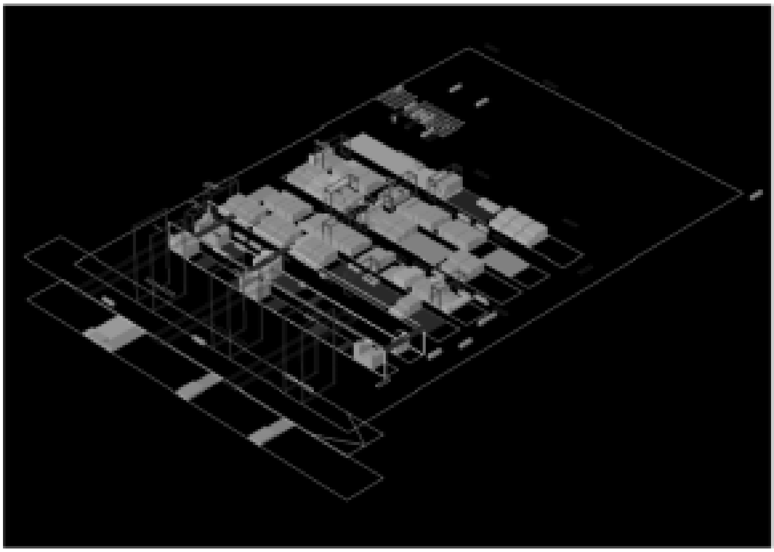


Figure 8: Simulation of complicated System.

References

1. Morita, K., Kawashima, K., Saito, J., Naruko, Y., Okamoto, M. & Suzuki, H. 1997. World Wide Simulation Environment (WISE). Computer Applications in Production and Engineering, IFIP, Chapman & Hall, pp. 330–339.

2. Morita, K., Kawashima, K. & Fukuda, Y. 2000. Web-based maintenance manual with three-dimensional simulation model. IFIP DIISM2000. Pp. 212–219.

3. Jorgensen, E. J. et al. A Web-Based Architecture for Interactive Electronic Technical Manuals (IETMs). http://navycals.dt.navy.mil/

4. Jorgensen, E. J. et al. DoD classes of electreonic technical manuals. http://navycals.dt.navy.mil/

Management of Best Practices in Construction through Interfacing with Product Models [1]

Abdul Samad (Sami) Kazi
VTT – Technical Research Centre of Finland (email: Sami.Kazi@vtt.fi)
Olli Nummelin
YIT Corporation, Finland (email: Olli.Nummelin@yit.fi)
Vesa Pirinen
YIT Corporation, Finland (email: Vesa.Pirinen@yit.fi)
Minna Huhtala
YIT Corporation, Finland (email: Minna.Huhtala@yit.fi)
Eve Huittinen
YIT Corporation, Finland (email: Eve.Huittinen@yit.fi)

Abstract

Compliance with best practices is seen as a key enabler of successful project delivery. This is seen as a key requirement in particular in industries such as construction where multiple partners share complementary competencies to deliver a unique product. Information integration and exchange in construction is being pioneered through the use of product data technology. Relying on common standards such as the Industry Foundation Classes (IFC) from the International Alliance for Interoperability (IAI), is seen as a main instrument for information exchange between heterogeneous information sources and applications. YIT Corporation is one of the pioneers in the use and exploitation of IFCs in the Finnish construction industry. Many of their construction related applications make use of IFCs for product (building) modelling, cost estimation, etc. At the same YIT makes use of its best practices library to provide information to its employees on how to best perform a particular task. This paper presents an approach that is being investigated at YIT through the IMS GLOBEMEN and e-COGNOS projects for the use of product models as an

[1] To be presented as, “Product models as an interface to best practice management in the construction industry”, at eSM@RT 2002, November 19–21, University of Salford, UK.

interface to best practice management in construction. In essence the approach relies on pre-populating a product model with references to relevant best practices. The results are available through a multi-dimensional visual interface for use by different categories of end-users. These end-users can be differentiated not only on the technical nature of their work, but also as to belonging to different types of organisations.

1. Introduction

The business of construction is a complex one as it involves the cooperation of different organisations in an inter-enterprise setting working together in a parallel or even sequential form to deliver a one-of-a-kind product such as a building. A well known fact and reality is that not only do participant organisations work on multiple projects at a given time, but there is a lack of homogeneity in the applications and data standards that are used across organisations. The classic mode of product delivery in virtual enterprise (VE) settings is the norm rather than the exception in the construction industry as illustrated in Figure 1 [8] for a typical building construction project.

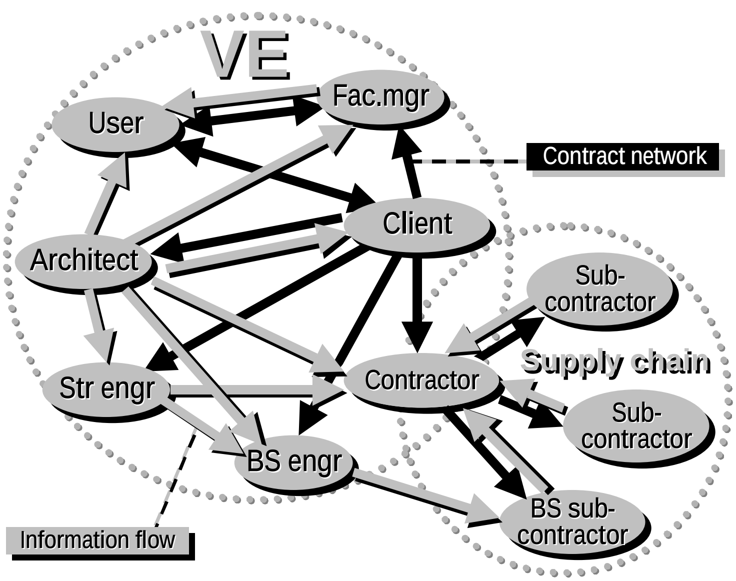


Figure 1. Key actors, information flows and contract networks in a construction project.

As may be noted from above, two types of inter-enterprise collaboration exist a virtual enterprise one in addition to a traditional supply chain one. Another point of interest is that while information flows seem to stem from the architect, contractual flows are around the client. While several variants of the above exist, rarely, if at all, information flows and contractual flows are in parallel [10]. Key characteristics of distributed engineering in construction for settings as shown in Figure 1 were identified by Hannus and Kazi [8]:

- temporary relationships
- some participants are not known in advance
- complementary competence is provided by distinct companies
- absence of a dominant actor
- disparity between contractual relationships and information flows
- participation of some actors in other distributed engineering settings concurrently.

The aim of this paper is to present the use of Product Data Technology (PDT)as a solution for information exchange in distributed engineering environments as seen from the perspective of a contractor, capture, sharing and re-use of best practices that are built on past experience, and finally to demonstrate a solution that would combine the two.

2. Background

2.1 Product Data Technology

Product data technology is "the application of information technology to all aspects of product developments, manufacturing and operation. It is based on a unified view of information captured in products throughout their life cycle" [13]. Significant developments in this area have led to the formulation, adoption, and exploitation of standards such as the Standard for exchange of product model data, STEP (ISO 10303) and Industry Foundation Classes (IFC) [3]. Based on these standards, first commercial CAD tools have started to emerge in addition to toolkits for developing file conversion software.

The belief that product models are the foundation for information sharing in the future is becoming generally accepted. Data transfer in the future will be based more on sharing than sending. A key problem however with product data technology is that data models are constantly evolving. This instigates the continuous upgrading of software to remain compliant. While significant developments have been noted in EU projects, CONCUR (2001) [4], PROCURE (2002) [5], ToCEE (2000) [6], ISTforCE (2002) [7], there still seems a gap in terms of support for product data warehouses, partial product model data exchange, server-client architectures, model merging, etc.

2.2 Knowledge Management

Knowledge management entails the capture, consolidation, dissemination, and reuse of knowledge in addition to the translation of new best practices to tangible programmable processes to be automated through IT [9].

Currently, knowledge management is not available as a packaged point solution, but needs to be built up through the combination of different "infrastructure" elements: open interoperable computing platforms, communication networks, knowledge creation analysis tools, external and internal content, collaboration tools, enterprise-wide and inter-enterprise-wide messaging, web content management tools, "push" and "pull" technologies, intelligent agents, case-based retrieval, portable documents, object databases, document management, process management tools, etc. State of the art tools today, facilitate concept classification to help identify knowledge, and then use either semantic, collaborative, or visualisation retrieval technologies to extract the knowledge from applications.

While there is evidence of support in terms of "process" knowledge management, there is a lack of solutions for "product" knowledge management.

3. YIT: In a Nutshell

YIT Corporation Ltd is the largest construction company in Finland, consisting of several production divisions and subsidiaries around the country and abroad.

The main product lines are Building Construction, Huber, Civil Engineering and Industry. The fields of business for Building Construction are building construction, and the property business as well as property services. Huber's field includes servicing and maintenance for industry, mechanical contracting and related engineering fabrication.

As a construction company YIT in most cases receives design information from external companies which are beyond its reach of influence. In order to solve problems related to heterogeneous IT environments and standards used by other companies in the industry YIT has developed knowledge based tools allowing a rapid transformation of incoming design data into a consistent product model. This approach has already demonstrated an opportunity for integral use of IT in a heterogeneous environment where open standards are still emerging and are not yet supported by available IT tools. Based on this approach YIT is developing model based IT applications and related operational practices for internal use as well as for enhanced collaboration with other companies in the construction value chain.

4. Distributed Engineering: The Case for Product Models

An analysis of the main building life cycle stages that could be impacted through the use of product models in distributed engineering was conducted. Current inefficiencies (process as is) were identified as were potential resolutions (process will be) through the use of shared product models by Kazi et al. [11].

The results from the analysis reported in Table 1 do have certain implications with regard to the roles different actors play. An analysis of the shift was presented by Kazi et al. [12].

Table 1. Analysis of current vs. to be processes.

Stage	Process as is	Process to be
Briefing	- Sketches are done by architect manually - No systematic analysis - Key figures manually calculated on a case by case basis	- All sketches are based on a product model - Visualisation (interface) is automatically available for end-user in he form of graphs, 3D models, key figures, etc.
Design	- Only advanced architect and designers can produce product model information	- Product model is utilised by all stakeholders including structural designers, HVAC engineers, etc.
Production planning	- No systematic feedback from contractor to architect/designer	- All partners have access to contractor's experience (available in the form of structural types, etc.)
Construction	- Information management is restricted to simple document management - Only some partners are able to use product models in their internal works and associated applications	- Shared product model is available for and used by all partners
Use & maintain	- No as built model is created	- Contractor and suppliers add as built information to product model - Product model information is exploitable for a long period

Table 2. Changing roles of actors due to use of product models.

Roles	Roles as-are	Roles to-be
Client	Define concept and provide initial data	Provide more detailed data and specifications of requirement
Architect	Produce 2D separate architectural drawings	Create a base model, share information, bear overall responsibility of the design and make use of the product model
Designer	Rewrite/recreate the architects drawings in their own tools and add their own data	Refer to base model and merge partial deigns into the required functional entities, acquire best practice and modelling templates from contractor, utilise product model
Contractor	Overall management	Collect and share model-based best practice experiences and solutions in the form of templates, recipes, etc., add scheduling information and merge the information in the product model, visualise the different available alternatives, etc.
Supplier	Material and compo-nent delivery as defined in project schedule	Utilise product model, create model based product libraries
User	Operate and maintain facility	Exploit and update as-built information (i.e. create as-maintained information)

Research in GLOBEMEN [1] identified some common end-user requirements for distributed engineering in construction through the use of product models. These were:

- Ability to utilise shared product models based on current standards network standards
- Management of concurrent use of product models
- Ability to use partial models
- The solution should rely on international data exchange standards such as the IFCs by the IAI
- The solution should be flexible enough to allow for frequent change of actors (consortia typically vary not only from project to project, but across different project phases as well)
- Set-up and configuration time must be extremely short (hours … few days)
- User rights and access control needs to be efficiently handled
- The system must be easy to use and require minimal training (if at all any).

It was observed that product model management was to be done with the aid of a product model server. Requirements from the product model server were identified as:

- Upload product model schema (e.g. IFC schema) into model server
- Initialise the model in the model server through pre-defined standard templates (structural types, composites, etc.)
- Insert a new product model into the model server
- Append a new product model into the model in the model server
- Modify a partial product model
- Delete a partial product model
- Merge two or more product models together

- Merge documents (could be in the form of references to different document repositories) into the product model
- Read a specified product model or partial model in different formats (e.g. EXPRESS, XML, etc.) from the model server
- Read specified parts from the product model (e.g. value of a specific attribute, component or instance)
- Read specified pre-defined standard templates (e.g. structural types, composites, etc.)
- Possibility for concurrent access of product model by different users.

Based on the above requirements identification and in line with the findings of Tables 1 and 2, three main high level use cases were identified for a shared product model-based solution: data exchange, manage models, and link documents with models. A more elaborate presentation of these use cases has been reported elsewhere [12] as has been the implementation architecture for the same [8].

5. Knowledge Management: The Case for Best Practices

Construction, being a project based one-of-a-kind production industry, knowledge and experience from past projects can be detrimental to the non-repetance of past mistakes and the re-use of good solutions. This however is not very easy as project partners typically change from project to project and new partners are little if at all aware of past experiences, good or bad. As such, a means to capture good/best practices is essential by the main contractor to then be provided to other partners for use in the joint delivery of a building.

Work towards the capture and reuse at YIT of best practices started in 1997. The initial focus was towards the standardisation of different structural components that they regularly used in buildings. Relying on this as a foundation, YIT’s best practices database was launched in 1998. This tool (used in parallel with several other ones) provides employees with access to best practices in the form of cards. Figure 2 is a high level illustration of the best practice card system used at

YIT. The current system operates under lotus notes and is available only through the Intranet. All updates are done manually by a knowledge manager.

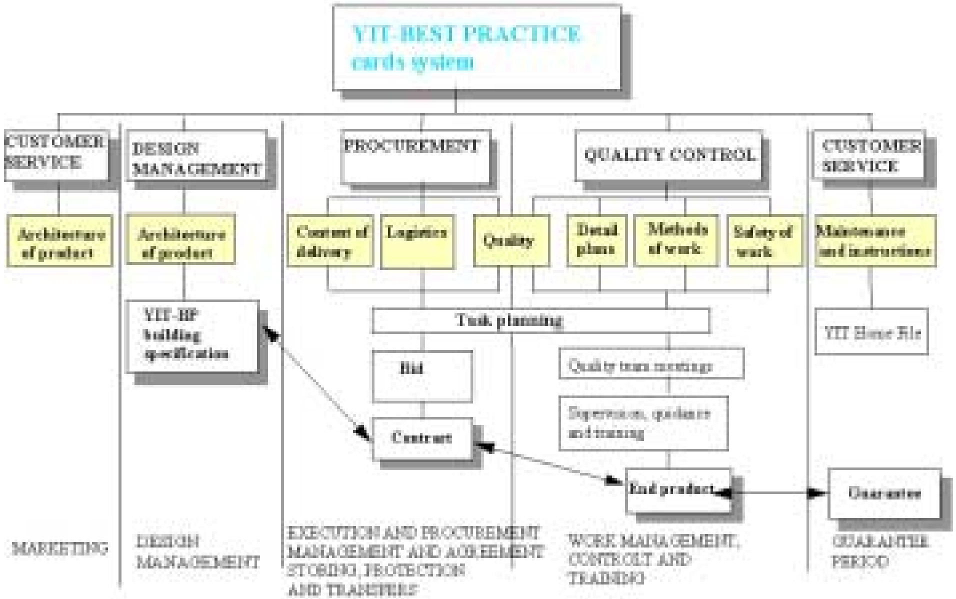


Figure 2. Structure of YIT's best practice cards.

An analysis of the current best practice database has revealed some in-efficiencies. A few are reported below:

- Best practices are not properly systematised in accordance to YIT's ontology
- Database updates are only a few times a month and are not done automatically
- Knowledge workers are not able to update items or comment on them
- When no knowledge is available, clear indication as to whom could be a potential knowledge provider is missing
- Customisable user interfaces both at user group and individual level are missing
- All information is accessible (only in Intranet)

- There is no possibility to access (in full or partiality) the best practices from outside YIT offices
- People replicate the database on their computers, hence they may not have access to the latest correct information.

Within the context of the e-COGNOS [2] project, YIT have identified the means to resolution of some of the above inefficiencies. This has been presented in the form of IDEF0 diagrams describing the situation "to-be". A high level view is shown in Figure 3 followed by a brief description of the main processes.

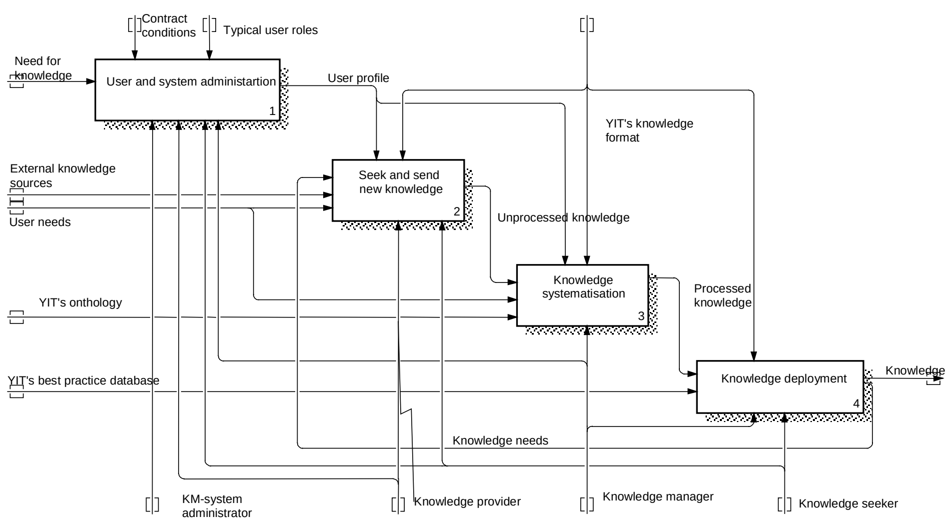


Figure 3. YIT best practices database – "To-Be".

<u>User and system administration:</u> The aim here is to create some generic user profiles based on certain user group classification. Once a user logins in, they are shown the customised user interface for the group(s) in which they partake. Furthermore, each end-user is given the flexibility to further customise the interface and profile based on personal application and knowledge needs. Access rights too are controlled here with a clear differentiation between rights based on whether the user is an employee of YIT, employee of a partner in an ongoing partner, etc. User rights to knowledge and application service invocation are typically based on contract conditions.

<u>Seek and send new knowledge:</u> The aim here is mainly to seek, comment, and then send for further processing the relevant knowledge (items). A user may

seek knowledge from two main sources, internal (YIT's resources) and external (external third party resources). Results are retrieved in alignment of the profile of the user and the rights which the user has. The user would check the received results for validity and satisfaction of the needs for which the search was conducted, thereby filtering out the relevant knowledge. Users would also comment the selected knowledge items (including where relevant some corrective actions). Selected items would then be submitted for further systematisation.

Knowledge systematisation: The aim here is to primarily maintain YIT's ontology based on user needs and experiences. It involves the processing and systematisation of knowledge in accordance of the ontology and YIT's knowledge presentation formats. This includes the organisation, classification, and modification of knowledge items. Processed knowledge items would be ready for use by different users and presented in accordance with different user profiles and made visible on the basis of a user's access rights.

Knowledge deployment: The aim here is to make available (publish) that knowledge which has been processed, systematised and retained for use. User's would be able to retrieve this knowledge through queries to the YIT best practice database and provide further comments when relevant. New knowledge needs may emerge on the basis of this knowledge and as such requests for the same will be directed to the relevant knowledge sources and experts.

6. The Solution: Product Models + Best Practices

Product models are at the heart of building design and are packaged with volumes of parametric information. This information on its own however is not structured in a meaningful way for a simple user to make use of it. Intelligent means and applications need to be developed to make the product model more "smart". As an example, the automatic generation of a project status report for an executive manager, or the generation of a detailed cost estimate report for the finance department.

At the current state of implementation in YIT, product models and the best practice database, though sharing a common data structure (as close as feasible) are distinct entities with no physical links. As such, it becomes necessary for one to perform specific searches to find for example construction techniques for a beam.

A means to make the use of product models in the daily lives of construction personnel (e.g. at the site) is currently under investigation at YIT. This involves the linking of the best practices database with a product model server. Linking (relationships between product model objects and best practice cards) would be done though an intermediate application. The main ambition being that once a product model is loaded into the product model server, it would be pre-populated with relevant best practice links from the best practices databases. It would for example automatically attach construction techniques, safety directives etc. for all walls that have a thickness of 20 cm or less. Concept implementation of the above is presented with the e-COGNOS infrastructure acting as a bridge between the product model server and the best practices database as shown in Figure 4.

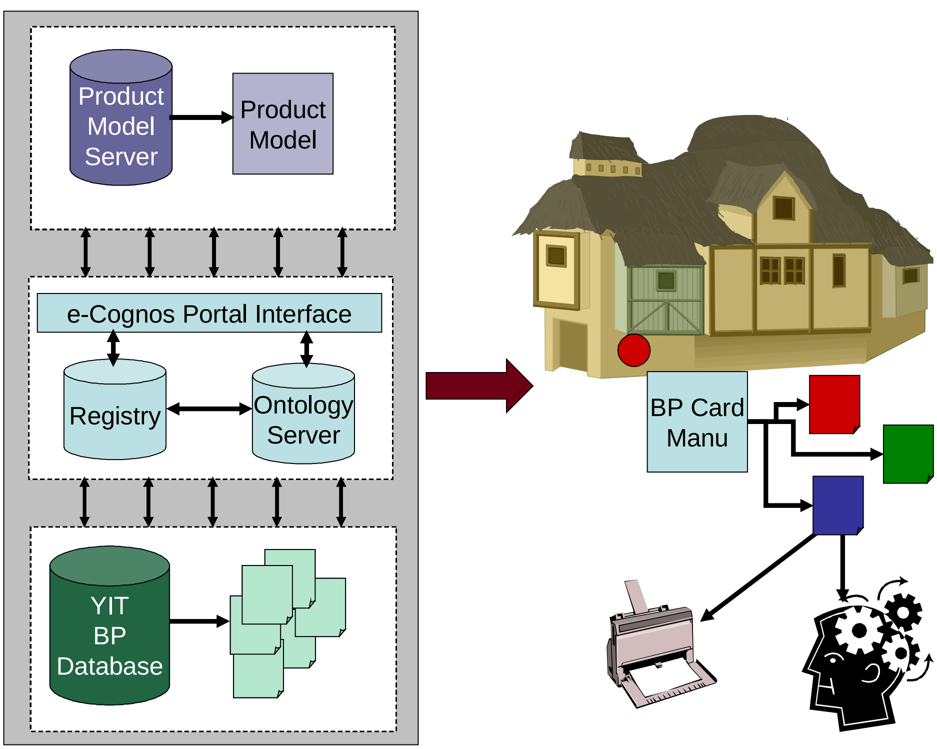


Figure 4. Connecting product models and best practices.

It is worthy to mention here “visual” experience that an end-user (e.g. at the site) would experience. The user would see a 3-Dimensional representation of the product model. This would be navigateable. Once a user clicks on a certain object (e.g. door), a menu would pop-up containing different best practice cards and report options. From here, one could select a particular report (e.g procurement details), or a best practice card (e.g. methods of work). These would be printable if needed.

7. Conclusions

This paper has concentrated on the presentation of three main issues: product models in distributed engineering, best practices in knowledge management, and a combination of the two.

YIT has for long been amongst the pioneers of the adoption of product models in its design work. This has been necessary to enable automation of certain tasks like cost estimation “on-the-fly” whenever a product model is updated. Furthermore, in distributed engineering environments, product models act as the common working dataset between different project participants.

The standardisation of different frequently used structural components and the capture and reuse of best practices has been an activity in place at YIT for near 5 years. This significantly reduces rework and furthermore, contributes towards better quality of the built building as it is based on identified successes. In the past, best practice information was only available internally within YIT, but now relevant information is to be made available to partners involved in joint projects.

The future lies in the convergence and interlinking of relevant applications and knowledge sources to the relevant objects in a building product model. Some background automation (transparent to the end user) will ensure that a product model is pre-populated with the latest information in terms of best practices and similar knowledge items. A simple approach to the same was recommended in this paper. This was complemented with a simple example of what the end-user would see.

References

1. GLOBEMEN 2002. Public website, http://globemen.vtt.fi

2. e-COGNOS 2002. Public website, http://www.e-cognos.org

3. IAI – International 2002. Public website, http://www.iai-international.org

4. CONCUR 2001. Public website, http://cic.vtt.fi/projects/concur

5. PROCURE 2002. Public website, http://cic.vtt.fi/projects/procure

6. ToCEE 2000. Public website, http://cic.vtt.fi/projects/tocee

7. ISTforCE 2002. Public website, http://www.istforce.com

8. Hannus, M. & Kazi, A. S. 2000. Requirements for distributed engineering. Proceedings of 3rd European conference on product and process modelling in the building and related industries: Product and process modelling in construction (Ed. by Gonçalves, P. et al.). 25–27 September 2000, Lisbon, Portugal. Balkema. Pp. 41–47.

9. Kazi, A. S., Hannus, M. & Charoenngam, C. 1999. An exploration of knowledge management for construction. Proceedings of the second international conference on concurrent engineering in construction: Concurrent engineering in construction, challenges for the new millennium (Ed. by Hannus, M., Salonen, M. & Kazi, A. S.). 25–27 August 1999, Espoo, Finland. CIB Publication 236. Pp. 247–256.

10. Kazi, A. S. et al. 2001a. ICT support for distributed engineering in construction. E-work and e-commerce: Novel solutions for a global networked economy (Ed. by Stanford-Smith, B. & Chiozza, E.). IOS Press. Pp. 909–915.

11. Kazi, A. S. et al. 2001b. Distributed engineering in construction: findings from the IMS GLOBEMEN project. ITcon 6. Pp. 129–148. (Available online at: http://www.itcon.org/2001/10/)

12. Kazi, A. S. et al. 2002. Product model management in construction virtual environments. Proceedings of 4th European conference on product and process modelling in the building and related industries: eWork and eBusiness in architecture, engineering and construction (Ed. by Turk, Z. & Scherer, R.). 9–11 September 2002, Porotorž, Republic of Slovenia. Balkema.

13. Product Data Technology Advisory Group 1998. Public website: http://www.cadlab.tu-berlin.de/~PDTAG

Part V

Performance Assessment

Assessment and Evaluation of Project Success and Partner Benefits of GLOBEMEN

Gerhard Burger and Ingo Hartel
Swiss Federal Institute of Technology Zürich – Center for Enterprise Sciences (ETHZ-BWI), Switzerland (email: gerhard.burger@ethz.ch)

Kim Jansson and Iris Karvonen
VTT Industrial Systems, Finland (email: kim.jansson@vtt.fi)

Abstract

Ensuring the qualitative project results is the way to secure the usefulness for the partners and thus also the benefits to the society and citizens. The paper presents the developed qualitative and quantitative approach together with examples from real cases. A measurement system has been defined using performance indicators for monitoring the progress towards the criteria used for project evaluation. Benefits from applying the methodology are reported. The paper concludes with proposals for generalising the mechanism to cover various public funded research projects and suggested improvements to the methodology.

1. Introduction

Continuous development and improvements of products and services is in the long run fundamental for the success of an industrial company. The development can take place in small continuous steps or by larger steps initiated by e.g. research and development (R&D) activities. The success or failure of an enterprise is dependent on activities under own control and influence e.g. R&D projects and development activities, and external events not under own control e.g. technology breakthroughs, economical trends or development in society and values like environmental concern.

All or some of the events and activities may take place concurrently. Some of these internal and external forces may even be contradictory. In general, it is not possible to independently measure the impact of one of the factors, like research project results, on the total success. The results of R&D work are enablers among many other co-producing enablers in the industrial companies. In order to evaluate the partners' success as a result of project success, partners need to focus on assessing project results.

In order to evaluate the success of partners in the IMS GLOBEMEN research project, the project has developed a mechanism based on evaluating project results and project progress. The objective of the assessment is not only to evaluate the success after the project but also to support the project management. A measurement system has been defined using performance indicators for monitoring the progress. Performance indicators are used to define project performance objectives and to monitor progress over time against these objectives. It is however important that the measurement of the project success continues after the project is finished.

2. Assessment objectives

The main purpose of the assessment is to make sure that the project is beneficial for the investors including project partners, society, tax-payers and citizens. Figure 1 presents a mechanism to create the benefits to the companies, citizens and society. The success has two pre-requisites which both are needed:

1. The project produces successful and exploitable results and knowledge.
2. The project results are disseminated and exploited.

Referring to Figure 1 the assessment and evaluation thus has three main targets:

1. The first target is the successful completion of defined project tasks and the delivery of all agreed documentation and other deliverables. These are the results and necessary steps that lead to the actual project partners external and internal benefits and effects.
2. The second target is then to evaluate the usability and effect of the results enabled by the R&D work.

3. A third target of the assessment and evaluation is the consortium collaboration, networking and learning.

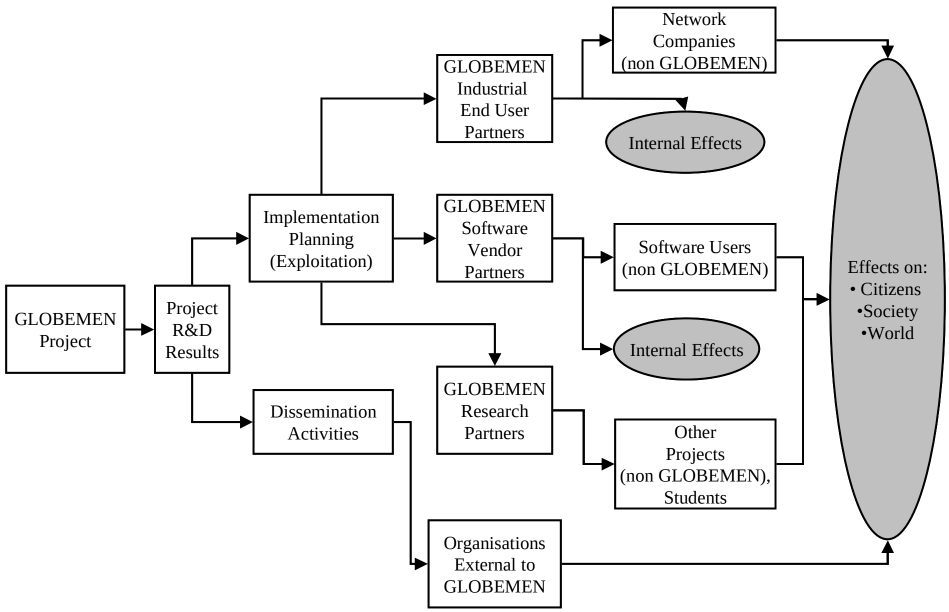


Figure 1. Mechanism to transfer R&D results to companies, citizens and society.

3. Assessment and evaluation methodology

The developed methodology consists of two types of project self assessment; qualitative and quantitative: The **qualitative** evaluation consists of a mechanism where project partners read, comment and propose improvement to documents produced by other partners. This mechanism secures not only high quality project results, but also promotes mutual understanding and project internal co-operation. The **quantitative** monitoring is based on the utilisation of simple performance indicators that can be seen as numerical measure of the degree to which the planned objectives are being achieved. Therefore the consortium defined two different types of performance indicators – the Partner Success Indicators (PSI's) and the Project Progress Indicators (PPI's).

The qualitative and quantitative evaluation have been executed in parallel. The different phases and events are illustrated in Figure 2.

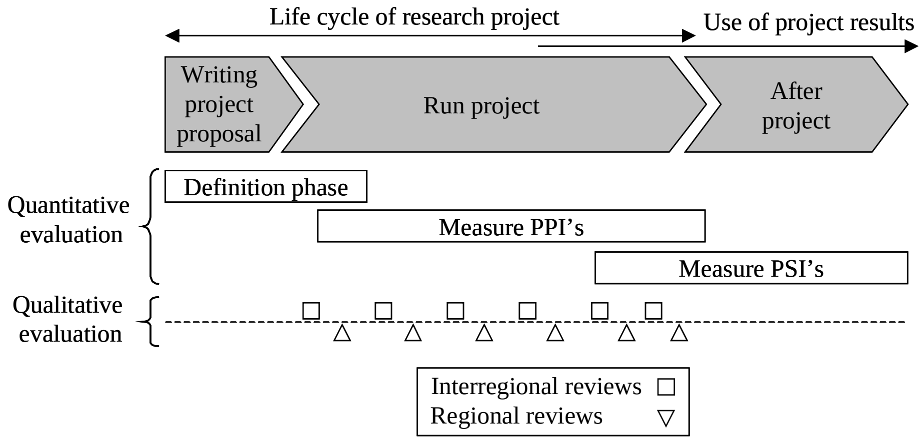


Figure 2. Definition and measurement phase and the relation to the project life cycle.

4. Qualitative assessment

Qualitative assessment is an integral part of the GLOBEMEN quality management. The following sections describe the main quality assurance methods, that has been used during the GLOBEMEN project and the experiences gained so far.

4.1 Developed qualitative mechanism

Review Cycles: Review cycles are unofficial activities conducted internally in the consortium. The subject for the review cycles activities are draft and working versions of all main documentation. The aim of the review cycles is to ensure the collaborative result of the project by the combination of the views and needs of different partners and industrial sectors (see Figure 3). All main deliverables have draft, working and final versions. Only the last one, the final version, is official and is made available outside the consortium. The focus of the review cycles is on the project internal unofficial versions.

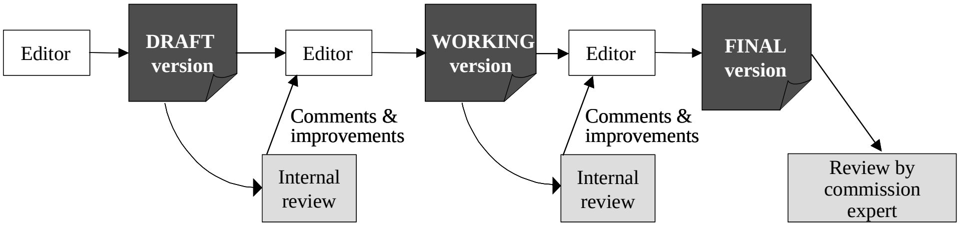


Figure 3. Review Cycles.

Interregional meetings: These plenary meetings are held twice a year alternating between the four involved IMS regions of GLOBEMEN and last normally one week. During these meetings the focus is on presentation of achievements and results. Presentations are given in parallel session, which are organized in relation to the different work packages of the project, or in plenary sessions. At least one day is used to present results in a conference style. Parts of the conference are open also for people outside the project. Since the later half of the project an exhibition showing the status of the prototype development is part of these conferences.

Industrial reference groups: These regional groups consist of representatives from companies outside the project consortium, including both end-user and system vendor representatives. The group regularly evaluates the achievements and gives guidance for future work in the project.

Formal project reviews: All regions in IMS projects have their own formal review mechanism. Successful reviews and approval of results are prerequisite for project payments from the supporting organisations.

4.2 Experiences of applying the qualitative mechanism

The benefits are unquestionably high. Benefits are:

- Partners are "forced" to read each other's documents.
- Partners are "forced" to produce intermediate results and keep agreed schedules.
- The quality of the produced documents has been improved significantly.
- The understanding of project progress and internal cohesion is higher.

However, the benefits do not come for free:

- The internal review system is quite heavy and requires continuous management and reminding of upcoming review activities.
- A decent review of a large document is time consuming.

5. Quantitative assessment

For a project like GLOBEMEN where methodologies and tools for innovative management will be developed practical results can be demonstrated with some reasonable and simple performance indicators, which have been set at the onset of the project. The performance can be measured in relation to the project as a whole and as measured within individual project partners. The following sections will explain the indicator system of GLOBEMEN with two types of performance indicators and will describe for each type the framework for measurement, examples and gained experiences.

5.1 Developed indicator systems

The **Partner Success Indicators (PSI's)** are established for indication on how the performance of a company will improve thanks to the adoption of one or more developed methods, models, tools or industrial prototypes, which have been developed in the project. The focus is on demonstrating that the project brings some practical results not only covers general "wishes".

The **Project Progress Indicators (PPI's)** are to provide a view of the project progress during the project life cycle (in GLOBEMEN 36 months). The focus of the project progress evaluation is on produced results and dissemination actions rather than in indicating dissipated resources like time and money.

5.2 Establishing a framework for the measurement of the partner success

As mentioned in the introduction, it is not possible to independently measure the impact of one of the factors on the total success. It is thus not possible to directly measure the effects of GLOBEMEN on partner's success. The results of R&D work are enablers among many other co-producing enablers in the industrial companies – compare systems theory. In order to evaluate the partners' success as a result of project success, partners need to focus on assessing project results.

The procedure to establish an indicator system is subdivided in three different steps. The starting points are the defined objectives and the planned outcomes from the project partners. The procedure for partner success performance measurement is described with an example in Figure 4.

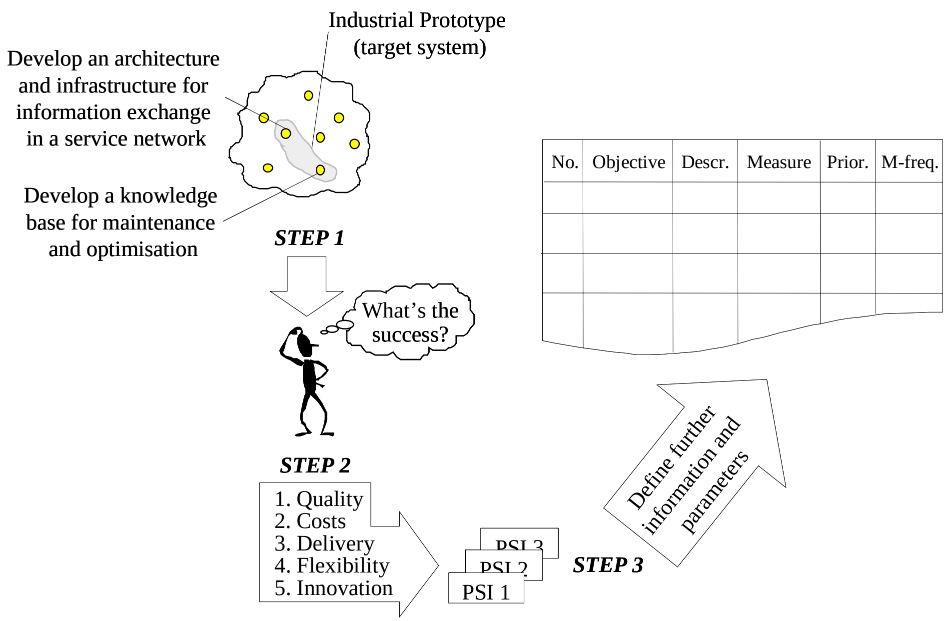


Figure 4. Example for the procedure for partner success performance measurement.

In the first step the target system where the performance will be measured has to be defined by the project partner. The target system can be seen as the end product/s that will be developed by the project partner. For example for an industrial partner the target system can be the industrial prototype, for a research institute the developed methodologies or tools. The definition of the target system should include a description of the system limit, the structure of the system and the selected objectives.

Based on the selected objectives the success of the target system (e.g. industrial prototype) has to be identified [1]. The question is: “How will the performance of a company improve thanks to the adoption of the new method, model, tool or industrial prototype?” In a further stage it has to be considered what are the expressive magnitudes for the interpretation of the success and what information are available about an actual status intended to be improved. With that information Partner Success Indicators can be defined and exactly described. Note that only performance indicators should be developed that can later be influenced by the researchers and developers.

The information about the actual status (“as-is value”) will be used for putting the new status (“value after starting to apply the developed methods, models, tools or industrial prototypes”) in relation to the actual status and to demonstrate the benefits gained. The defining PSI’s must be selected so that they are as easy as possible to measure and understand. To keep the assessment and evaluation simple the number of PSI’s describing the project success should be small, e.g. 2–4.

Table 1 gives examples of PSI definition. The example construction company uses a product model server to rationalise the virtual enterprise operations

Table 1. Example of Partner Success Indicators in a construction company.

NO.	OBJECTIVE	PSI	UNIT	DEFINITION	MEASURE-MENT METHOD	MEASURE-MENT FREQUENCY
1	More efficient tendering activity including draft scheduling and production planning	Scheduled lead time for tendering activities	Person Days	Time to define quantities and their locations from customer / owner documen-tation, mailing tenders and draft production planning	Data from company IT system	Yearly
2	Wider utilisation of production model approach to construction projects	Number/% of construction projects based on product model PM?	Integer	Number projects that are based on the utilisation of product model technology	Data from company IT system	Yearly

5.3 Experiences of applying the PSI mechanism

The project results will be available towards the end of the project (see Figure 2). As the measurement starts towards the end of the project, experience about the success of the measurement system will be available at a later stage. Thus the first evaluations have just been made.

The procedure for industrial partners to set-up a performance indictors systems already in itself has a positive impact on project success. “What you measure is what you get!” is a well known slogan!

5.4 Framework for measurement of project progress

The definition of PPI’s supports the following measurable project management objectives: Activity, innovation, dissemination and timeliness of work. A few examples of defined indicators are in Table 2.

Table 2. Examples of used Project Progress Indicators.

MEASURE-MENT OBJECTIVE	NAME OF THE PPI	UNIT	DEFINITION	MEASURE-MENT FREQUENCY
Activity	Contribution to documents	%	Measures the contribution of GLOBEMEN partners to documents. Contribution = The person has added text to the document.	Half yearly
	Partners attending to international meetings	%	Count of the attending partners at international meetings / Count of maximally possible attending partners.	Half yearly
Innovation	Standardisation	Integer	Measures the number of proposals made to standardisation bodies	Yearly
	Theses	Integer	Measures the number of academic theses produced by GLOBEMEN team members	Yearly
Dissemination	Publications	Integer	Measures the total number of publi-cations to commercial journals, magazines or newspapers	Quarterly
	Conference & symposia presentations	Integer	Measures the number of presentations shown during national and international conferences and symposia	Quarterly
	Review Cycles activities	Integer	Measure the fulfilment of the review cycle plan	Quarterly
Timeliness of work	Late deliverables	Integer	Count of the late deliverables	Quarterly
	Deliverables produced	Integer	Measure number of produced deliverables in relation to deliverables schedule. Applies to draft, working and final versions.	Quarterly

The measurement cycle process has the following characteristics:

Data acquisition: In the case of PPI's the amount of data is fairly small and the structure is simple. Typically the data consists of dates and integer numbers. The data is available in progress reports, reports on completed tasks or deliverables, and meeting minutes. Because of the small amount of data, it is most convenient that one partner regionally does the acquisition.

Measurement frequency: The measurement frequency is specified together with the definition of the performance indicators. This can e.g. be once, yearly, half-yearly, quarterly, monthly, or continuously.

Scheduling the assessment: The main assessment point is at the end of each three-month period. Additionally, the Project Progress Indicators have been reported before major events like, international plenary meetings, official review meetings and major consortium meetings.

Communication of the results: The data needed to calculate the PPI's are maintained in simple spreadsheet tables. Graphs can be produced semi-automatically. The results are published on the project document server.

5.6 Experiences of applying the PPI mechanism

The first to benefit is project management. As a result of the assessment proposals for actions were given for the project management. For example: The production of project reports (deliverables) started to lag behind the schedule. The number of late deliverable showed an increasing trend. The consortium decided to establish a new indicator for monitoring the production of internal deliverables (see section 4.1). Thus the consortium partners could proactively influence the timeliness of the project and avoid delays. Additionally the time needed for the quality assessment could be secured. The good progress in producing internal deliverables will lead to final deliverables of high quality.

The graph on the left side of Figure 5 exemplifies how there was an indication that the meeting frequency in one region was becoming smaller. The declining meeting activity corresponded to less project progress. The consortium realised the situation and the necessity to keeping up meeting activity, which forces partners to come prepared to meetings. Several meetings where scheduled which kept also partner activity high.

The graph on the right side of Figure 5 illustrates how many of the 19 GLOBEMEN consortium members were able to attend international plenary meetings in minimum with one person. Depending on these numbers the project management has to define the best proportion of regional and interregional meetings, so that all project partners are sufficiently informed and involved about the project progress.

As in the definition phase simple indicators are defined, performance of measurement can be kept in limit. Furthermore data exchange between project partners is supported by an Internet – based content management system. So some information for performance measurement e.g. authors of documents, delivery dates etc. can be collected from one single data source.

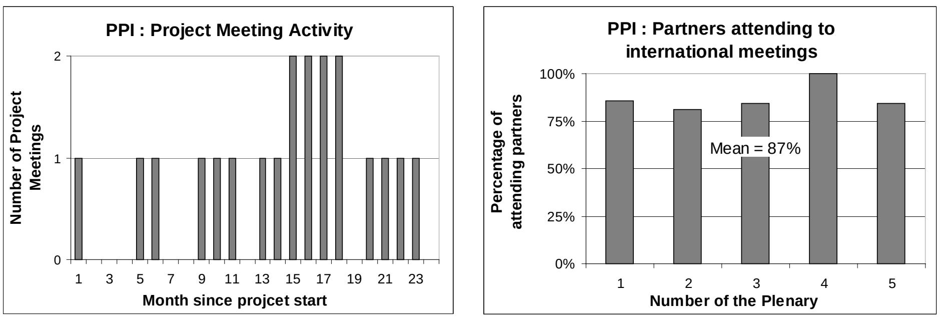


Figure 5. Examples of Project Progress Indicators.

6. Proposed improvements qualitative and quantitative project evaluation

Based on the experience of the evaluation approach the following improvements have been suggested:

1. Keep the assessment system as simple as possible. For the qualitative assessment select only the main documents. Create a review form to collect the main results of qualitative assessment. (This may complement the direct comments to the documents.)
2. Include also final documents in the reviewing activities. This would further improve the quality and internal communication.
3. Automate the reminding and tracking work. This would reduce the resources needed to manage the qualitative assessment.
4. Improve communication of results, not only once per quarter or half year. "Web enable" the indicators. Make indicators online and publicly available within the consortium and up to date all the time. This would put pressure to partners to perform on time.

5. It is suggested that at least in Europe the EU commission could provide this kind of service to projects (like ProTool and Electra for project proposal and contract preparation). The project monitoring against objectives should be part of continuous project management work.
6. Some measurement could be automated by an information system. E.g. Number of authors on a document by automatically reading the document header.

7. Conclusions

The GLOBEMEN consortium partners have an extensive experience of participating in international research and collaborative projects. The developed evaluation and assessment mechanism addresses some of the common difficulties and complications such as:

- Difficult project management, especially in globally distributed project with little formal force on partners.
- Distance, communication is not very easy over time and cultural borders.
- Partners have different goals.
- Partners are not interested in each other's results or do not read each other's documents.
- Difficult to get feedback on results.
- Timeliness, difficulties to keep agreed schedules.
- Quality is not sufficient to all partners.

7.1 Questions answered based on the existing experience

7.1.1 Can the effort put in be motivated?

The answer to the first question is positive. The qualitative assessment has promoted the understanding and integration between the cases in different industrial sectors and lifecycle stages. This has been one of the main prerequisites in GLOBEMEN which has aimed to build an integrated view of operating in networks and virtual enterprises in one-of-kind manufacturing.

The performance indicator system, which has been fairly lightweight, has given graphic illustration of projects status and development trends to all partners and supported project management in a way that has enabled preventive actions in a proactive fashion. The effort put in for the quantitative assessment is small. The endeavour to maintain the project progress parameters has been small, while the experience from measuring the partner success indicators is at this stage of the project not yet available (cf. Figure 2).

7.1.2 Can this approach be used in other projects?

With some improvements both the quantitative and qualitative assessment can be used in other research projects. Suggested improvements for the project self assessment are:

- Focus more on documents closer to final versions.
- Limit the number of review activities by concentrating on central documents.
- Automate the tracking and reminding system to keep up with the reviewing schedule.
- Web enabled progress indicator system.

References

1. CTI-Project PERFECT, Ref. 3694.1 1998. Abschlussbericht: Performance Measurement für Forschungsprojekte. Institut für Technologiemanagement, Universität St. Gallen, Schweiz.

2. Jansson, K. 1993. A toolset for company performance analysis and strategic specification, 2nd International Conference on Computer Integrated Manufacturing. 6–10 Sept. 1993, Singapore, Vol. 1. World Scientific Publishing, Singapore. Pp. 35–41.

Published by

Series title, number and report code of publication

VTT Symposium 224
VTT–SYMP–224

Author(s)
Karvonen, I., van den Berg, R., Bernus, P., Fukuda, Y., Hannus, M., Hartel, I. & Vesterager, J. (eds)

Title

Global Engineering and Manufacturing in Enterprise Networks (GLOBEMEN)

Abstract
In one-of-kind production the products are usually large deliveries, like production plants, ships, telecommunication or other infrastructure systems. It is not possible for any enterprise to manufacture these products alone. Cooperation with other enterprises, often globally, is needed during the entire product life cycle. The IMS project GLOBEMEN was started to develop tools, methods and guidelines to support the creation, operation and management of enterprise networks and virtual enterprises (VE), which are the temporary cooperation forms to perform a specific task. GLOBEMEN has addressed three main aspects of manufacturing: sales and services, inter-enterprise delivery management and distributed engineering. In these life cycle phases tools and processes have been developed and tested in industrial cases. The findings have been integrated to an architectural framework called VERAM (Virtual Enterprise Reference Architecture and Methodology). The framework aims to offer handles that contribute to solving the problems that enterprises face when they want to cooperate in a Network and a Virtual Enterprise. The publication is the proceedings of the final conference of GLOBEMEN in December 2002 in Helsinki.

Keywords
manufacturing, engineering, networks, virtual enterprises, integration, collaboration, virtual organisations

Activity unit
VTT Industrial Systems, Tekniikantie 12, P.O.Box 1301, FIN–02044 VTT, Finland

ISBN			Project number
951–38–5739–5 (soft back ed.) 951–38–6275–5 (URL: http://www.inf.vtt.fi/pdf/)			G0SU00002
Date February 2003	Language English	Pages 394 p.	Price H
Name of project GLOBEMEN		Commissioned by	
Series title and ISSN VTT Symposium 0357–9387 (soft back ed.) 1455–0873 (URL: http://www.inf.vtt.fi/pdf/)		Sold by VTT Information Service P.O.Box 2000, FIN–02044 VTT, Finland Phone internat. +358 9 456 4404 Fax +358 9 456 4374	

The publication includes the Proceedings of the GLOBEMEN (Global Engineering and Manufacturing in Enterprise Networks) Conference in Helsinki in December 2002. It is based on the results of the IMS project GLOBEMEN (2000–2002), which consists of partners in Australia, Europe and Japan. In GLOBEMEN a reference architecture called VERAM, guidelines and tools to support inter-enterprise operations in one-of-kind industry have been developed. One-of-kind production usually consists of large deliveries, like process and power plants, infrastructure projects, production lines, telecommunication systems, ships etc. The project has addressed three main business processes: sales and services, inter-enterprise management and distributed engineering.

VTT SYMPOSIUM 224 Global Engineering and Manufacturing in Enterprise Networks. GLOBEMEN

Tätä julkaisua myy	Denna publikation säljs av	This publication is available from
VTT TIETOPALVELU	VTT INFORMATIONSTJÄNST	VTT INFORMATION SERVICE
PL 2000	PB 2000	P.O.Box 2000
02044 VTT	02044 VTT	FIN–02044 VTT, Finland
Puh. (09) 456 4404	Tel. (09) 456 4404	Phone internat. +358 9 456 4404
Faksi (09) 456 4374	Fax (09) 456 4374	Fax +358 9 456 4374

ISBN 951–38–5739–5 (soft back ed.)
ISSN 0357–9387 (soft back ed.)

ISBN 951–38–6275–5 (URL: http://www.inf.vtt.fi/pdf/)
ISSN 1455–0873 (URL: http://www.inf.vtt.fi/pdf/)