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Modelling methodology for development of Virtual Organisation's supporting systems

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ABSTRACT

Purpose: of this paper is to introduce modelling methodology that would be usable for building of virtual organisations. Nowadays this concept is widely accepted both in academic and industry community. However, slow implementation in practise causes inability to reach expected advantages. One of the main reasons is the lack of such systems that would support cooperation and integration in accordance with principles of virtual organisation.
Design/methodology/approach: Modelling as a research and development method is requirement to creation of adequate supporting systems. Rationale reference models will contribute to mistakes elimination, reduction of implementation time and total costs decreasing during whole lifecycle of the integrated systems. This approach requires unified modelling methodology.
Findings: This Frame system is describe in the paper for virtual organisation modelling VO-PLM (Virtual Organisation supported by Product Lifecycle Management). This system describes theoretical starting points, way to formalization, structure, content and terminology of future models. Methodology is based on unified modelling language UML concerning principles of system decomposition, object-oriented modelling and required expandability.
Research limitations/implications: There is important to note, that UML as a language provides set of symbols and rules for their notation, but not uniquely determined methods. Consequently, in next solution there is necessary to pay attention to this question. GRAPPLE (Guidelines for Rapid APPLication Engineering) could be used as a source complex methodology. The Frame system VO-PLM will unify modelling methodology which is necessary for research continuity, design, development and implementation of supporting software systems.
Originality/value: Paper refers to results of integrated applied research at the Department of Manufacturing Systems STU in Bratislava. Authors have analysed actual outcomes of the important European projects in the field of virtual organisation modelling and business modelling.
Keywords: Industrial management and organisation; Production and operations management; Virtual Organisation; Product Lifecycle Management

1. Introduction

Nowadays, the inter-enterprise cooperation through all product lifecycle stages is becoming of cardinal importance. This is necessary mainly for small and medium sized enterprises to keep their own position and progress continuity.

The virtual organization paradigm is gaining a growing importance in manufacturing as an instrument to help companies face the challenges of fast evolving market conditions within global environment. [1] In order to participate in global business, manufacturing companies need to develop their ability to respond quickly to customer's requirements, cooperate closely with their global partners, and participate actively in worldwide manufacturing projects. [2]

Many supporting systems coming out of leading R&D projects still require massive configuration and customization effort. Therefore modelling as a research and development method is the natural requirement to creation of adequate supporting infrastructure. Reference models will contribute to mistakes elimination, setup time reduction and total costs decreasing. Such approach requires unified methodology, which is presented in this paper as a result of integrated research program on the Department of Manufacturing Systems, STU in Bratislava. The aim of this applied research is to setup processes within companies to be able to perform electronically all activities connected with product preparation and manufacturing.

2. Theoretical starting points

2.1. VO and VO-PLM concepts

Nowadays the concept of Virtual Organization (VO) is widely accepted both in academic and industry community. VO means a multi-enterprise environment supporting common approach to products and services creation. Such environment is based on several principles: 1. Emphasis on custom requirements, 2. Value chain decentralization, 3. Complex electronic model of the product, 4. Pervasive ICT disposition, 5. Two-level integration. The first level of the integration, called Virtual Breeding Environment (VBE), is a long-term cluster of enterprises (manufacturers, service companies, vendors, ICT providers, distributors etc.) which concern over common cooperation. This covers especially consultant and coordination roles. Virtual Enterprise (VE) is established at the second level creates specific product as in Figure 1.

Virtual Organisation is a co-operative 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 VE's and to prepare product life cycles. 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. Compared to a virtual enterprise a network can accordingly be perceived as a relative long termed co-operation since it typically sets up multiple VE's [3].

Systems integration is a typical tendency for increase of information system (IS) efficiency. The objective is to create a virtual organism, in which the data would be only once and in one place. Concept of Virtual Organization supported by Product Lifecycle Management (VO-PLM) is a contribution along this line. Enterprises are able to coordinate activities from the first idea till product dissolution, without any geographical, time or cultural obstacles as in Figure 2. Many studies emphasize advantages of this concept. Expectable contributions are competitiveness and innovation activity strengthening, advantages from scale, access to new markets, new knowledge and technology acquisition, sharing of resources and risks and more.

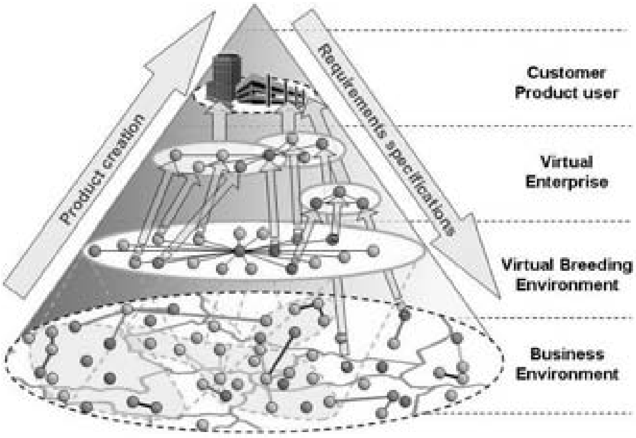

Fig. 1. Virtual organisation concept

However described concept causes a "revolution" during initial phase. This requires adjustment of IS, business process reorganization, workflow and organization structure modification, adaptation of corporate culture and management strategy. Along technical views there is necessary to consider also economical, legal and other aspects. The applicable solution requires multidisciplinary approach based on suitable modelling methods and use of reference models. Design, development and implementation of supporting systems require expert knowledge, skilled approach and heavy effort of all concerned persons. Reference models may decrease total costs on virtual organisation building in industrial environment.

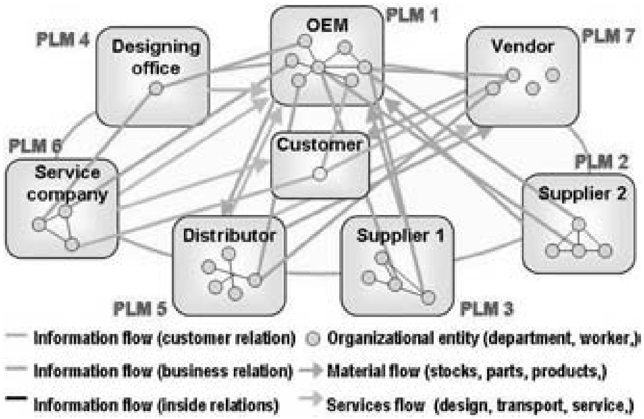

Fig. 2. VO-PLM concept

2.2. Modelling theory

Virtual organization modelling includes tasks analysis, models design and development, modification of the models and utilization them within decision and control. Reference model (RM) plays a central role in pursuing a fast and efficient setup of virtual organization. Reference model captures characteristics/ concepts common to several entities. The purpose is to capitalize

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. [3]
In a sense the model formalizes engagement of resources (financial, technological, personal and intellectual capacities). Knowledge contained in the model can accelerate coordination of partners both simplify understanding and acceptance of any common rules and principles.

Various studies consider lack of convenient theories, unified terminology and use of traditional tools as critical factors of VO success. Virtual organizations are complex systems composed of material, personal and data subsystems with dynamic behaviour. Therefore a holistic approach is necessary for modelling. Several specific methodologies have been created by different authors. There is possible to determine some common features of them. General conception defines three factors of modelling, identified on the highest level of abstraction as in Figure 3. Such structure or at least some of its features can be found in any original methodology developed for VO modelling. [5]

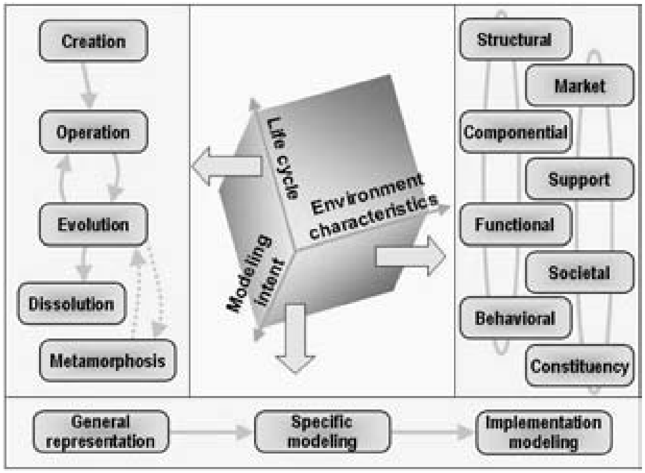

Fig. 3. Factors of virtual organization modelling

The first factor describes chronological evolution of the system, i.e. virtual organization lifecycle. Distinction among evolutionary phases is important to through analysis of all components, relations and influences stated in the time.
The second factor facilitates exact description of the system by abstraction of virtual organization components that are actually needles. Within the project Ecolead two groups of characteristics have been defined: 1. internal characteristics of VO (Structural, Componential, Functional and Behavioural dimension), 2. external characteristics of VO (Market, Support, Societal and Constituency dimension).
The third factor allows distinguishing of the modelling intent. The reference models belong to general representation or conceptual level. They facilitate development of specific and implementation models. Nearly always three levels of the modelling intent are presented according to detail and accuracy of description:

- General representation. The objective is to analyze and understand the problem without considering implementation technique and any technological barriers. The output is a universal model of a system usable without repeated analysis (for example first model of VBE).
- Specific modelling. At this level there is important to created more detailed models focused on various VO characteristics (typology, branch of industry, form of cooperation, resources structure etc.)
- Implementation modelling. The implementation models contain unique information and describe all technological specification of the designed solution that are essential for its implementation (exact architecture of information system, specific organizational structure, business processes etc.).

The organization structure is reflected from the product structure and influences manner and form of knowledge and information processing in the company [4]. Based on this reason there is rational to accept and consequently develop the idea that final product has cardinal influence on characteristics of VO. Such reality implies certain solution for methodology design.

3. Frame Modelling System VO-PLM

Following state of the art of business modelling and virtual organization modelling Frame modelling system VO-PLM was created for our purpose. The figure 4 shows also cooperation between research group (Laboratory of PLM and innovation, STU in Bratislava) and Slovak industrial establishment (small and medium enterprises engaged in applied research program). Frame system consists of three components which define theoretical background, formalization methodology and application areas for RMs in term of VO building and PLM implementation.

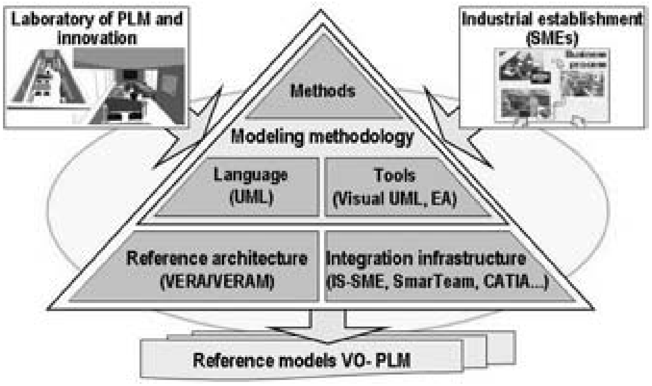

Fig. 4. Frame modelling system VO-PLM

3.1. Reference architecture

The reference architecture provides an area to discussion about problems, and also facilitates analysis, specification and understanding. Many reference architectures have arisen in parallel with development of business modelling concepts. In point of inter-enterprise integration modelling, Virtual enterprise reference architecture (VERA) developed by the project

Globemen, is significant contribution. [6] Authors have been operating with this reference conception within modelling process. Architecture VERA describes modelling using three-dimensional array as in Figure 5: 1. lifecycle, 2. modelling genericity, 3. modelling view. Lifecycle of VO is represented in accordance with two-level integration. The Virtual enterprise consists only of chosen partners each of those takes responsibility for agreed tasks. One product can be concurrently realized by many enterprises. Four different modelling views have to be separately evaluated:

- Function. 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.
- Information. The information view describes the content and flow of information, which is created, shared, used, modified and disposed along the life-cycle of the different entities of a VO.
- Resources. The resource view represents the resources of the members as they are used in the course of the network and VE set up and operations. Resources can be e.g. Competencies and know-how, capacity of service technicians, material and machines or specific software.
- Organization. This view describes the organizational structure of the relevant entities and the roles of these entities with their responsibilities and tasks. The main entities are production facilities, the service network, the resulting VE's and the delivered products.

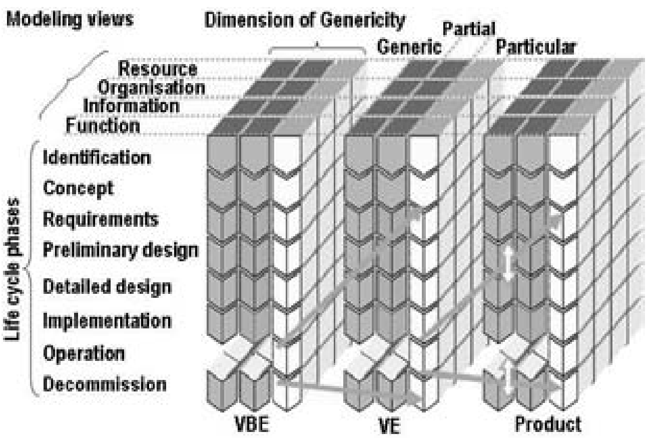

Fig. 5. Virtual enterprise reference architecture [6]

3.2. Integrating infrastructure

The routine operation of the virtual organization is associated with interactive data processing, sharing and exchange. Structure of the information flow is variable with constantly increasing volume of diverse data (design, technological, production, business and organizational). Information systems consist of many hardware and software components connected trough local and global network with access to high capacity databases. Integral part of the infrastructure is the worker who uses computer and applications for tasks performance. Hardware, software and personnel, as in Figure 6, are the key elements necessary for creation of adequate information flow. Specific tools can vary from case to case.

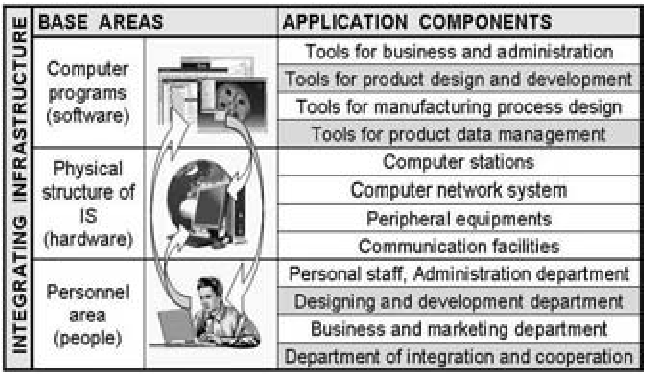

Fig. 6. Integrating infrastructure of virtual organisation

3.3. Modelling methodology

Modelling Methodology provides mechanisms (language, tool and methods) which can be used for transformation of first requirements into reference models. From the frame system VO-PLM there is obvious that methodology have to determine way from the reference architecture to models of the integrating infrastructure.

Modelling language defines generic textual or graphical constructs for modelling adapted to the needs of people who are creating and using models. Modelling tool, usually software application, allows writing of models – language constructs arrangement with accordance to rules. Modelling tool should provide for analysis, design and use of VE models. Modelling methods support the modelling process by means of guidelines, which guide a user in making models. Modelling Methods support modelling languages, and may be “embedded” in modelling tools. Modelling languages are supported by tools and methods, and are used to define reference models.

In case of virtual organization modelling there is possible on the basis of the connections among product, breeding environment, virtual enterprise and integrating infrastructure entities to determine the information dependency of models as in Figure 7.

Within the research projects, being solved at Laboratory of PLM and innovation, the Unified Modelling Language (UML) will be used for modelling in its current version 2.0. According to the company OMG this language is convenient for specification, visualization, design, development and documentation of systems. Mainly it is designated for software systems but also for other systems of un-software and corporate nature as well. The UML language in conjunct with its modelling tools supports work effectiveness of analysts, developers, users and other participants in creation and introduction process of the systems.

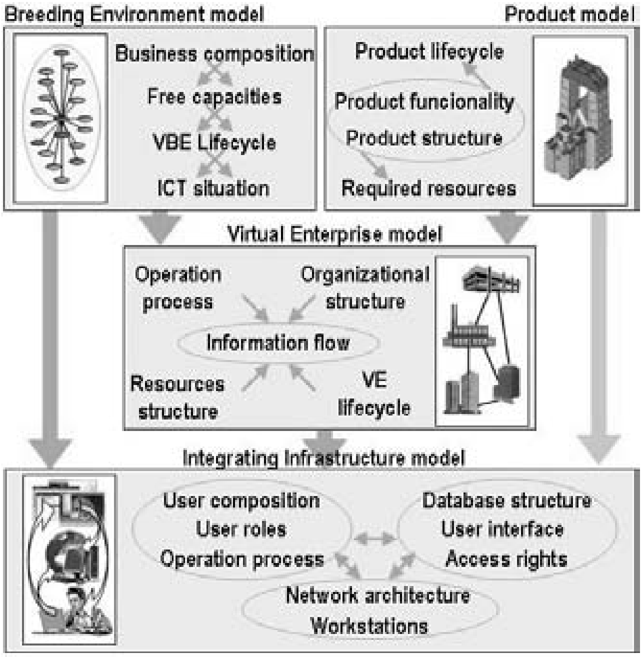

Fig. 7. Information dependency of VO models

4. Use of the UML modelling language

Definition of the UML language is based on several principles, by those there is possible to tailor and expand the language according to users' requirements:

- Four-level architecture. The architecture allows recursive description of the language and itself-specification through meta-model.
- Expendability. The language may be constantly developed to absorb new findings from VO modelling theory. For this purpose meta-model offers standard extension mechanisms.
- Object orientation. Object orientation means a way to problem understanding and solution. It supports system development based on definition of the objects/components and their properties.
- Lexical structure. Lexical elements are the smallest expressive units. Using them there is possible to create models according to syntax rules in the form of two-dimensional diagrams and textual files.
- System decomposition. Usually description of the system requires analysis from many views. Expression of any meaningful view in UML stands for utilization of convenient diagram. The language contains nine different kinds of diagram each of them has its own specific purpose. No single diagram is sufficient for system description on its own.

A survey of diagrams including the point of view is presented in the table 1. There is obvious that descriptive character of individual diagrams is different. Utilization of them depends on the modelling methodology. Methodology of the frame modelling system VO-PLM will have to respect this internal logic of the language.

Table 1.
Utilisation of UML diagrams

Diagram	Point of view	Description
Class diagram	S	Class diagrams are the mainstay of object-oriented analysis and design. They show the classes of the system, their inter-relationships (including characteristics inheritance, aggregation, and association), the operations and attributes of the classes.
Object diagram	S	Object diagrams show the objects of the system, their inter-relationships and the operations and attributes of the objects. Every object is a unique instance of the class.
Use case diagram	F D	The use-case diagram depicts a collection of use cases, actors, their associations and system boundary. An actor is a person, organization, or external system that plays a role in interactions with the system. Relationships between actors and classes are indicated in use case diagrams. A use case describes a sequence of actions representing the functionality to implement.
Sequence diagram	F D	Sequence diagrams are used to model the logic of usage scenarios. A usage scenario is the description of a potential way that the system is used. Sequence diagrams model the flow of logic within the system, enabling to both document and validate the logic, and are commonly used for both analysis and design purposes.
Collaboration diagram	F D	Collaboration diagrams show the message flow between objects in an object oriented application, and also imply the basic associations (relationships) between classes.
State chart diagram	D	State chart diagrams depict the various states that an object may be in and the transitions between those states. A state represents a stage in the behaviour pattern of an object. A transition is a progression from one state to another and will be triggered by an event that is either internal or external to the object.
Activity diagram	F D	Activity diagrams are used to document the logic of a single operation/method, a single use case, or the flow of logic of a business process. In many ways activity diagrams are the object-oriented equivalent of flow charts and data-flow diagrams from structured development.
Component diagram	S	Component-based and object-oriented development go hand-in-hand and it is generally recognized that object technology is the preferred foundation from which to build components. The UML includes a component diagram that can be used to both analyze and design of the component-based software.
Deployment diagram	S	Deployment diagram depicts a static view of the run-time configuration of processing nodes and the components that run on those nodes. In other words, deployment diagrams show the hardware for the system, the software that is installed on that hardware, and the middleware used to connect the disparate machines to one another.

S – static characteristic
F – functional characteristic
D – dynamical characteristic

In case of information system life cycle there is generally used following selection. For analysis there are used class/object, use case, sequence diagrams, state chart and activity diagrams. For design phase there are typical class/object, collaboration, activity, component and deployment diagrams. During the implementation phase there are assigned class/object, component and deployment diagrams. [8]

5. Conclusions

Virtual organisations are playing an increasing role, providing the companies with a powerful tool to handle all issues of fast changing and evolving conditions. However there is a need for more holistic understanding of the area, namely in terms of the emerging collaborative organizations, and the development of appropriate support infrastructures and tools. It is also important to reach some harmonization of models and approaches in order to achieve inter-operability. Therefore, it is a need for an integrated multi-disciplinary approach leading to truly joint work among researchers, system engineers and ICT developers, social & organizational experts, economists, standardization bodies, the application domain experts and company representatives to set SMEs on VO paradigm.

Authors have analysed actual outcomes of important European projects in the field of virtual organisation and business modelling. In the paper there was presented the frame modelling system VO-PLM as a result of this analysis. Further work will be focused on adaptation of the general UML methodology. The main objective is to create reference models of virtual organisations within research projects. The applied research is aimed at development and implementation of supporting integrating infrastructure in industrial environment.

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