THE USE OF SYSTEMIC METHODOLOGIES IN WORKFLOW MANAGEMENT

Nikitas A. Assimakopoulos and
Apostolos E. Lydakis

Contact Addresses:

Nikitas A. Assimakopoulos
Department of Informatics
University of Piraeus
Karaoli & Dimitriou 80,
185 34 Piraeus, Greece
Email: assinik@unipi.gr

Apostolos E. Lydakis
Department of Informatics
University of Piraeus
Karaoli & Dimitriou 80,
185 34 Piraeus, Greece

May 27, 2003

Proceedings of the 47th Annual Meeting of the International Society for the Systems Sciences, at Hersonissos, Crete, July 6-11, 2003, http://www.isss.org

THE USE OF SYSTEMIC METHODOLOGIES IN WORKFLOW MANAGEMENT SYSTEMS

Nikitas A. Assimakopoulos, Apostolos E. Lydakis
Department of Informatics, University of Piraeus,
Karaoli & Dimitriou 80, 185 34 Piraeus, Greece.
Email: assinik@unipi.gr

ABSTRACT

Workflow management using workflow management systems (WMS) not only facilitates electronic commerce, but also allows virtual enterprises to collaboratively manage business processes. The support of a WMS allows various participants to collaborate in effectively managing workflow-controlled business processes. The participants represent particular positions in a company or particular companies in a supply chain and in practice they possess different needs and levels of authority when obtaining information on business processes. To facilitate effective workflow management, a WMS should provide various participants with adequate process information.

This paper focuses on improving the modeling of the virtual workflow process using Systemic Methodologies such as the Problem Structure Methodology (PSM), Strategic Assumption Surfacing & Testing (SAST), Interactive Planning (IP), and Metasystems approach. The methodologies' target is to correctly analyze and form the model and in parallel to improve it. The systemic methodologies concentrate on the human factor that is evolving in those systems and they constitute a very valuable tool helping us to understand and define the system functions. Thus the model's usability and agility is improved, having a reduced abstraction level and giving the business high and realizable functionality.

Keywords: Workflow management; Process modeling; Problem Structure Methodology (PSM); Strategic Assumption Surfacing & Testing (SAST); Interactive Planning (IP); Metasystems approach; Strategic management.

INTRODUCTION

The fact that the control area of the contemporary organizations spreads even across continents, and that the complexity of the process-sequence for works made even in the same building has increased, made necessary the development and use of appropriate management techniques. The use of workflow management has provided electronic business and virtual enterprises with various techniques for analyzing, designing and controlling their overall functionality. (Georgakopoulos D., 1995, Leymann F., 1994)

The different participants in an organization, whether talking about working members of a company or about collaborator companies in a supply chain, have different needs for information. As we climb up the organizational pyramid of a company the detail level is reduced. The decisions to be taken are more of a strategic nature rather than functional. Therefore there is a difference in the quality of information needed across the different hierarchical levels.

Workflow Management Systems using activity-based methodologies design a workflow process in a top-down approach. Despite forcing a process modeler to follow an organizational hierarchy while decomposing a process, different organizational units may have difficulties in obtaining adequate abstractions of the process/supply chain they participate in.

The activity-based approach can be enhanced to provide different process abstractions by using a virtual workflow process derived from an implemented base-process (Duen-Ren Liu, 2001). The concept of the virtual workflow process is based on the notion of views in database management systems, and allows each participant to retrieve and monitor appropriate process information via the related process-view instance. In this way, coordination between different participants is improved.

Focus in this paper is given on improving the modeling of the virtual workflow process by using Systemic Methodologies. Although, each participant may now have his own view of the workflow process, the whole workflow management procedure remains activity-focused. This fact, keeps the derived model user-unfriendly, especially for work positions with no managerial experience. Most of all, there is some danger of underestimating the human factor's importance for the overall workflow effectiveness. Such a situation could be avoided by improving the designing procedure with the help of Systemic Methodologies. These methodologies' main focus is individuals inside the analyzed system and the way they interact with each other and with the other systems and subsystems examined. Thus, the improved model will maintain its multiple-view abstraction, but in a more user-friendly way, reducing conflicts during communications, and improving the business' functionality.

This paper is organized as follows. Firstly, a definition of business processes is presented. Secondly, follows a description and definition of a process-view (virtual workflow process). Then, the process view modeling is improved through a Systemic Methodologies' approach; the Problem Structure Methodology (PSM), the Strategic Assumption Surfacing & Testing (SAST), the Interactive Planning (IP), and the Metasystems approach are presented. Conclusions are finally made.

VIRTUAL WORKFLOW PROCESS

A process modeler firstly develops a base process definition and then defines the virtual workflow process (process-view). Consequently, the base-process needs to be presented prior to the process-view.

Base-Process

The term *base process* refers to a process that may have multiple process-views (virtual workflow processes). *Activities* and *dependencies* are generally used in activity-based workflow models to describe a process, where dependencies represent the ordering relationships between activities. In general, the following six ordering structures appear in business processes (Workflow Management Coalition, 1998). *Sequence*: when an activity has a single subsequent activity. *AND-SPLIT*: when an activity splits into multiple parallel activities that are all executed. *XOR-SPLIT*: when an activity splits into multiple mutually exclusive alternative activities, only one of which is followed. *AND-JOIN*: when multiple parallel executing activities join into a single activity. *XOR-JOIN*: when multiple mutually exclusive alternative activities join into a single activity. *Loop*: when one or more activities are repeatedly executed until the exit condition is satisfied.

AND-SPLIT must pair with AND-JOIN, and XOR-SPLIT must pair with XOR-JOIN. Wrong combinations of ordering structures may cause structural conflicts such as deadlock and non-reachability (W. M. P. van der Aalst, 2000), (Sadiq W., 2000). Moreover, a well-structured loop in a process definition should have a single entry and a single exit, as the iteration statements in programming languages. Allowing multiple entries/exits makes the complex control flow hard to understand, and induces ambiguities in the evaluation of exit conditions. (Leymann F., 2000)

A *directed graph* (Gross J. L., 1999) is similar to a process graphical representation in which each node is an activity and each directed edge is a dependency. A rectangle is used to denote an activity and a solid arrow to represent a dependency in a process graph. Furthermore, a blank arrow indicates a loop dependency used to construct a loop structure. Figure 1 depicts a sample process. The split of activity α_4 in activities α_5 and α_6 may be AND-SPLIT or XOR-SPLIT, but the adequate join of activities α_5 and α_6 in activity α_7 must be of the same type as the split (AND-JOIN for AND-SPLIT and XOR-JOIN for XOR-SPLIT). No loop dependency is included for simplicity reasons.

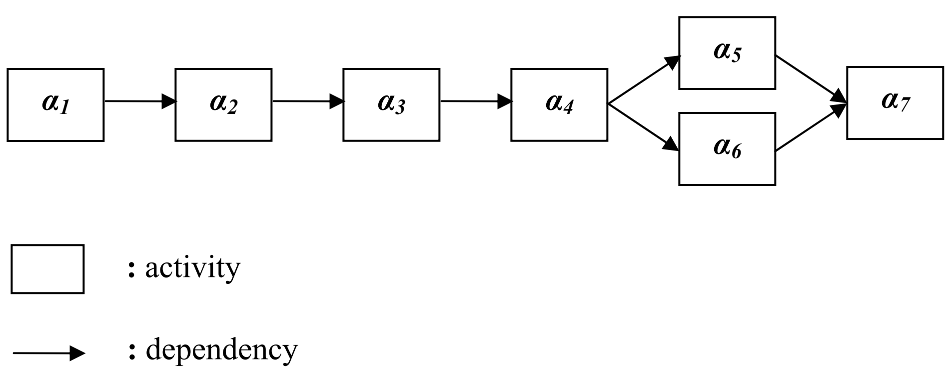

Figure 1. Sample Process

Virtual-Process

The concept of virtual processes is similar to that of views in DBMSs. Views in DBMSs are virtual tables generated from either physical tables or previously defined views. Similarly, process-views are generated from either base processes or other process-views, and are considered *virtual processes*. During design time, a process modeler defines various process-views based on the roles of participants. During run time, a WfMS initiates all process-view instances if their base process is initiated. Process-views allow a process modeler to flexibly provide different roles with appropriate views of an implemented process (Duen-Ren Liu, 2001). As a result a modeler has the ability to provide only the information that participants need to know, while filtering and concealing information as desired.

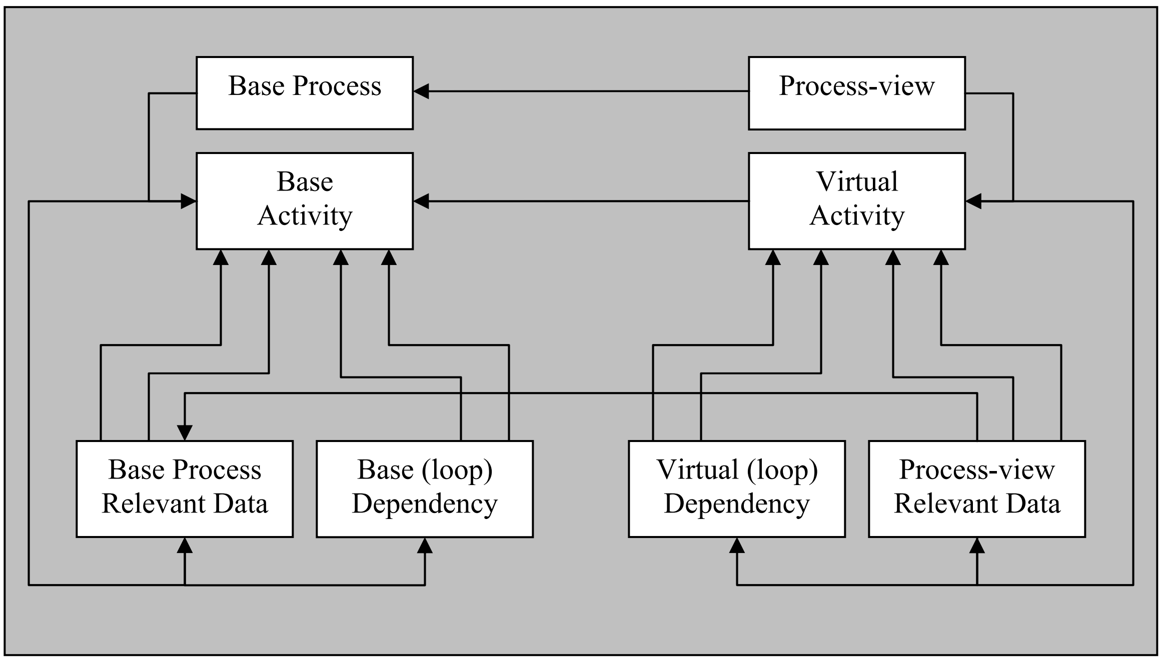

Figure 2. Process View Model

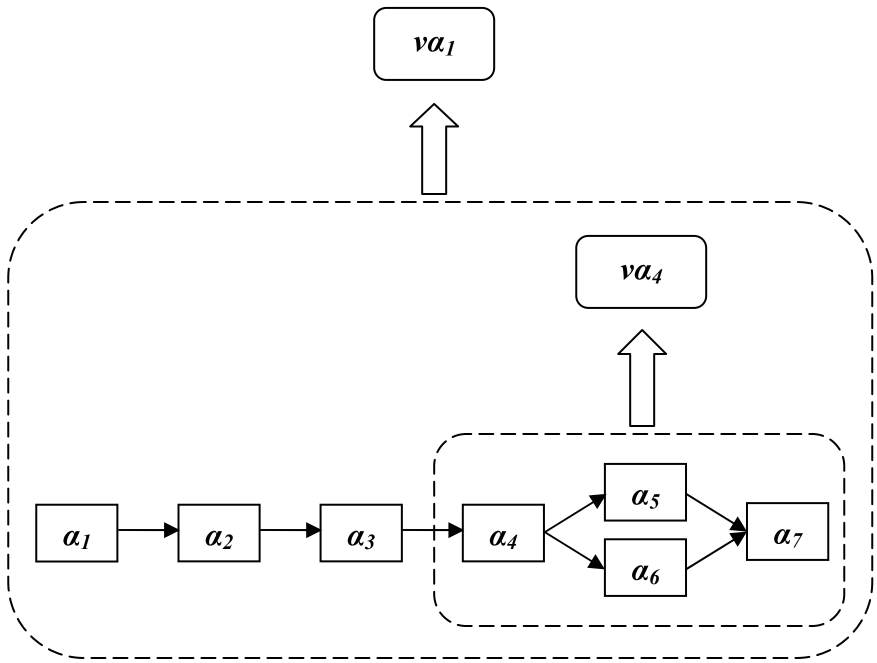

Figure 3. Virtual Process Concept

In Figure 2 we can observe the relationship between the components of the Process View Model. During workflow enactment the produced and consumed data of a process view (Process View Relevant Data) derive from the data created and used by the process instance (Base Process Relevant Data) (Duen-Ren Liu, 2001), (Workflow Management Coalition, 1998).

Assuming that the base process in Figure 1 is a manufacturing process, marketers do not need to know every step in the process, although they must know the progress of order fulfillment to serve their customers. A process modeler can design an appropriate process-view for the marketing department as follows: a_4 , a_5 , a_6 and a_7 are mapped into va_4 (Figure 3). When a customer places a new order, the WfMS initiates a new manufacturing process instance and corresponding process-view instances. Marketers can use the information from the process-view instance to serve customers. Similarly, but now for a hierarchically higher working post, as of a manager, all a_1 , a_2 , a_3 and va_4 can be mapped into va_1 as a virtual activity, part of a wider workflow process.

While a virtual activity is derived from a bottom-up aggregation of a set of activities within a process, a base activity is generated from a top-down decomposition of a business process. A process modeler develops a process definition and then defines process-views.

SYSTEMIC METHODOLOGIES' APPROACH

We will use the base process of Figure 1 as an example. The split of activity α_4, in activities α_5 and α_6 , is considered as an XOR-SPLIT. Consequently the join of α_5 and α_6 in α_7 is an XOR-JOIN. The analysis and formation of the virtual workflow process model will be improved through the use of systemic methodologies.

The systemic methodologies' approach helps us analyze, design and structure our problem. These methodologies main focus is the human factor, enabling us monitor the information flow and finally control communications. Thus, the virtual workflow process formation will be mostly human-focused rather then activity-focused it was before, having a reduced abstraction level and increased usability.

Problem Structuring Methodology (PSM)

We use the systemic approach to design and structure our problem. This usually leads to a clear justification of a problem. This methodology can be used by consultants in order to help their clients solve their problems; the result of this cooperation will remain to the clients as a tool for further decision making. The methodology will be effective if we have a very good knowledge of all the views of a problem and receive the exact data from experts with whom we are going to cooperate. In this way, we create a "knowledge base", based on which we prepare the problem's structure which will be the tool for the coordination and monitoring of the improvements.

The main focus of this methodology is to fully identify the problem by analyzing its structures, its procedures, the individuals' role, the information flow and finally to control the communications. All our organization's activities can be illustrated and explained using only one piece of paper or with computer graphics. In combination with the other systemic methodologies it is a very valuable tool for analyzing, designing and structuring our problem (Assimakopoulos N., 2001).

After having studied in detail the organization's activities, gathered all the information derived from our interviews with the experts, and formed the correspondent knowledge base, our problem is structured as illustrated in Figure 4.

There are five basic systems (1S, 2S, 3S, 4S, and 5S), three main non-basic subsystems of 1S (11S, 12S, and 13S), eight subsystems of the main non-basic subsystems (111S, 112S, 113S, 121S, 122S, 131S, 132S, and 133S), and all the other elements with their communications. All these derive from a top-down approach and can be viewed by levels.

With the PSM figure we have a general view of our organization, and we can make some observations. The communication between our Retailer 2S and the Ordering Department 12S is a negative communication in a conflict condition (P) (Assimakopoulos N., 2001). The same can be stated about the communication between our Assembling Department 11S and Warehouse A 4S. On the contrary, communication between the General Administration 3S and our IT Department 133S is a good communication (C), and the

Data Base Administration 1331S has an interaction with no particular pressure (G) with the Logistics Department 1332S. The employees of the Ordering Department 12S have a good indispensable communication (U).

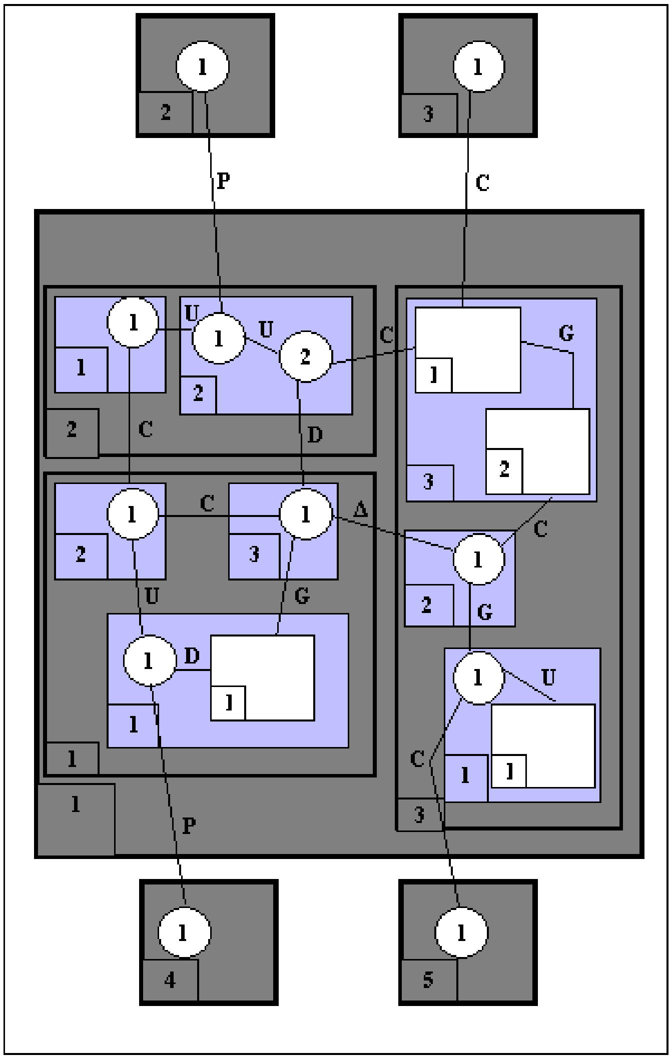

Figure 4. The first structured design using PSM

A very sensitive part of our organization is the Ordering Coordination Department 113S; the Ordering Coordinator 1131I has an incomplete communication with information divergence (D) with Ordering Department Employee B 1222I, and at the same time an incomplete communication with intentional information divergence (Δ) with the Informatics Secretariat 132S. Because of its crucial post, as every ordering process has to pass from this node, special care must be taken in order to control and improve these problematic communications. Such achievement could have as a result better cooperation between the involved parts and consequently a better coordination during every ordering process.

The Metasystems Approach, in the next section, is the appropriate systemic methodology in order to be able to control and improve our organization parts' communications. A proposed solution for the problematic situation stated above will be presented.

Based on the semantics of PSM (Assimakopoulos N., 2001), Table 1 is formed and describes Figure 4.

Encoding Type	*Subsystems*
1S	Organization
11S	Assembling Department
111S	Technical Department
1111S	Technical Assembling
112S	Assembling Department Secretariat
113S	Ordering Coordination Department
12S	Ordering Department
121S	Ordering Department Secretariat
122S	Ordering Reception Department
13S	Technology Sector
131S	Technological Department
1311S	Technological Assembling
132S	Informatics Secretariat
133S	IT Department
1331S	Data Base Administration
1332S	Logistics
2S	Retailer
3S	General Administration and Financial Services
4S	Warehouse A
5S	Warehouse B
Encoding Type	*Individuals*
1111I	Assembling Manager
1121I	Assembling Secretary
1131I	Ordering coordinator
1211I	Ordering Department Secretary
1221I	Ordering Department Employee A
1222I	Ordering Department Employee B
1311I	Technological Assembling Manager
1321I	Informatics' Secretary
21I	Retailer's ordering representative
31I	General Administration's Secretary
41I	Warehouse A employee
51I	Warehouse B employee

Table 1. The subsystems and individuals' catalog for the PSM Figure

The Communication Matrix, in Table 2, gives us a general view of the quality, and the communicating parts of the information flow.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	1**S**																																
2	11**S**																																
3	111**S**																																
4	1111**S**																					**D**		**G**									
5	112**S**																																
6	113**S**																																
7	12**S**																																
8	121**S**																																
9	122**S**																																
10	13**S**																																
11	131**S**																																
12	1311**S**																											**U**					
13	132**S**																																
14	133**S**																																
15	1331**S**																**G**										**C**				**C**		
1	133															**G**													**C**				

6	2**S**																																
17	2**S**																																
18	3**S**																																
19	4**S**																																
20	5**S**																																
21	111 1**I**				**D**																		**U**									**P**	
22	112 1**I**																					**U**		**C**	**C**								
23	113 1**I**				**G**																		**C**				**D**		**Δ**				
24	121 1**I**																						**C**			**U**							
25	122 1**I**																								**U**		**U**			**P**			
26	122 2**I**															**C**								**D**		**U**							
27	131 1**I**												**U**																**G**				**C**
28	132 1**I**																**C**							**Δ**				**G**					
29	21**I**																									**P**							
30	31**I**															**C**																	
3	41**I**																					**P**											

1																																	
3 2	51**I**																											**C**					

Table 2. Communication Matrix of PSM Figure

In this phase, having our problem structured, we can relate our base process activities with the corresponding communications (communications taking place during each activity). This can be done for each abstraction level of the top-down approach (L1, L2, and L3). Communications take place as stated in Table 3 below:

Activity	**L1**	**L2**	**L3**
α_1	(2S*1S)	(2S*12S)	(21I*1221I, 1221I*1211I, 1221I*1222I)
α_2		(12S*11S)	(1211I*1121I, 1222I*1131I, 1121I*1111I, 1131I*1111S)
α_3		(11S*13S)	(1131I*1321I, 1321I*131I, 1321I*1332S)
α_4		(11S*13S)	(1321I*1332S, 1332S*1331S, 1321I*1131I)
α_5	(1S*4S)	(11S*4S)	(1111I*41I)
α_6	(1S*5S)	(13S*5S)	(1311I*51I)
α_7	(1S*2S)	(11S*12S, 12S*2S) or (13S*11S, 11S*12S, 12S*2S)	(1121I*1211I, 1221I*21I) or (1321I*1131I, 1121I*1211I, 1221I*21I)

Table 3. Activities' communications for top-down-approach levels L1, L2, and L3

A first grouping of activities into a new virtual activity can be made, based on the communications taking place for activities α_2, α_3, α_4 . All three of these activities' communications occur inside one subsystem: 1S. As a result, a new virtual activity, $v\alpha_2$, can be generated as shown in Figure 5. The derived virtual workflow process is illustrated in Figure 6. The $v\alpha_1$ virtual activity derives from α_1, while $v\alpha_3$ from α_5, $v\alpha_4$ from α_6, and $v\alpha_5$ from α_7 .

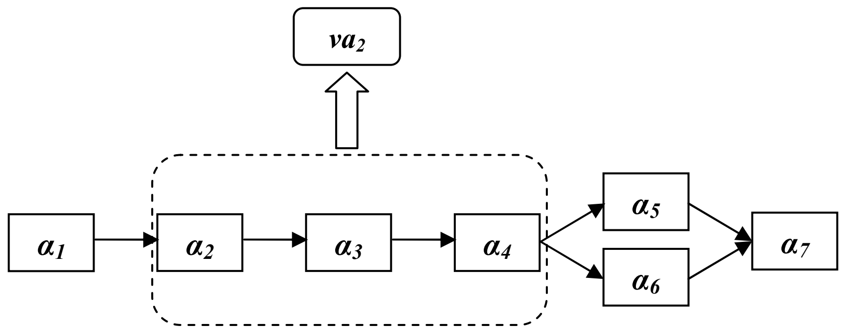

Figure 5. Virtual Process Scenario 1-a

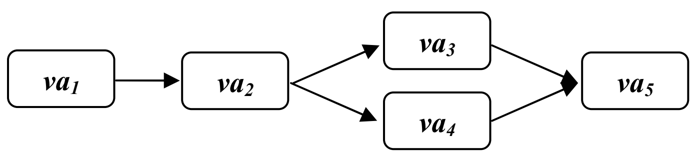

Figure 6. Virtual Process Scenario 1-b

Similarly, but for a higher abstraction level, an alternative virtual workflow process is that illustrated in Figure 7, as one may be interested only in communications between systems 1S and 2S. In this case, virtual activities $v\alpha_2$, $v\alpha_3$, $v\alpha_4$, are grouped into $v\alpha_{2+}$ (as they include communications between 1S and 4S, or 1S and 5S), while $v\alpha_{1+}$ derives from $v\alpha_1$ and $v\alpha_{3+}$ from $v\alpha_5$.

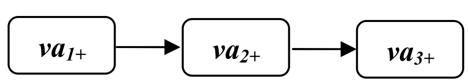

Figure 7. Virtual Workflow Process

In this way, each participant can be provided with the appropriate process information. Relatively to his working position and the quality of information needed, a participant is provided with the adequate virtual workflow process by the process modeler.

PSM 's contribution to improving the virtual workflow process modeling is now clear. Human communications and information flow are of major importance for a business' functionality and agility. PSM focuses on these two issues and structures clearly our problem, providing us with the ability to more accurately design the different process views. Thus, cooperating parts are provided with adequate process information based on the human factor while potential communication conflicts can be monitored and controlled.

Metasystems Approach

The Metasystems Approach incorporates metamodeling in organizational decision making. The metasystem constitutes the framework of decision making relatively to decision making. While one focuses on the objects - elements and relations -, which define a system, the views of the system are of object level. When we overcome this level, the views are of metasystemic level.

The adoption of a control system view can lead us to a better perception of decision making. This can provide us a well defined conceptual framework in which consistently coexist the concepts of structured, functional and process decision making (Assimakopoulos N., 2001). The derived model focuses not only on decisions, but also on changes caused by them during their application.

Relatively to our organization's problematic situation described, while presenting the PSM, the Metasystems Approach proposes the solution illustrated in Figure 8.

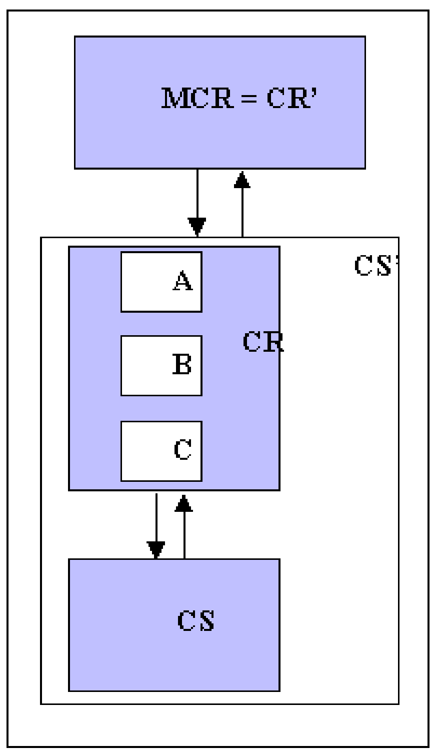

Figure 8: Meta-control in Decision Making

The controller CR consists of A, B, and C, which are the decision makers involved in the problematic situation. "A" is 1131I, "B" is 1222I, and "C" is 1321I. Their controlled system CS consists of the ordering coordination, during which take place their communications. In order to control their communications and propose solutions to improve them, a metacontroller MCR is proposed, 141I. He is responsible for the improving of their decision making procedure by helping them reduce conflicts and have a good communication. ***Duties of the Meta-controller should be:***

- Monitoring their decision making procedures and communications, and
- Controlling the appropriate application of the decisions made.

In this way, there is a metalevel control where the controller CR' is now the metacontroller and the controlled system CS' is the combination of CR and CS. The metacontrol can be illustrated also in the PSM figure as shown in Figure 9.

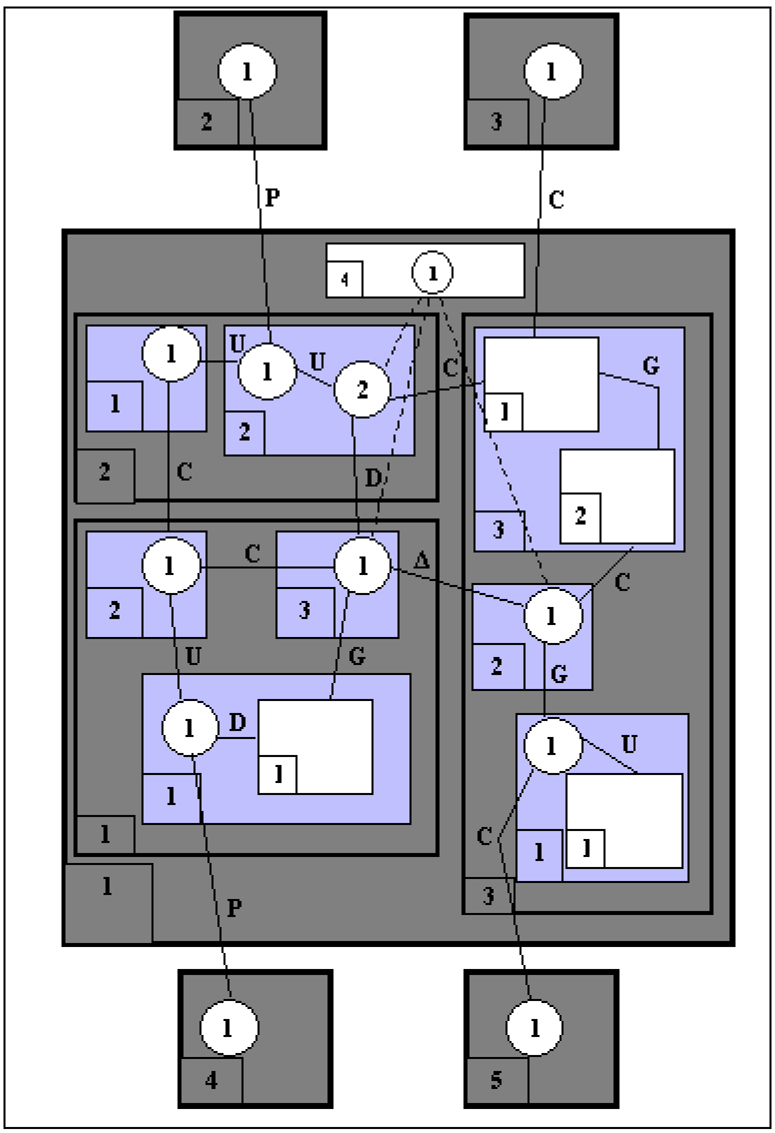

Figure 9: Using a Meta-controller in PSM Schema

Thus, the located problematic communication area is now controlled through the use of a meta-controller and communications are improved, providing effective process coordination and better functionality in our organization.

Strategic Assumption Surfacing & Testing (SAST)

We use the Strategic Assumption Surfacing and Testing (SAST) methodology to help the decision makers with their work, by concentrating their attention to the relations between individuals who are part of the general framework of a problem and not to its supposed attributes that form its main framework (Assimakopoulos N., 2001).

The methodology has four main stages:

- Team formation
- Assumption making
- Dialectical conversation
- Composition

Participants in these stages proceedings are 1131I, 1222I, 1311I, 1111I, 1221I. We will see every one of these stages adapted to our virtual workflow process systemic approach:

<u>Team formation</u>

The purpose of this stage is to form groups in a way that the next stages of the methodology are more productive. As many individuals as possible, involved in the examined base process, should get in touch with each other. These individuals are then separated into groups based on the hierarchical organization level they belong to, potential cooperation during an activity regardless their post and/or their personality type.

<u>Assumption making</u>

Each group must develop a preferred virtual workflow process solution. Three techniques are important for helping this procedure:

Participants' analysis –each group must determine key-persons by which success of their solution is dependant.

Assumption determination –each group deploys its assumptions for the determined participants

Assumption evaluation –each group evaluates every assumption it makes so as to deploy those who are most important.

In this way heterogeneous participants work together as groups with a common approach in order to produce collective proposals for their preferred virtual processes.

<u>Dialectical conversation</u>

Groups get in touch with each other and each one makes its best possible assumption for its preferred solution. Then, a dialectical conversation is allowed between groups. After conversation has proceeded enough, each group must consider modifying its assumptions, based on other groups' proposed process-views. This, procedure continues as long as there is progress made.

Composition

This stage's aim is to compromise between all the assumptions made in order to come up with a higher solution level, which will combine the best parts of each assumption in order to form commonly accepted process views. Assumptions still are negotiable and modifications are still being made in key-assumptions.

SAST aims: to improve the modeling of the virtual workflow process, because it can combine different points of view to form a commonly accepted solution. In this way, a process modeler will be able to make a commonly accepted modeling approach for the virtual workflow process. PSM can be used during SAST's procedures to make negotiations on a common basis.

Interactive Planning (IP)

The Interactive Planning (IP) methodology's contribution to a manager is that it enables him to help all organization's participants to plan a desirable for them future and to invent ways to fulfill it. IP's planning stages concentrate on the planning of an ideal future. (Assimakopoulos N., 2001)

There are five stages in IP methodology:

- Mess formulation
- Goal planning
- Means planning
- Resources planning
- Implementation and control planning

The participants in this methodology are 1111I, 1311I, 1131I, 1221I, 1222I, 41I, 51I, 21I, and a representative from the general administration. Each one of these stages is analyzed relatively to our virtual workflow process systemic approach below:

Mess formulation

During this stage the problems, the perspectives, the dangers and the opportunities which will be faced by the organization are analyzed. There are three types of analysis:
Systemic analysis –giving a detailed organization's and its functionality's image relatively to existing base processes
Impeding analysis – deploying all development related impeding issues
Views reports preparation –using the organization's present operation in order to forecast the future operation if nothing was done and thus observe the consequences on base processes structure

Goal planning

This stage refers to determination of goals to be pursued from an ideals, objectives and goals point of view. The procedure begins with an ideal plan for the organization's processes with which the participants would replace the existing ones if they could do so. This is done by:

-Choosing a vision about how the organization could be, something causing a commitment
-Determining the desired processes' plan properties
-Designing the system and presenting how the determined properties of the ideal plan could be realized

<u>Means planning</u>
Means planning, policies and propositions are produced and controlled in order to determine if they are appropriate for helping bridge the gap between the desired future and the future as it seems based on the present. The first two stages' outcomes are combined here to help discover ways so as the organization steps towards the implementation of his desired virtual processes.

<u>Resources planning</u>
For every type of resource it must be determined how much is needed, when is needed and how these types of resource can be obtained.

<u>Implementation and control planning</u>
This final stage of IP aims at assuring that all the decisions made this far are implemented. The implementation is always controlled to assure that the plans are applied and the desired results for the virtual processes achieved.

IP, and SAST, doesn't reassure that the right decisions are made as far as the virtual workflow process modeling is concerned. In similar cases though, in the past, both have given good results (Assimakopoulos N., 2001)

CONCLUSION

Workflow Management Systems allow organizations to manage business processes, facilitating electronic commerce and allowing virtual enterprises inner collaboration. The different needs for information between members of a company, or collaborator companies of a supply chain, are satisfied through the use of virtual workflow processes derived from implemented base processes. The base activity derives from a top-down decomposition of a business process, while a virtual activity is generated from a bottom-up aggregation of a set of base or virtual activities within a process. The process modeler develops a process definition and then defines process-views, providing different participants with adequate process information.

The Systemic Methodologies Approach improves the modeling of the virtual workflow process by correctly analyzing and forming the model, concentrating on the human factor. The PSM helps us structure the problem, monitor and control the communications, providing a better virtual process modeling approach. The Metasystems Approach enables us establish a well structured and defined control system, by providing object level and meta-level control for the problematic areas spotted during the use of the PSM, and improves the organizations' effectiveness through its communications. Finally, the combination of SAST and IP methodologies facilitates the coordination of participants from different groups during the planning procedure and guides it towards a productive, representative, and effective virtual workflow process. Thus, the model's usability and agility is improved giving the business high and realizable functionality.

REFERENCES

Assimakopoulos Nikitas 2001, "Systemic Analysis, University of Piraeus"

Duen-Ren Liu, Minxin Shen, "Workflow Modeling for Virtual Processes: an Order-Preserving Process-View Approach"

Georgakopoulos D., M. Hornick, and A. Sheth, "An Overview of Workflow Management – from Process Modeling to Workflow Automation Infrastructure", *Distributed and Parallel Databases*, 3(2), pp. 119-153, 1995.

Leymann F. and W. Altenhuber, "Managing Business Processes as an Information Resource", *IBM Systems Journal*, 33(2), pp. 326-348, 1994.

Leymann F. and D. Roller, *Production Workflow: Concepts and Techniques*. Prentice-Hill, 2000.

Gross J. L. and J. Yellen, *Graph Theory and Its Applications*. CRC Press, 1999.

Workflow Management Coalition, "Interface 1: Process Definition Interchange Process Model", Technical report WfMC TC-1016-P, Nov. 12, 1998.

W. M. P. van der Aalst and A. H. M. ter Hofstede, "Verification of Workflow Task Structures: A Petri-Net-Based Approach", *Information Systems*, 25(1), pp. 43-69, 2000.

Sadiq W. and M. E. Orlowska, "Analyzing Process Models Using Graph Reduction Techniques", *Information Systems*, 25(2), pp. 117-134, 2000.