KNOWLEDGE-BASED REFINEMENT OF BUSINESS MANAGEMENT FUNCTIONS

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Abstract: The paper deals with knowledge-based business process (BP) modeling. The enterprise management is considered from the control point of view – a formal structure of any enterprise management function is formally predefined as Elementary Management Cycle (EMC). The acquired from business domain empirical BP model is interactively enhanced and transformed to business management function model using predefined knowledge. Transformations are handled by knowledge structure – meta-model of enterprise management function. Two types of logical gaps are identified by transformations of BP models. Modified types of WFM are declared and deployed for refinement of business management functions.

1 INTRODUCTION

The business process modeling relies heavily on the analyst and user; therefore it is not clear whether the acquired information about problem domain is adequate (Kapocius K., Butleris R., 2005). Many mistakes in the area of business process (BP) modelling and user requirements acquisition can be avoided when applying knowledge-based enterprise (business process) modelling (Lopata, A., Gudas S., 2009), focusing on the verification and validation of acquired BP models.

There is a great number of Enterprise modelling methodologies (such as CIMOSA, GERAM (GERAM, 1999), IDEF suite, GRAI, MDA (Stephen J., Kendall S., Uhl A., Weise D., 2004), , standards and methods (ISO 14258, ISO 15704, PSL, ISO TR 10314, CEN EN 12204 (ENV12204, 1996), CEN 40003 (ENV40003, 1990), UEML (Vernadat F., 2001), DoDAF (DoDAF, 1996), which define the Enterprise modelling components.

An expert (user as well as analyst) plays the major role in domain knowledge elicitation and verification process, and few formalized methods of information acquisition control are taken into consideration.

There are two paradigms for Enterprise modelling (same as for BP modelling):

- The empirical Enterprise modelling: it is based on the problem domain analysis, when empirically acquired information is captured, and later *BP model* is represented using some structured notations (DFD, WFM, IDEF, BPMN or some others); in other words this is a traditional BP modelling.
- The knowledge-based Enterprise modelling: it is based on the predefined knowledge about essential features of some problem domain (i.e. in this case about *Enterprise as a system*), and handling of robust problem domain analysis using this domain-specific knowledge for verification and validation of the empirically acquired information. In this case we are discussing the methodological problems in the area of Enterprise modelling for BP re-engineering as well as for information systems development. The problem domain is Enterprise activities, so, essential feature of Enterprise activities is knowledge about information structure of the *Enterprise management (control) activity*. Verified and validated *BP management model* also is represented using some structured notations (DFD, WFM, IDEF, BPMN or some others).

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The difference of these two paradigms could be highlighted in brief as follows: the empirical BP modelling is focused on the *Enterprise business process* modelling. The major concepts from this modelling perspective are as follows: business process (activity, action or function), flow (material or information flow), organizational units (role, department, organization). There are no predefined constraints, except syntactical requirements of selected graphical notation.

Meanwhile knowledge-based BP modelling (from control point of view (Gudas, S., 1991), (Gupta, M.M., Sinha, N.K., 1996) is focused on the essential feature of Enterprise as a system - on the modelling of components of the *Enterprise management (control) process: enterprise process* (concerning only material flows and transformation), *enterprise management function* (concerning only information transformations in the *enterprise process* management (control) loop), *enterprise goals* and *objectives* as well as organizational units (role, department, organization) (Gudas S., Skersys T., Lopata A., 2004 and 2005).

Knowledge–based Enterprise modelling (BP modelling) includes verification and validation of empirically acquired BP model against predefined knowledge about inside structure of the *Enterprise management (control) activity* formally defined as Elementary Management Cycle (EMC) (Gudas S., Skersys T., Lopata A., 2004 and 2005).

Therefore, the user and the analyst are two sources of information about business domain in traditional IS engineering. Most of user requirements acquisition techniques are based on empirical information provided by the user (business domain expert). Problems occur when empirically acquired problem domain information (BP model) has to be verified and validated.

The Enterprise Knowledge Repository of CASE system is considered to be the third source of domain knowledge for empirical information about BP acquired from user. The core component of Knowledge Repository is Enterprise Meta-Model which is based on the definition of enterprise management cycle EMC (Gudas S., Skersys T., Lopata A., 2004 and 2005), as well as on the EM standards (ENV 12204) and languages (PSL, UEML core) (Vernadat F., 2001).

The presented BP modelling process is developed from management (control) point of view (Gudas, S., 1991), (Gudas, S., Lopata A., Skersys, T., 2005). The workflow modelling (WFM) notation is selected for representation of BP models. Naturally, some other BPM notations could be employed instead of selected WFM notation, for instance, the BPMN, IDEF0 or IDEF3 as well as DFD or Activity diagram (UML).

2 THE PRINCIPLES OF KNOWLEDGE-BASED ENTERPRISE MANAGEMENT MODELING

The peculiarity of this approach is as follows - BP modelling is focused on the modelling of *enterprise management (control)* aspects. *An enterprise management (control) modelling* is considered as modelling of enterprise information feedback between two concepts, namely, *enterprise management function* and *enterprise process.*

The information feedback between *enterprise management functions {F}* and *enterprise processes {P}* could be illustrated, for instance by analysis of Value Chain Model (Porter, M.E., 1985). The traditional *support activities* of Value Chain Model (financial policy, accounting, human resource management, technology development, procurement, etc.) are referred in this approach as *enterprise management functions*.

So, an enterprise management function (Fj) is identified as a type of support activities and *enterprise process* (Pi) is identified as a type of *primary activities* (see Figure 1).

In this approach structured Value Chain Model is considered as a framework of *enterprise management activity* which refines as a set of pairs (interactions) {(*Fj ; Pi*)} of *enterprise management functions* {Fj} and *enterprise processes* {Pi}: Formally *an enterprise management activity* is defined as Elementary Management Cycle (EMC) from the control point of view (see Figure 2) (Gudas, S., 1991).

The components of enterprise management function (aligned with the definition of EMC) are depicted in Figure 3.

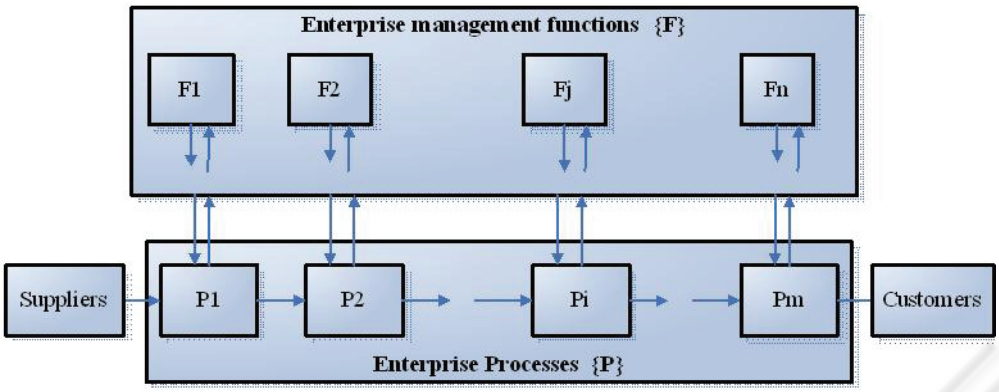

Figure 1: The structured Value Chain Model.

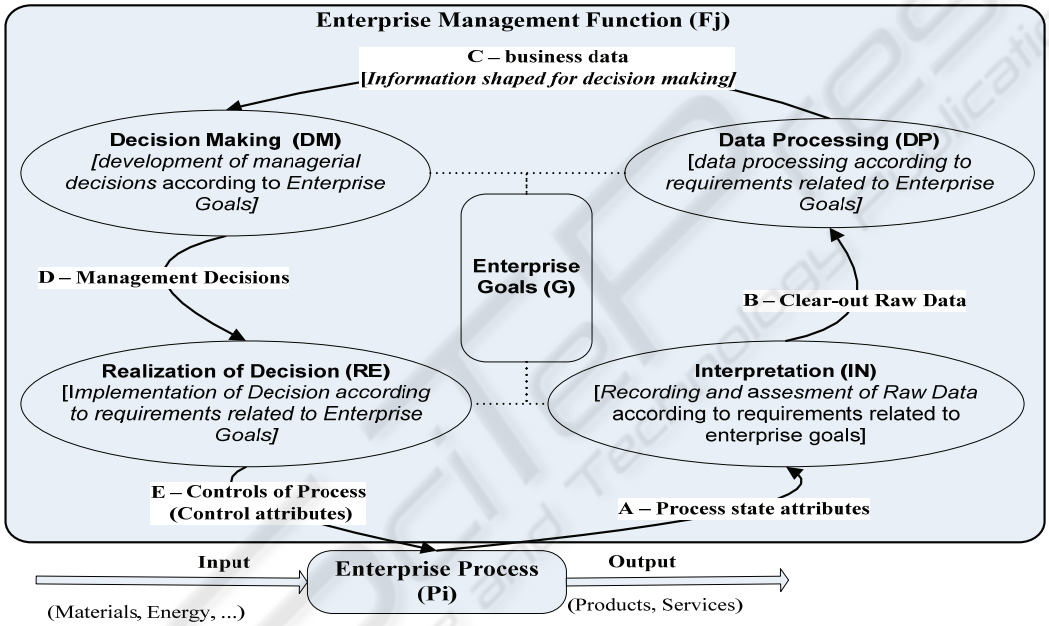

Figure 2: The information structure of any enterprise management function (Fj) is considered as cycle of information flows and transformations.

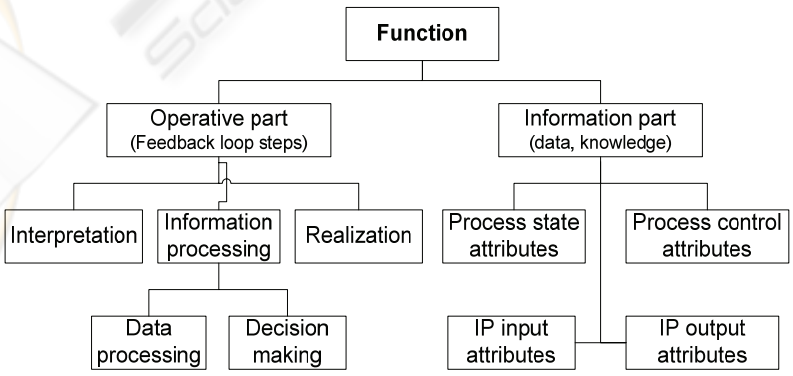

Figure 3: The structure of enterprise management function aligned with the definition of EMC.

Table 1: Comparison of traditional and modified workflow models.

Workflow model Components	Traditional WFM	VP_WFM (BPM1)	P_ WFM (BPM2)	F_ WFM (BPM3)	P_WFM* (BPM2*)	F_WFM* (BPM3*)	FS_WFM (BPM4)
Business Process	+ (not detailed)	+	–	–	–	–	–
Activity		–	–	+	–	+	+
Process		–	+	–	+	–	+
Material Flow	+ (not detailed)	+	+	–	+	–	+
Information Flow		+	–	+	–	+	+
Actor	+	+	+	+	+	+	+
Activity type	–	–	–	–	–	–	+
Logical Gaps	+	+	+	+	–	–	–

An enterprise management *Function (Fj)* consists of the predefined sequence of mandatory steps of information transformation (*Interpretation (IN), Data Processing (DP), Decision Making (DM), Realization of Decision (RE))*; all these steps compose a closed management cycle (a feedback loop). A definite types of attributes (*Process State Attributes (A), Clear-out Raw Data (B), Business Data (C), Management Decisions (D), Controls of Process (E))* are formed and transmitted during each management cycle step (Gudas S., Lopata A., Skersys T., 2005).

The workflow modelling (WFM) notation is used for business process modelling. Few new types of WFM (modified WFM) are defined and deployed for presentation and transformation of initial (empirical) *Business Process model (BPM1)* into *Enterprise Management model* (i.e. *knowledge-based BP management model (BPM4)*).

3 STEPS OF ENTERPRISE MANAGEMENT KNOWLEDGE ELICITATION

This knowledge–based BP modelling approach includes transformations of few types (modifications) of the workflow model as follows:

1. BPM1 is empirical BP model, represented as Workflow Model of Business Processes (VP_WFM);
2. BPM2 is model of enterprise processes (material flow), represented as Workflow Model of Processes (P_WFM);
3. BPM3 is model of enterprise information activities (information flow), represented as Workflow Model of Functions (F_WFM);
4. Intermediate results (BPM*):
   a. BPM2* is enhanced Workflow Model of Processes without gaps;
   b. BPM3* is enhanced Workflow Model of Functions without gaps;
5. BPM4 is formally correct enterprise management function model, refined using predefined knowledge, and represented as Workflow Model of Functional Composition (FS_WFM).

The model of *Business Processes* BPM1 (VP_WFM) is a traditional (empirical) workflow model aimed to specify an expert knowledge (empirical information) about problem domain (i.e. enterprise processes or functions, material and informational flows and actors).

The model of enterprise *Processes* BPM2 (P_WFM) is a part of VP_WFM and includes only material (manufacturing) processes, material flows and related actors of the problem domain.

BPM3 or model of enterprise Functions (F_WFM) includes only information (data) flows and related actors of the problem domain. BPM2* is model of enterprise Processes without gaps as well as BPM3 is model of Functions without gaps are intermediate results in transformations from empirical BP model (VP_WFM) to knowledge-based BP management model (FS_WFM).

BPM4 is model of Functional Composition (FS_WFM) and specifies the internal components of definite (selected by user or analyst) business management function in accordance with definition of EMC (Gudas S., Lopata A., Skersys T., 2005).

The refinement of formally correct enterprise management function is a sequence of transformations of BP models listed above.

Comparison of components of traditional workflow model and modified workflow models is presented in Table 1 where "+" means that the component is the part of the following Workflow model and "-" means that the component is not the part of such model.

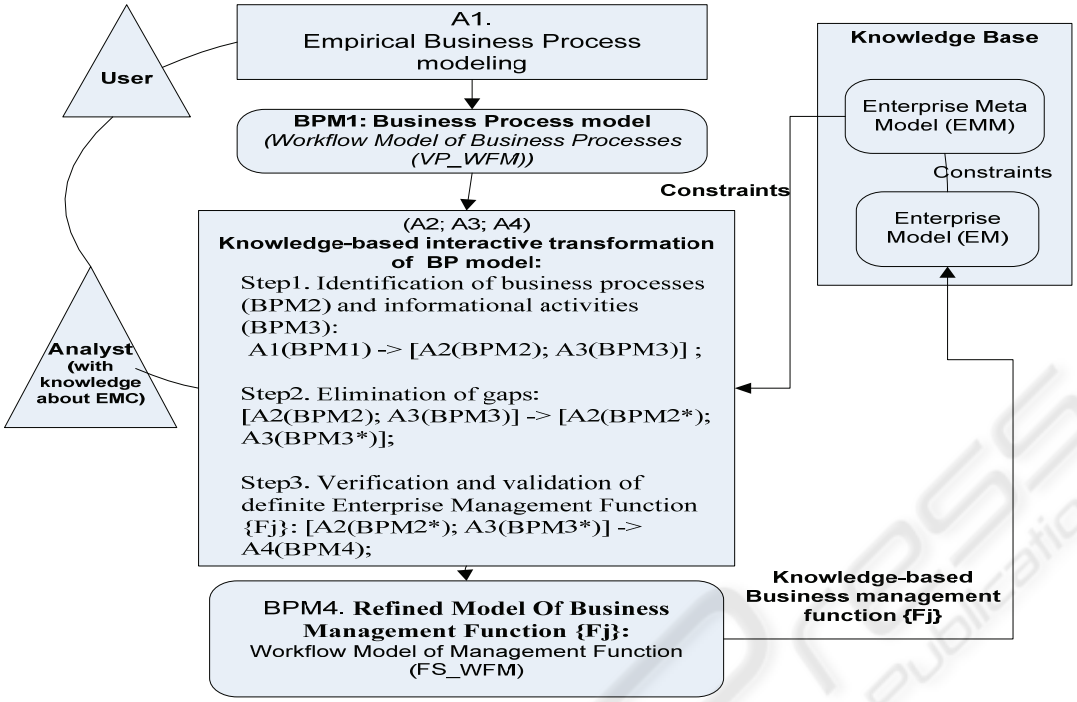

Figure 4: Knowledge-based refinement of business management function.

The refinement of formally correct enterprise management function (according to definition of EMC, i.e. according to composition of EMM) is a sequence of transformations of BP models BPM1 – BPM4:

Step1. Analysis of empirical model BPM1, identification of business processes (BPM2) and informational activities (BPM3): A1(BPM1) -> [A2(BPM2); A3(BPM3)] ;

Step2. Interactive identification and elimination of gaps in the BPM2 and BPM3: [A2(BPM2); A3(BPM3)] -> [A2(BPM2*); A3(BPM3*)];

Step3. Verification and validation of selected (definite) enterprise management function (Fj): [A2(BPM2*); A3(BPM3*)] -> A4(BPM4);

The analysis steps of the BP models (analysis starts with empirical one BPM1 (VP_WFM) finally refines formally correct model BPM4 of some selected (defined by analyst or user) enterprise management function (FS_WFM)*)*:

a) A1 -> A2: Identifies informational activities and material processes (presented in empirical BP model BPM1 (VP_WFM) and separates VP_WFM into Model of Processes BPM2 (P_WFM) and Model of Functions BPM3 (F_WFM);

b) A2. Identifies and eliminates logical gaps in the Model of Processes BPM2 (P_WFM); verified model BPM2* is developed;

c) A3. Identifies and eliminates logical gaps in the Model of Functions (F_WFM); verified model BPM3* is developed;

d) [A2; A3] -> A4. Validation of enhanced models BPM2* and BPM3* against Knowledge Base constraints, and composition BPM4 (FS_WFM) of selected (particular) enterprise management function (Fj). Validation of BPM4 is performed according to the formal definition of enterprise management function (predefined as Elementary Management Cycle (EMC)).

The major steps of problem domain analysis and knowledge acquisition are presented in Figure 4.

4 IDENTIFICATION AND ELIMINATION OF BP MODELLING GAPS

The logical gaps could appear when problem domain knowledge (i.e. empirical BPM1) is incomplete. Logical gaps are identified during the analysis of input and output flows of enterprise activities. For instance, a logical gap in the BPM2 (P_WFM) or BPM3 (F_WFM) is identified if some *Process* or *Activity* is not related to *input flow* or *output flow*.

It is likely that on separating VP_WFM into F_WFM and P_WFM logical gaps may be identified in newly created F_WFM and P_WFM. A logical

gap is a semantic discontinuity among the elements of the workflow model. The logical gaps appear when problem domain knowledge is acquired incompletely. On purpose to eliminate gaps of P_WFM, detecting and eliminating algorithm is applied. Without reference to elimination method, P_WFM is complemented by non–existing, but wrongly or hardly specified knowledge (process, material flow and actor). Logical gaps of P_WFM are identified during the analysis of input and output flows of each material process.

Except the first and the last processes of the workflow model each Process of the P_WFM must be related to at least one input material flow and one output material flow, in the same as each Activity of F_WFM must be related to at least one input information flow and one output information flow. On purpose to eliminate logical gaps of P_WFM, the prototype of informational system, eliminating P_WFM gaps was created by MS "VISIO 2000" CASE tool and MS "ACCESS 2000" data base management system.

The principles of elimination logical gaps in the BPM3 (F_WFM) are analogical to that of BPM2 (P_WFM). The main difference is that all analysis actions of BPM3 (F_WFM) are performed with modeling concepts *activities* and *information flows*, but not with *processes* and *material flows* of BPM2 (P_WFM).

Table 2 presents the components of management function model BPM4 (FS_WFM), which are defined according to *activities* input and output flows identified in BPM3 (F_WFM). According to the types of informational input and output flows, three types of the BPM4 information activities (internal steps of management function by definition – see Figure 2) can be distinguished: *Interpretation*, *IP* and *Realization* (described in detail in (Gudas S., Lopata A., Skersys T., 2005).

A set of rules for BPM4 analysis is developed. For instance, if input and output of FS_WFM *information activity* are information flows "*Process Output*", situation "impossible type of activity" is identified. Information activities of FS_WFM, according to definition of EMC, cannot have informational input and output flows of the same type. Activities, which have information input and output flows *("Process Output",* "*IP Input*", "*IP Output*", "*Process Input*") of same type, can exist neither. If activity input is "*Process Output*" and output is "*IP Input*", the activity will be identified as component (part) *Interpretation* of management function. *Interpretation* is set of rules, intended to transform information flow "*Process Output*" into "*IP Input*", which is prepared for *IP* processing. *Interpretation* is a necessary component of management function, because "*Process Output*" information flow can mismatch data format, determined for functional IP element input "*IP Input*".

If activity input is "*IP Input*" and output is "*IP Output*", the activity is identified as component *Information Processing* (IP) of management function. *Information Processing (IP)* is functional component, which is mainly intended to control process of information processing and decision making. If activity input is "*IP Output*" and output is "*Process Input*", the activity is identified as component (part) *Realization (RE)* of management function. *Realization* is functional part, performing process, which is contrary to Interpretation (IN). *Realization* transforms "*IP Output*" data (processed in *IP* stage) into "*Process Input*" format (suitable to direct process control).

5 META-MODEL OF ENTERPRISE MANAGEMENT FUNCTION

The result of validation of functional composition (Step3 in Figure 4) is model BPM4 of formally correct Enterprise Management Function (presented as Work Flow Model of Functional Composition (FS_WFM). Elements of Workflow Model of Functions (F_WFM) are specified in the Enterprise Management Function model (FS_WFM) as component types, formally defined by structure of EMC (see Figure 3).

Every Enterprise Management Function model (FS_WFM) specifies some particular Enterprise management function (Fj), which controls one of processes (Pi), specified in model BPM2 of Enterprise Processes (P_WFM).

According to the internal structure of Enterprise management function (Fiji) (see Figure 3), there are three allowable types of information activities: *Information activity of interpretation, Information activity of data processing and decision making (IP), Information activity of realization*.

Each BPM3 (F_WFM) information activity may correspond to one of the above mentioned component parts of functions.

Table 2: Input flows and output flows of components "information activity" of BPM4.

Type of Activity Output / Type of Activity Input	***Process Output***	***IP Input***	***IP Output***	***Process Input***
Process Output	Impossible	*Interpretation (IN)*	*Interpretation (IN)*, Information Processing (*IP*)	*Interpretation (IN), Information Processing (IP), Realization (RE)*
IP Input	Impossible	Impossible	*Information Processing (IP)*	*Information Processing (IP), Realization (RE)*
IP Output	Impossible	Impossible	Impossible	*Realization (RE)*
Process Input	Impossible	Impossible	Impossible	Impossible

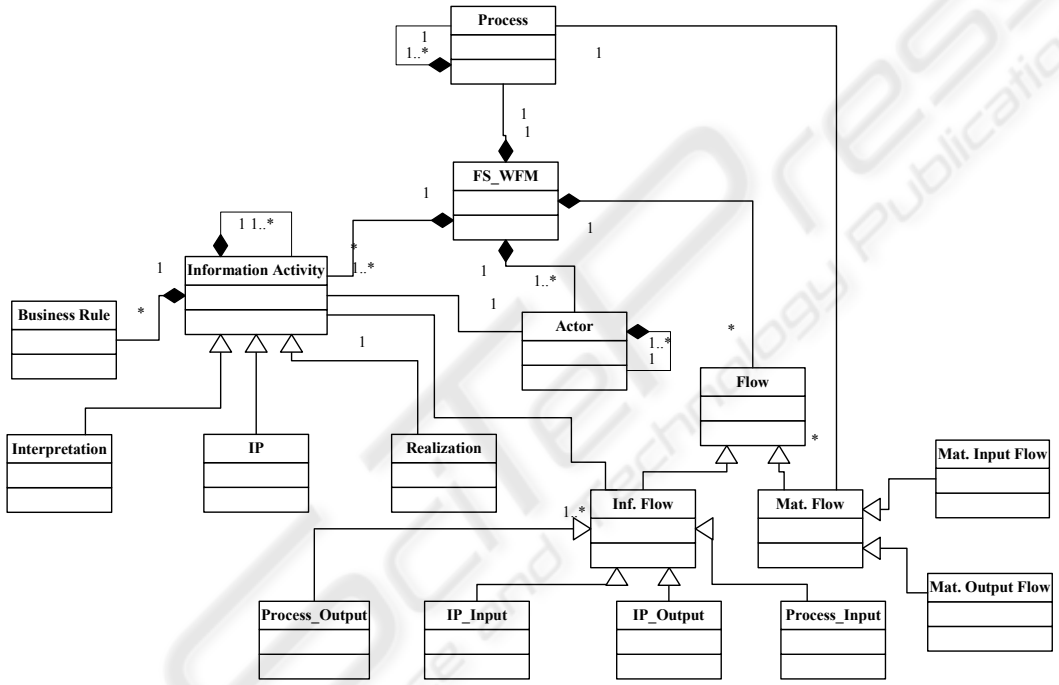

Figure 5: Meta-model of enterprise (business) management function (represented as Work Flow Model of Functional Composition (FS_WFM).

Algorithm determines what part of function activities belong to and what material process do they control in F_WFM. Each activity of F_WFM, specified in FS_WFM, can be analogical component (Interpretation, IP or Realization) of several FS_WFM. FS_WFM metamodel is presented in Figure 5.

6 CONCLUSIONS

The peculiarity of this approach to BP modelling is the enterprise management (control) modelling view (Gudas S., Lopata A., Skersys T., 2005). An enterprise management modelling is considered as modelling of interaction of two major concepts, namely, enterprise management function and enterprise process. The concepts of *enterprise management function* and *enterprise process* is illustrated by analysis of Value Chain Model.

The acquired from business domain BP model is represented as Workflow model. This empirical BP model is interactively enhanced and transformed step by step to business management function model using predefined knowledge. Transformations are handled by knowledge structure – meta-model of enterprise management function.

The enterprise management activities are considered from the control point of view. The predefined knowledge about enterprise management functions (namely, defined as *Elementary Management Cycle (EMC))* is used for modelling, verification and validation of enterprise management (control) interactions. Workflow modelling notation is used for visualization of BP models. Modified types of WFM are declared and deployed for refinement of business management functions.

The selected notation for manifestation of BP models and refinement of enterprise management function is Workflow modelling notation, meanwhile some other notations could be used instead, for instance, DFD, BPMN as well as Activity diagram of UML or IDEF3.

Domain knowledge acquisition and analysis process is described as a sequence of interactive transformations of empirical BP model to formally defined BP management function model where a Knowledge Base is an active source of essential knowledge about structure and behaviour of enterprise management components.

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