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# BUSINESS PROCESS MANAGEMENT: A CONCEPTUAL AND OPERATIONAL OPTIMISATION APPROACH

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RÉSUMÉ :

MOTS CLÉS :

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ABSTRACT:

To optimise business processes is a very complex task. The goal is double: to improve productivity and quality. The method, developed in this paper, is composed of 4 steps : the first one is the modelisation step (to describe the business process in a very rigorous way), then a conceptual optimisation (supported by evaluation and simulation tools) to improve the business process structure (to make it more consistent, to normalise it), then an operational optimisation to improve the business process performing (to make it more efficient) by providing to each operation the necessary resources and at last a global optimisation (to take into account all the business processes of the company under study). The conceptual optimisation is, in fact, a static optimisation (achieved independently of resources) while the operational optimisation is dynamic. The main difference between these 2 steps is the fact that the first one is totally hand made (we want to build, from the set of indicators provided by evaluation and simulation, the best business process as possible), in opposition with the second which is totally automatic (since it requires linear and non linear programming tools). This method is the result of three years research achieved for the French organism *Caisses d'Allocations Familiales: CAF*. It was validated on the business processes of the CAF, which deal with information (files and documents), but it can also be applied on industrial business processes (dealing with products and materials).

KEY WORDS :

business process management,, modelling, quality

# BUSINESS PROCESS MANAGEMENT: A CONCEPTUAL AND OPERATIONAL OPTIMISATION APPROACH

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**ABSTRACT:** To optimise business processes is a very complex task. The goal is double: to improve productivity and quality. The method, developed in this paper, is composed of 4 steps : the first one is the **modelisation step** (to describe the business process in a very rigorous way), then a **conceptual optimisation** (supported by evaluation and simulation tools) to improve the business process structure (to make it more consistent, to normalise it), then an **operational optimisation** to improve the business process performing (to make it more efficient) by providing to each operation the necessary resources and at last a **global optimisation** (to take into account all the business processes of the company under study). The conceptual optimisation is, in fact, a static optimisation (achieved independently of resources) while the operational optimisation is dynamic. The main difference between these 2 steps is the fact that the first one is totally hand made (we want to build, from the set of indicators provided by evaluation and simulation, the best business process as possible), in opposition with the second which is totally automatic (since it requires linear and non linear programming tools). This method is the result of three years research achieved for the French organism "Caisses d'Allocations Familiales: CAF". It was validated on the business processes of the CAF, which deal with information (files and documents), but it can also be applied on industrial business processes (dealing with products and materials).

**KEY WORDS:** Business process management, quality, modelisation, evaluation, simulation, optimisation, linear and non linear programming, activity diagrams, resources affectation.

## 1. INTRODUCTION

Business process optimisation is one of the major issues of any company. The main goals are to improve processes quality and to improve their productivity, by increasing the number of output flows and/or by decreasing the quantity of necessary resources.

Since the appearing of object oriented paradigm, methods to design Information Systems have been oriented towards the class notion instead of the process notion. But evolutions of technical environment, use of Internet technology, led to consider Information Systems as a tool to change ways of working and led companies to adopt a process approach [Rolland 1996, Butler 1999]. A **business process** (BP) is composed of **operations** (tasks) (automated or not) and **resources** (possessing **competencies**) which have to deal with **flows** (of data, or materials). Business process **management** and **optimization** are quite recent ideas since processes were implicit in each organisation culture so far [Aalst 2002]. Traditional re-engineering methods were based on an informal graphical representation of processes to reorganize. But processes are more and more complex; to optimize them means improve their performances and so be able to qualify and measure these performances in order to create new processes more efficient. In most cases, processes performances evolve during time, depending on the volumes of treated flows and resources availability. Then, to be efficient, processes optimisation has to be done with an approach where organisational dimension is above technological dimension. BP re-engineering has been studied in the last few years by [Jonkers 1999] and most of re-engineering tools are based on informal graphic techniques. On the other hand, if flows optimisation [Jensen 2001, Krajewski 2001] is considered as a part of modelisation step, the research of the best solution remains problematic. Recent works have used artificial intelligence techniques for BP management, [Drabble 2002, Nareyek 2001] for example to define ontologies, and multi-agents systems. In the case of planning, the most known strategy is to satisfy the goal instead of searching the best solution [Aalst 2002]. However, the works of [Haslum 2000, Williamson 1994] search an optimum depending on pre-defined criteria and [Ambite 2001] propose a specific technique to improve BP's performing. Others works [Aler 2002b, Borrajo 2001, Estlin 1996, Iwamoto 1994, Ruby 1992] used learning machine approaches. We may note that the use of models to study BP's behaviour and optimisation is not very frequent. However a formal framework may provide more flexibility and rigor to improve BP's quality. A first step is the elicitation or design of the organisation model. This model may be documented, analysed, and simulated by using high level modelling tools. Then workflow management systems become necessary for performing, monitoring, and dynamically adapting processes to changes. It is generally driven by requirements and time constraints. A large number of representation languages, modelling tools and techniques have been proposed. Indeed organisations need powerful tools to model, simulate and optimise their processes in such a way that the generated models comply with business rules. Designing business processes is a knowledge-

intensive human activity supported by modelling software and simulation tools. A workflow management system is used to define the coordination of activities and transfer of documents within a business process.

The method presented in this paper starts with a previous modelling step followed by three main steps:

- Modelisation step makes it possible to represent BP with a model which has the usual guarantees of any good model: **readability, normalisation, genericity**, and which induces an optimisation more rigorous, more consistent and less hazardous. Modelisation was decided for all these reasons in order to avoid an empirical optimisation consisting in improving each BP from clues based on its behaviour, by trying to find out **local** solutions for the parts which run worst or the less correctly.
- Conceptual optimisation step which does not take into account resources; it is a structural and static optimisation.
- Operational optimisation step which consists in optimising the performing of the BP by taking into account resources, which means by locating them the best way as possible. It is a dynamic optimisation since the goal is to optimise performances.
- Multi-BP optimisation step which is used to optimise (in the operational way) several BP simultaneously.

## **2. MODELISATION**

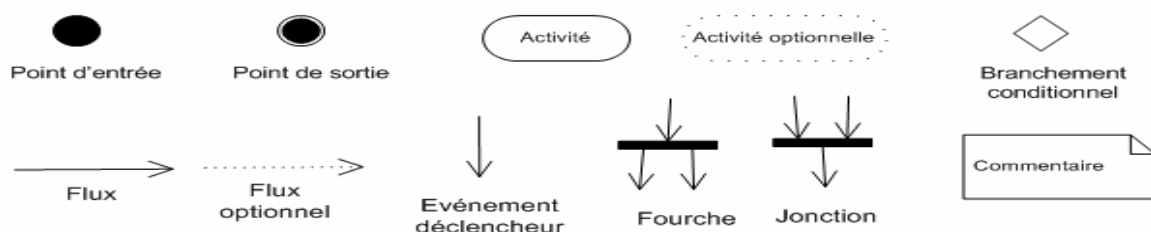
### **2.1 CONCEPTS**

Four concepts are necessary to model business processes: **operation, flow, resources and competencies**.

- OPERATIONS: an operation is a task of a business process. Each operation can be mandatory or optional, and disactivable (or not). A mandatory operation has to be used systematically (always), which means it is necessary for the right performing of the BP. An optional operation may not be used depending on the decided options. A disactivable operation is an operation which can be shunted if the corresponding resources are not available.
- FLOWS: A flow is a set of homogeneous elements passing through the BP and treated by operations. An optional flow is a flow associated to an optional operation. We consider 3 types of flows: primary flows, secondary flows and triggering operations events.
  - Primary flows : are the flows (of data or materials) which are to be treated (in input or output)
  - Secondary flows: are data flows containing useful and helpful information to deal with primary flows (guidelines, precisions, complements,...)
  - Triggering operations events: are necessary events (not always sufficient because a primary flow is most of the time also necessary) to trigger operations (for example a special date).
- RESOURCES AND COMPETENCIES: These 2 concepts are linked. A resource is a group of persons having the same set of competencies. A resource possesses one or several competencies. A competency can be associated to several resources (N: M link). The set of resources is a partition of the persons set. We consider that each operation is one-competency (to be performed an operation needs persons having the same competency). In a BP, each swim lane contains all the operations which need the same competency. A specific swim lane is associated to automatic operations.

### **2.2 MODEL**

The chosen model is directly inspired from the UML activity diagrams. Fig. 1 shows the UML concepts which are used. It is a subset of the available set of elements in UML.

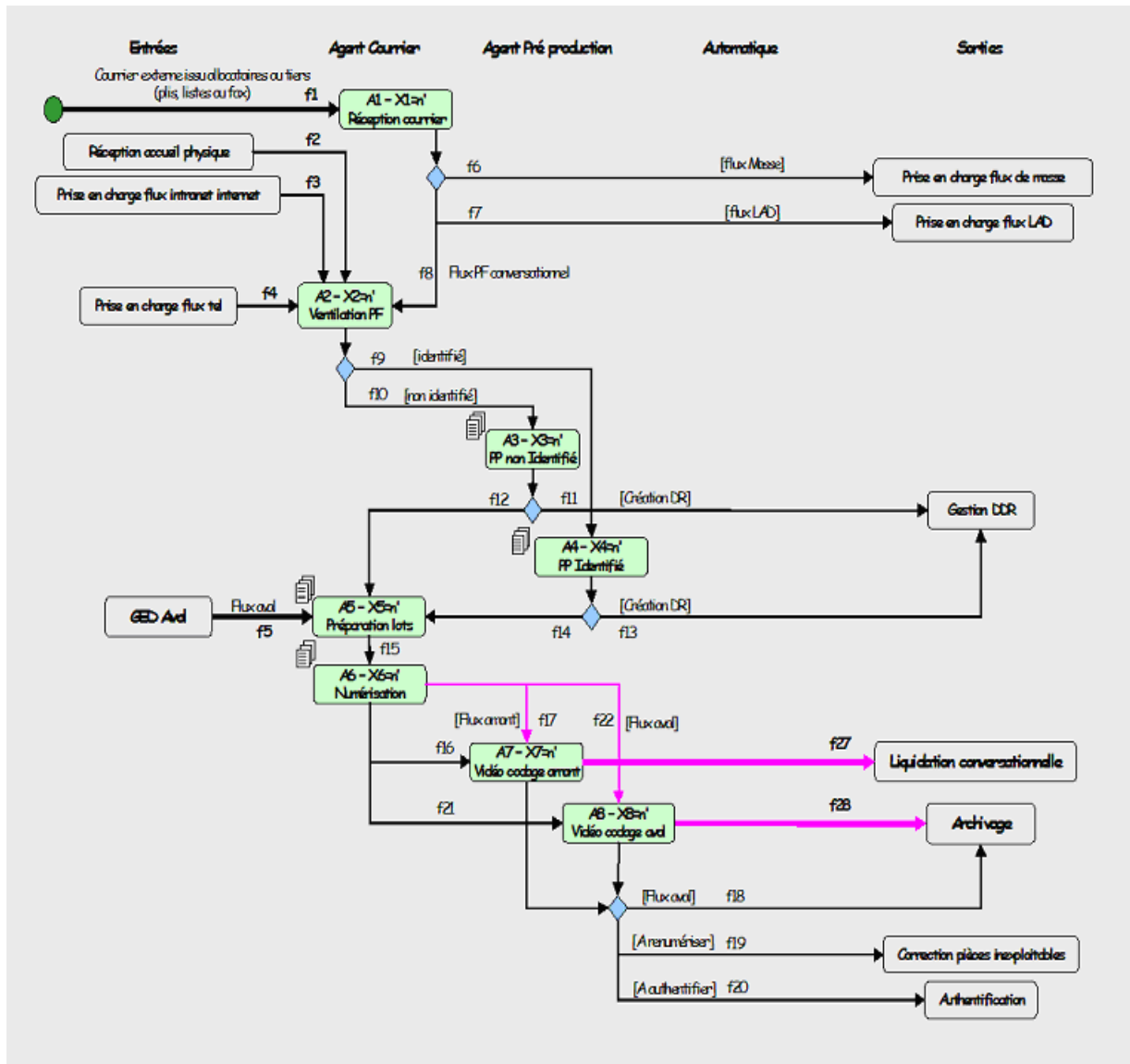


*Fig. 1: UML concepts to build activity diagrams*

### **2.3 TOOL**

In order to build activity diagrams, we can use any tool supporting UML notations. We can choose either a full UML environment like RATIONAL ROSE or DESCRIBE or a graphic modelling tool like VISIO or SMARTDRAW. Several criteria are to be taken into account to make the right choice: conformity with the UML 1.4 norm, graphic quality of documents, opportunity of exporting diagrams in XML in order to provide right inputs for simulation tools, learning facilities, ergonomoy.

DESCRIBE was finally chosen, because it is the tool which satisfy the better these criteria. As an example, Fig 2 shows a part of a real diagram built for the CAF.



**Fig. 2: Example of Business process diagram built with DESCRIBE**

### 3 CONCEPTUAL OPTIMISATION

The modelling step provides a diagram of the BP (by using the previous concepts) in order to **evaluate** it (with simulation and evaluation tools) and to **optimise** it in the right directions by taking into account its structure and its defaults (and still so far without resources). The conceptual optimisation is static.

#### 3.1 EVALUATION STEP

The goal of this step is to collect all useful information to improve the BP structure. This information is given by indicators and objectives graph. Some of them are provided by simulation.

##### 3.1.1 INDICATORS

Indicators are used to evaluate a BP. They are of 2 kinds: model indicators and BP indicators.

- Model indicators: they are used to evaluate the consistency of a BP independently of its finality. They are theoretical indicators (in opposition to BP indicators). They provide an evaluation of the diagram quality and make it possible to check that diagrams are satisfying the norms given by the model. In others words, to check that the conceptual optimisation step delivers **well built** diagrams. The list of model indicators is following: maximum number of input flows in each operation, maximum number of output flows in each operation, average number of flows per operation, number of optional operations / number of operations, number of disactivable operations / number of operations, number of loops, cyclomatic number (number of bows-number of nodes + 2), diagram density (number of bows/maximum number of bows), average number of operations per competency, average number of flows per competency.

- BP indicators: they are used to evaluate performances and dysfunctionings of a BP. Their values are useful to determine the optimisation priorities (see below objectives graph, Fig. 4).

Once achieved the conceptual optimisation, a second evaluation of these indicators can be done in order to check that the goals have been satisfied. The modelling step and the objectives graph step make it possible to find out (for a given BP) the list of the useful indicators.

Fig. 3 shows some examples of BP indicators in a specific BP from the CAF. These indicators are located in the graph (see Fig. 4).

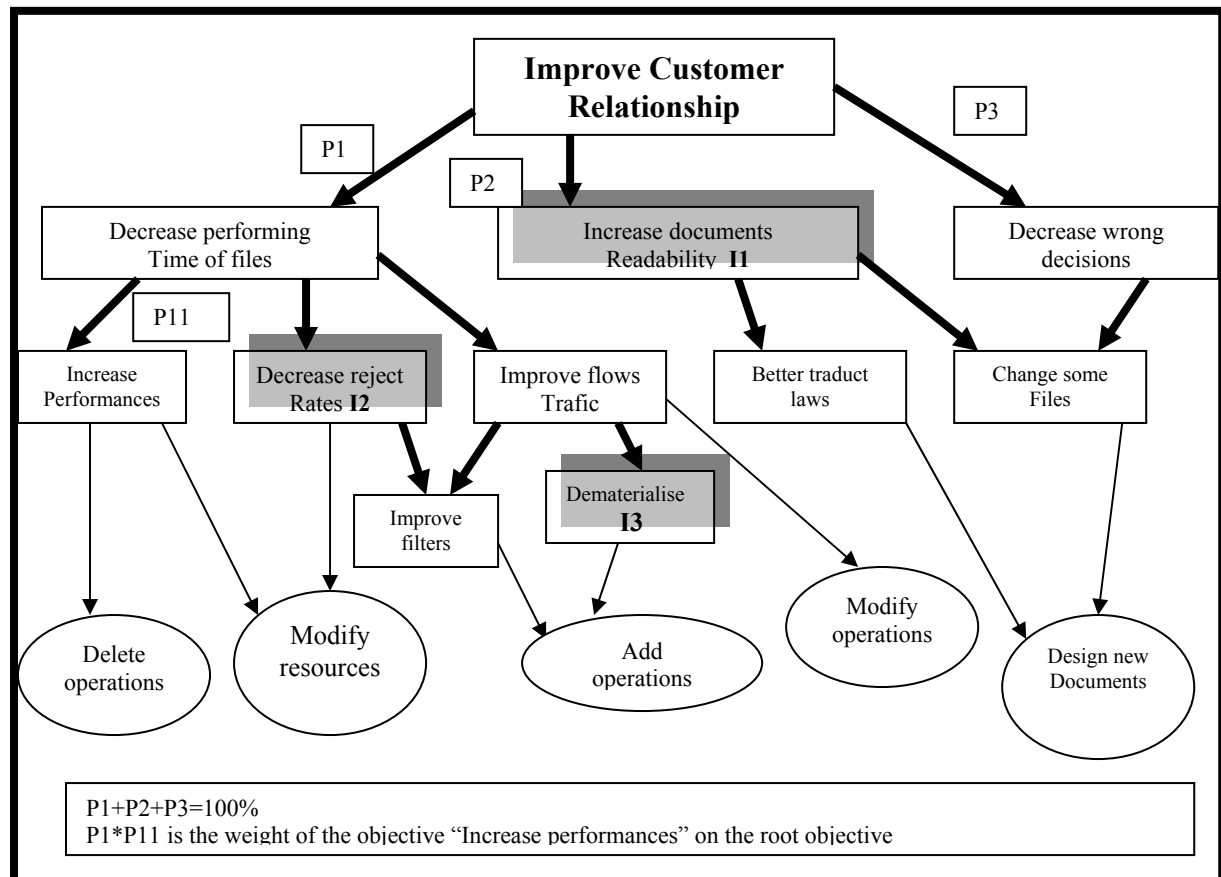
NODES OF THE GRAPH	INDICATORS	FORMAT	OBTENTION
READABILITY OF DOCUMENTS	I1 : SATISFACTION PER DOCUMENT	VECTOR	OBSERVATION
DECREASE RATE REJECT	I2 : % REJECT PER OPERATION	VECTOR	SIMULATION
DEMATERIALIZATION	I3 : % DEMATERIALIZATION	NUMBER	OBSERVATION

**Fig. 3: Examples of BP indicators**

### 3.1.2 HIERARCHICAL OBJECTIVES GRAPH

It is necessary to build a hierarchy of optimisation objectives and to identify precisely those which are means compare to the others. Thus, we propose to build a “hierarchical objectives graph” (HOG). This kind of graph makes it possible to show clearly the hierarchical relationships between objectives.

If the graph is well built and exhaustive, all its leaves **are the actions to perform** in order to optimise the BP. More precisely, the graph is built by connecting (if possible) to each node (objective) some indicators, values of which will be provided by evaluation and simulation steps (in the example I1, I2 and I3). The graph is helpful to build an optimise BP because it gives the hierarchical links between objectives and then optimisation priorities. Each BP has its own graph. The bows of the graph have to be valued (with percentages) in order to give the satisfaction weight of an objective to another one (higher in the hierarchy) and to guide the process optimisation. Fig. 4 shows a part of the objectives graph of the BP introduced in Fig. 3.



**Fig. 4: Example of hierarchical objectives graph**

### 3. 1.3 SIMULATION STEP

This step is dedicated to the study of the BP behaviour in order to find out some of the possible improvements (addition or deleting operations and/or flows, detection of wrong cycles, detection of congestion points,...). Obviously, this step requires a simulation tool (SIMPROCESS was chosen).

The simulation step is also used to give values to indicators, such as the reject ratio per operation. It is an essential step to evaluate correctly BP.

Note: the use of a simulation tool requires to modelise the BP (in the form wanted by the tool). In our case, since BP are already modelled (in DESCRIBE), we had to build a specific tool to convert DESCRIBE diagrams into SIMPROCESS diagrams (in XML).

### 3. 2 CONCEPTUAL OPTIMISATION STEP

The conceptual optimisation of a BP is achieved from information provided by evaluation step, simulation step and objectives graph step. The goal is to build the best BP as possible (in regards to norms, indicators, objectives hierarchy). It is a very tough step (totally hand made) which requires to take into account simultaneously a very large number of information and a great know how. Thus, values of some model indicators will induce creation or suppression of some operations and/or flows, values of some BP indicators will generate creation of some new paths in the diagram (by validating or deleting optional operations) or creation of new documents, analysis of the objectives graph make it possible to identify the parts of the BP which have to be optimised in priority.

Conceptual optimisation is totally guided by the objectives graph: weights are used to know priorities and indicators are used to decide if the nodes are easy to optimise or not. In the example, we can decide to give a priority to the objective "decrease the time to perform a file" if the values of I2 are too high and if the weight of this objective in regards to the root objective is high. In this case, we have to (following the graph) modify some resources and add some operations. In opposition, if the value of I1 is too low and if the weight of the objective "to increase readability of documents" is high, then we have to design new documents.

Actually, the conceptual optimisation of a BP is achieved par a lot of improvements (defined in the leaves of the graph) performed on its diagram, in regards to the objectives graph which gives the right directions. But the diagram's improvement has to be done in respect of concepts: we can't do anything forbidden or in opposition with the given rules. For this reason, we have defined the exhaustive list of generic actions (meta-actions) which are possible to do. This list is the tools box in which the designer can find any action which may optimise the BP. **Each leaf of the graph has to be obviously an instance of one meta-action.**

**Examples of meta-actions:** to add a new operation, to automate partially an operation, to split an operation (in 2 or more) to add a new flow, to split a flow (in 2 or more), to merge 2 or more flows into 1, to modify a flow, to add a new competency, to modify a competency's profile, to change the destination operation of a flow.

Fig. 5 shows the whole schema of the conceptual optimisation step. We may note that evaluation and simulation can be performed several times: once to provide necessary information to optimise, and then others to check the results of the optimisation.

**Example:** *this example is purely formal. It does not correspond to a real case but it illustrates most of the available improvement possibilities in the conceptual optimisation step. The BP to optimise is described in Fig. 6. It contains 13 operations and 22 flows. Optional operations and flows are in dotted lines. Loops are in bold lines. 5 competencies are necessary (C1 to C5) as indicated in each operation. There are 2 input flows f1 and f2. The associated objectives graph is given in Fig. 7. Nodes possessing indicators are shadowed.*

**Values of the main model indicators are:**

*maximum number of input flows in each operation: 3*

*maximum number of output flows in each operation: 2*

*average number of flows per operation: 22/13*

*number of optional operations / number of operations: 2/13*

*number of loops: 2*

*cyclomatic number (number of bows-number of nodes + 2): 11*

*diagram density (number of bows/maximum number of bows): 22/12X13*

*average number of operations per competency: 13/5*

**Values of the main BP indicators are (most of these values are provided by simulation):**

*I1 Reject rates of operations O10 and O11: too high*

*I2 Performing time of files for operations O12 and O9: too high*

*I3 Flows traffic between O4 and O11 as well as O7 and O12: too low*

*I4 Satisfaction rates of filters for O2 and O6: normal*

*I5 automated operations rate: normal*

*I6 Users satisfaction rates: too low*

*4 indicators out of 6 are not correct.*

**Values of the main model indicators show that:**

*maximum number of input flows in each operation: 3 normal*

*maximum number of output flows in each operation: 2 normal*

average number of flows per operation: **22/13 too high**  
 number of optional operations / number of operations: **2/13 normal**  
 number of loops: **2 normal**  
 cyclomatic number (number of bows-number of nodes + 2): **11 too high**  
 diagram density (number of bows/maximum number of bows): **22/12X13 normal**  
 average number of operations per competency: **13/5 normal**  
 3 indicators out of 8 have a value which is not satisfying (because the number of flows is too high).

**Values of the main BP indicators show that: I1, I2, I3 and I6 are not satisfying.**

In regards to the objectives graph, we have to modify competencies (I1), delete the less efficient operations (I2), modify some operations (I2 and I3), delete some flows (I3) and design new documents (I6). This last action will have no impact on the BP diagram.

**The objectives graph shows that:** 4 nodes are involved by incorrect indicators and then the 5 associated leaves (shadowed on the figure 7). Parts of the graph which contains the possible improvements are bolded. We have then to choose those which are the most important in regards to the weights of each bow. For example, if p2 is stronger than p1 and p3, the main improvement will consist in modifying documents. We will consider, from now on, that all the weights are equal and so all improvements are possible.

**The decisions to take are:**

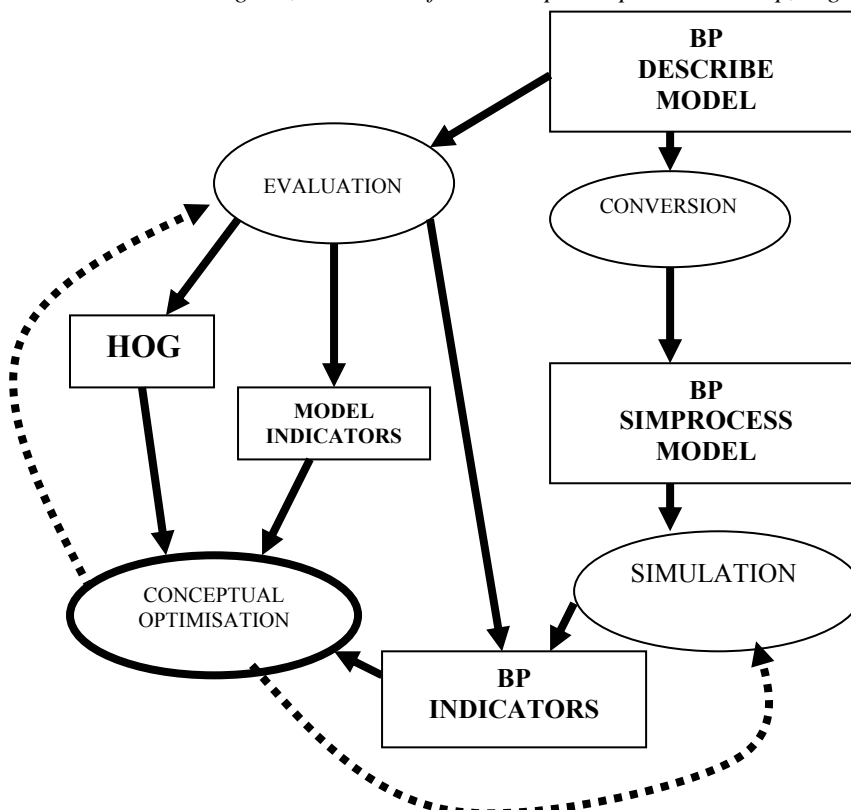
- in regards to the model indicators : delete some flows
- in regards to the BP indicators: modify competencies (I1), delete the less efficient operations (I2), modify and delete some flows (I3) and design new documents (I6).

All the weights being equal, we will take all these actions.

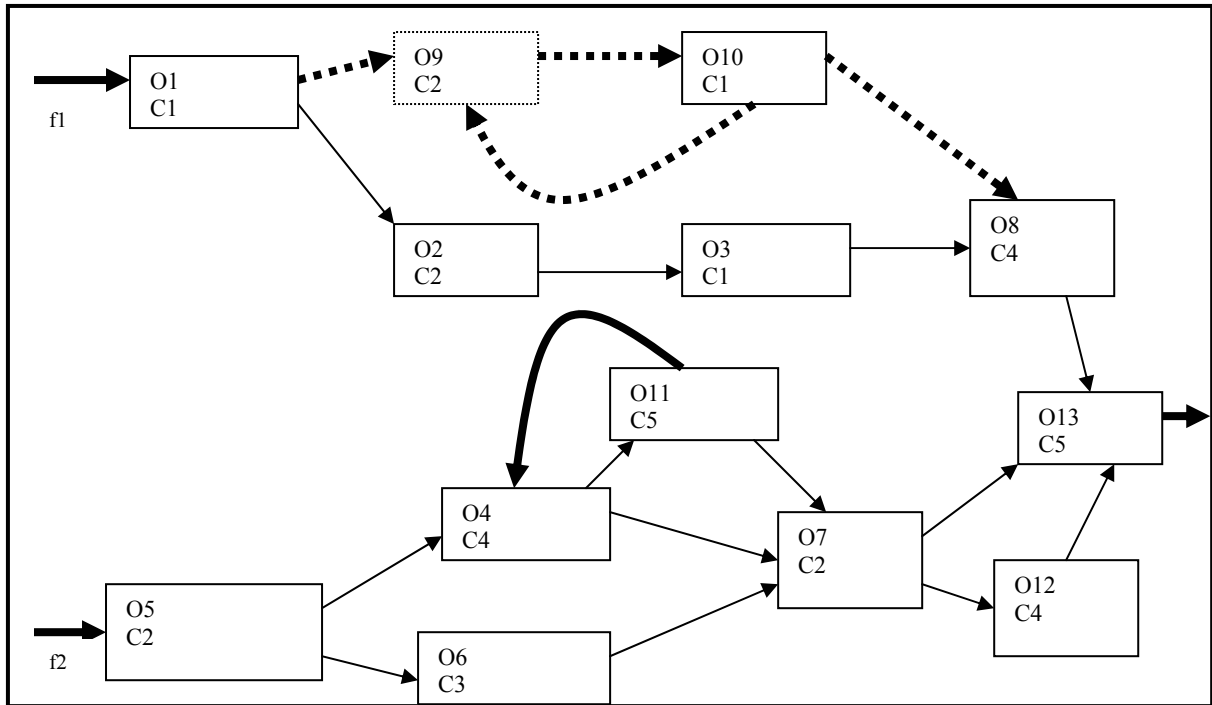
**In conclusion:**

- the option O9 and O10 will be deleted
- Operations O11 and O12 will be deleted (this action will induce the suppression of O13 and C5 as well as the second loop).
- The associated flows are deleted (improvement of model indicators)
- Operation O8 will be modified in order to capture the processes of O13
- Operation O4 will be modified in order to capture the processes of O11
- Competency C4 will be enhanced by adjunction of C5

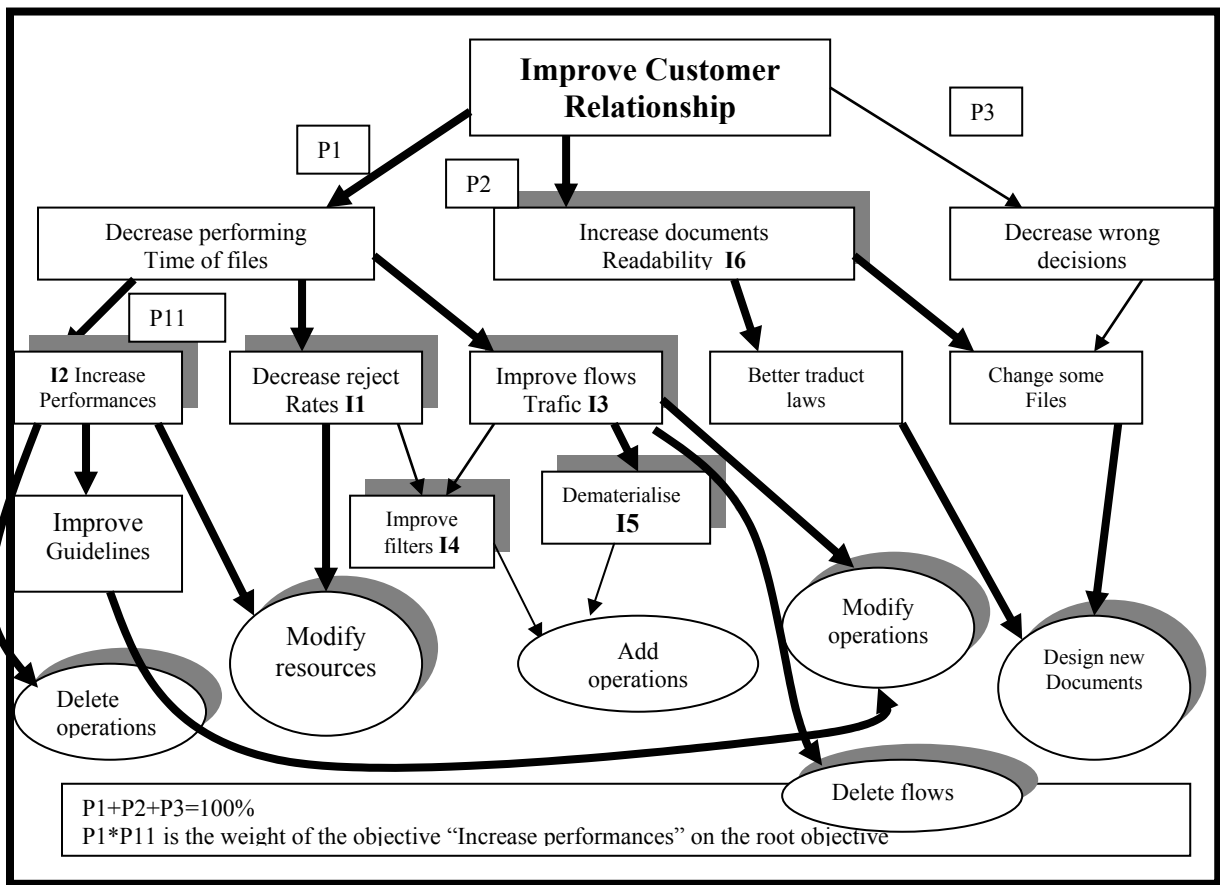
The new BP diagram, at the end of the conceptual optimisation step, is given in figure 8.



**Fig. 5: The conceptual optimisation step**



**Fig. 6: Example of BP to optimise**



**Fig. 7: Objectives graph**

**4 OPERATIONAL OPTIMISATION STEP**

This step consists in giving to each operation of a BP, resources and competencies, in order to **maximise** output flows. Actually, the final goal is to provide a **command tool** to predict the best resources affectation as possible,

by taking into account different hypothesis of degraded performing (for example absenteeism) as well as flows stocks (flows which have not been treated).

This third step is divided in two distinct issues:

**Issue 1:** Searching optimum of outputs flows (by an optimised affectation of resources and competencies to operations (**linear optimisation**)).

**Issue 2:** Locating resources and competencies on each operation **at the right time (non linear optimisation)**.

The BP to optimise is composed of 8 operations (A1, A2,..., A8) and 9 resources (R1, R2,..., R9) (see Fig. 8). The relationships between resources and competencies are given in Fig. 9, the stocks are given in Fig. 10.

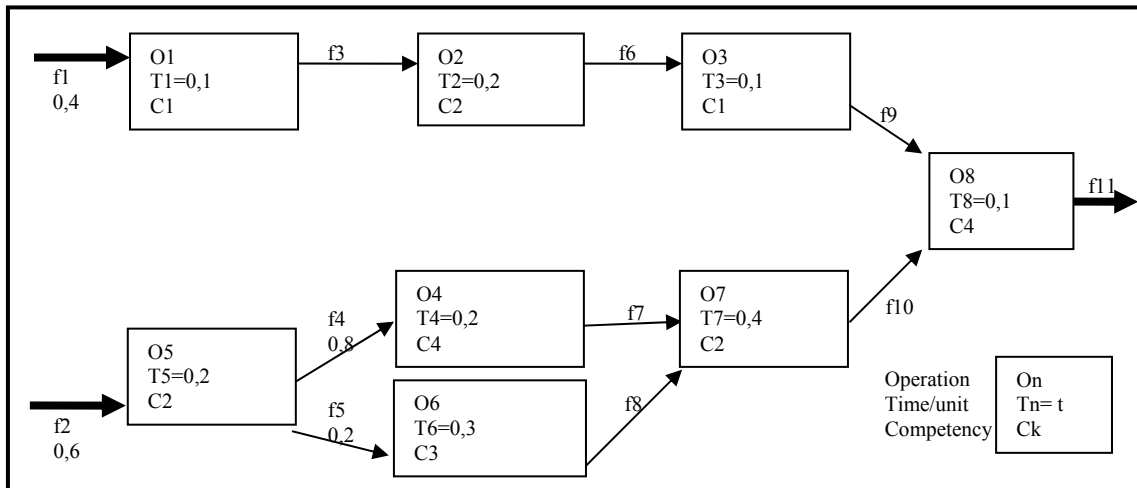
Let  $f_p$  be the number of units of flow  $p$  treated and  $w_{jk}$  be the used time of the resource  $R_j$  for its competency  $C_k$  (during the chosen period).

**Issue 1** consists in giving resources and competencies to each operation (by finding out optimal values of  $f_p$  and  $w_{jk}$ ) (who does what?) and in computing the maximum number of output flow units (which can be treated on the period).

The equations system to solve is following; it corresponds to using conditions of competencies on the period.

$$\begin{aligned}
 \text{Competency } C1 & T1*f3 + T3*f9 = w21 + w41 + w91 \\
 \text{Competency } C2 & T2*f6 + T5*(f4+f5) + T7*f10 = w12 + w22 + w62 + w72 + w82 \\
 \text{Competency } C3 & T6*f8 = w33 + w63 \\
 \text{Competency } C4 & T4*f7 + T8*f11 = w44 + w54
 \end{aligned}$$

The first legs of these equations are the total used time of competencies. For example, competency C1 which is used in operations A1 and A3 is engaged for a time  $T1*f3$  in A1 and  $T3*f9$  in A3. The second legs correspond to the used time of competencies in regards to resources. For example, competency C1 is provided for a time  $w21$  by resource R2, for a time  $w41$  by resource R4 and for a time  $w91$  by resource R9.



**Fig. 8: BP to optimise**

RESOURCE	COMPETENCY	AVAILABILITY/PERIOD
R1	C2	TR1=35
R2	C1, C2	TR2=35
R3	C3	TR3=35
R4	C1, C4	TR4=35
R5	C4	TR5=35
R6	C2, C3	TR6=35
R7	C2	TR7=35
R8	C2	TR8=17.5
R9	C1	TR9=17.5

**Fig. 9 : Table resources/competencies**

FLOWS	STOCKS
f1	29
f2	58
f3	6
f4	2
f5	6
f6	4
f7	4
f8	2
f9	4
f10	8
f11	0

**Fig. 10: Table of flows stocks**

These equations can also be formulated by using variables  $x_i$  (instead of variables  $f_p$ ),  $x_i$  being the number of times operation  $A_i$  is performed. Fig. 11 shows relationships between  $x_i$  and  $f_p$ .

$x_i$	$f_p$
$x_1$	$f_3$
$x_2$	$f_6$
$x_3$	$f_9$
$x_4$	$f_7$
$x_5$	$f_4+f_5$
$x_6$	$f_8$
$x_7$	$f_{10}$
$x_8$	$f_{11}$

**Fig. 11 : Table  $x_i/f_p$**

To solve the system we also have to take into account two types of constraints:

**Availability constraints of resources:**

For each resource, total used time should not be higher than available time. There are 9 constraints of this kind:

Resource R1:  $w_{12} \leq TR_1$       Resource R2:  $w_{21} + w_{22} \leq TR_2$       Resource R3:  $w_{33} \leq TR_3$   
 Resource R4:  $w_{41} + w_{44} \leq TR_4$       Resource R5:  $w_{54} \leq TR_5$       Resource R6:  $w_{62} + w_{63} \leq TR_6$   
 Resource R7:  $w_{72} \leq TR_7$       Resource R8:  $w_{82} \leq TR_8$       Resource R9:  $w_{91} \leq TR_9$

**Pouring constraints on flows:** Input and output flows can be multiple. To express that input flow  $f_2$  is appreciatively 60% of the total input flow ( $f_1+f_2$ ), we write one constraint on the flow from  $f_1$  and on the flow from  $f_2$ :  $f_2 \geq 1.4 * f_1$  and  $f_2 \leq 1.6 * f_1$ . To express that output flow  $f_4$  is appreciatively 80% of the total output flow ( $f_4+f_5$ ), we write one constraint on the flow from  $f_4$  and on the flow from  $f_5$ ; we write a similar constraint on the flows  $f_7$  and  $f_8$ :  $f_4 \geq 3.9 * f_5$  and  $f_4 \leq 4.1 * f_5$  /  $f_7 \geq 3.9 * f_8$  and  $f_7 \leq 4.1 * f_8$ .

For each operation, the sum of output flows has to be inferior to the sum of input flows :

$f_{11} \leq f_9 + f_{10}$ ,  $f_9 \leq f_6$ ,  $f_6 \leq f_3$ ,  $f_3 \leq f_1$ ,  $f_{10} \leq f_7 + f_8$ ,  $f_7 \leq f_4$ ,  $f_8 \leq f_5$ ,  $f_4 + f_5 \leq f_2$

**The solver provides values of  $x_i$ ,  $f_p$  and  $w_{jk}$  which optimise output flows. The results are given in the next 4 tables.**

RESOURCE		$\sum_k w_{jk}$	AVAILABLE TIME
R1	$w_{12} : 28$	28	7
R2	$w_{21} : 10.5$ $w_{22} : 21$	31.5	3.5
R3	$w_{33} : 17.5$	17.5	17.5
R4	$w_{41} : 3.5$ $w_{44} : 31.5$	35	0
R5	$w_{54} : 21$	21	14
R6	$w_{62} : 28$ $w_{63} : 3.5$	31.5	3.5
R7	$w_{72} : 31.5$	31.5	3.5
R8	$w_{82} : 17.5$	17.5	0
R9	$w_{91} : 17.5$	17.5	0
TOTAL		231	49

**Fig. 12: Table of competencies used time**

<b>Input flows</b>	
$f_1$	95
$f_2$	176
<b>Stocks</b>	123
<b>Total (input + stocks)</b>	394
<b>Output flows (<math>f_{11}</math>)</b>	280
<b>Non treated flows</b>	114

**Fig. 13: Flows results**

OPERATION	NUMBER OF RUNS	TOTAL PERFORMING TIME
O1	x1	96
O2	x2	102
O3	x3	35.6
O4	x4	120.4
O5	x5	148
O6	x6	35.6
O7	x7	162
O8	x8	280

**Fig. 14: Table of operations runs**

COMPETENCY	POTENTIAL	USED	AVAILABLE
Ck	Pck	Uck	Dck
C1	87.5	31.5	3.5
C2	157.5	126	17.5
C3	70	21	21
C4	70	52.5	14
TOTAL	385	231	56

**Fig. 15: Table of operations availability**

**Issue 2** consists in searching dated resources locations. (Who does what and **when?**).

For this reason, we have to split the period (35 hours in the example) in 10 slices of same length D (3,5 h in the example), and we have to find out quantities of resources to give to each operation in each slice.

For this issue, the system solving has to take into account 3 types of constraints:

**Exclusivity constraints on competencies:**

For each multiple competency resource, at most one competency is used in each slice. As we have 9 resources and 10 slices, we have 90 constraints of this kind. If we name  $\{C_{jk}\}_{k \in 1..p}$  the set of competencies associated to resource  $R_j$ , the constraint may be expressed in the following way:

$\forall$  (Resource  $R_j$ , slice  $t$ )  $\exists$  at most one  $k \in 1..p$  such that  $C_{jk}$  is used in slice  $t$ .

**Using constraints of resources in operations:**

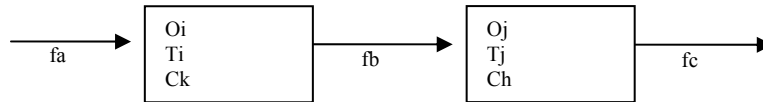
They are equality constraints. For each slice and for each competency, there is equality between quantities of competencies used by operations and quantities of competencies taken in resources. In the example, there are four competencies and 10 slices; we have then 40 constraints of this kind.

If we name  $\{a_{ik}(t)\}_{k \in 1..p}$  the set of used times of competency  $C_k$  for the operation  $A_i$  on the slice  $t$  and  $\{w'_{jk}(t)\}_{k \in 1..q}$  the set of used times of resource  $R_j$  for its competency  $C_k$  on the same slice, the constraint may be expressed in the following way:  $\sum_i a_{ik}(t) = \sum_j w'_{jk}(t)$

Where  $a_{ik}(t) = \alpha_{ik}(t) * D$ ;  $\alpha_{ik}(t)$  representing the number of times competency  $C_k$  is used for operation  $A_i$  on the slice  $t$  (that is the number of used resources).

**Evolution constraints on flows:**

We assume that flows evolve in a discontinuous way. After each slice, flows evolve in regards to resources provided to operations and available flows of the previous slice. Let's take a basic example:



**Fig. 16: Evolution of flows**

The formula which gives flow  $f_b$  after slice  $t$  is:

$$Flux(b,t) = Flux(b,t-1) + Min(Flux(a,t-1), \alpha_{ik}(t)*D/T_i) - Min(Flux(b,t-1), \alpha_{jk}(t)*D/T_j)$$

Where  $\alpha_{ik}(t)$  represents the number of times competency  $C_k$  is used for operation  $A_i$  on the slice  $t$ .

It is necessary to adapt this formula if operation  $A_i$  or  $A_j$  are preceded and/or followed by several operations.

An additional table is used to give quantities of input flows on each slice (in regards to the chosen arrival law).

during	slice1	slice2	slice3	slice4	slice5	slice6	slice7	slice8	slice9	slice10
input f1	15	21	15	8	8	8	8	6	4	2
input f2	32	58	14	14	12	11	12	10	10	3

**Fig. 17: Table of input flows**

The solver provides values of  $\alpha_{ik}(t)$  which optimise the repartition of resources and competencies on each slice and associated flows.

The table of Fig. 18 shows, the number of times  $\alpha_{ik}(t)$  competency  $C_k$  is used for operation  $A_i$  for the slice  $t$ . For example, on the first slice, three resources of competency  $C_2$  are given to operation  $A_5$  and on the fourth slice two resources of competency  $C_3$  are given to operation  $A_6$ .

OPERATION	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	COMPETENCY
O1	1	0	1	0	0	1	0	0	0	0	C1
O2	0	1	0	0	0	1	3	1	0	0	C2
O3	0	0	0	0	1	1	0	2	2	0	C1
O4	0	1	1	1	1	2	1	0	0	0	C4
O5	3	3	5	0	0	0	0	0	0	0	C2
O6	0	0	1	2	1	1	0	1	0	0	C3
O7	0	0	0	4	5	3	1	3	3	0	C2
O8	0	0	0	0	1	0	1	2	2	2	C4

Fig. 18: Table of competency/operation affectation for each slice

The table of Fig. 19 shows the number of flows units treated after each slice.

TREATED FLOWS UNITS	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
f1	15	36	16	24	32	8	16	22	26	28
f2	38	58	14	28	40	51	63	73	83	86
f3	35	18	53	53	53	67	15	0	0	0
f4	44	57	85	68	50	15	0	0	0	0
f5	17	24	24	1	0	0	0	0	0	0
f6	4	22	22	22	0	18	70	15	0	0
f7	4	22	39	31	25	40	47	21	0	0
f8	2	2	14	28	8	2	1	1	0	0
f9	4	4	4	4	23	23	15	71	38	0
f10	8	8	8	43	55	81	62	32	32	0
f11	0	0	0	0	35	35	70	140	210	280

Fig. 19: Table of flows units treated after each slice

The table of Fig. 20 shows, for each resource and each slice, the use of associated competencies. For example, on the first slice, resources R2, R6 and R7 are the three resources of competency C2 given to operation A5 and on the fourth slice, resources R4 and R5 are the two resources of competency C4 given to operation A6.

RESOURCE	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	
R1 (C2)	0	0	1	0	1	0	1	0	1	0	0
R2 (C1, C2)	0	1	0	1	0	1	0	1	0	1	0
R3 (C3)	0	0	0	1	0	1	0	1	0	0	0
R4 (C1, C4)	1	0	0	0	1	0	1	0	1	0	1
R5 (C4)	0	0	0	0	0	1	0	1	0	1	0
R6 (C2, C3)	1	0	1	0	1	0	1	0	1	0	0
R7 (C2)	1	0	1	0	1	0	1	0	1	0	0
R8 (C2)	0	0	0	1	0	1	0	1	0	0	0
R9 (C1)	0	0	0	1	0	1	0	1	0	1	0

Fig. 20: Table of used competencies and resources on each slice

The last three tables give the command diagram of the BP which makes it possible to pilot by defining for each slice, the optimal affectation of resources and competencies to operations.

Note: the tool « Premium Solver » was used for the operational step.

## 5 MULTI-BP OPTIMISATION STEP

As indicated by its name, multi-BP optimisation consists in optimising simultaneously several BP. Obviously, this step does not involve conceptual optimisation (which is, by definition, made on one BP, independently from the others) but only operational optimisation in the case where resources and competencies are shared by several BP.

If so, the persons in charge of the business processes have to define:

- 1- priorities between BPs and between objectives
- 2- constraints on resources and competencies which will be given to BPs and operations

For point 1, priorities will be listed in a decreasing order (example: for BP 1 / objective: to get 90% of input flows in output, BP 3 / objective: to get 75% of input flows in output,...).

For point 2, constraints will also be listed in a decreasing order. These constraints are of two kinds:

- To give a maximum quantity Q of resource R of competency C to one particular BP or to one particular operation (example: to give 20 units maximum of resource R2 to operation O3).
- To give in priority resource R or competency C to one particular BP or to one particular operation (example: competency C4 is dedicated in priority to BP2).

When priorities and constraints are defined, the solver can be run (one to N times) by deleting one by one constraints (from the bottom of the list) while objectives are not satisfied. The multi-BP optimisation step is, thus, a generalisation of the operational optimisation step, using the same tool and being done several times in a row. The final goal is to achieve a full and global command of all the BPs of the company.

## **6 CONCLUSION**

The optimisation method presented in this paper is composed of 4 steps: modelisation step, conceptual optimisation step, operational optimisation step, multi-BP optimisation step. Its originality consists in separating clearly issues related to modelisation and issues connected to optimisation. The first step (modelisation step) is necessary to model BPs under study and so necessary for the 3 others steps. The second one (conceptual optimisation step) make it possible to build the best BPs as possible, consistent and normalised (in regards to norms, objectives and indicators). It is an optional step, since it is not necessary to achieve operational optimisation. It is, though, strongly recommended because it is not very judicious to try to affect resources and competencies on a BP which is not correctly built. The third one (operational optimisation) is probably the main one. Its goal is to improve the performances and behaviour of BPs by optimising resources and competencies locations. The main advantage of this 2 steps optimisation is to improve BPs quality as well as better control their evolution.

This method was validated on administrative BPs. It also works on industrial BPs, under condition to take into account (during the operational optimisation) issues of breakdowns and maintenance of machines (by using complementary tools), issues which were not presented in this paper. This research is going to be extended by introducing data mining techniques in the conceptual step in order to find out more efficient optimising rules. We would like to thank the CNEDI 06 and more particularly M.P. Bourgeot who made this research possible.

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