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DESIGN OF VALUE CHAINS IN COMPANIES – AN INTEGRATED OPTIMISATION OF THE VALUE OF PRODUCTS AND PROCESSES

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Abstract

Value approaches in design and management have been widely adopted and applied in companies since the middle of the last century. The "value-oriented view" of a firm, well reflected by the concept of Value Chain considers a firm as a process of value creation consuming and transforming input values in order to provide clients and other stakeholders with output values. This view tries to study, analyse and control the value imbedded in the products and services designed and developed through the accomplishment of the set of activities composing the different firm processes. Therefore, it is interesting to translate this theoretical concept in a computerized qualitative/quantitative model that can provide managers and designers with a forecasting tool to simulate and to optimise the configuration of value chains in their companies and the value of their products.

The development of such a tool to simulate and analyse the whole value creation process necessitates the definition of the value components involved in the value model and the adoption of an approach to characterise stakeholders satisfaction and appreciation of the created value. This paper is an attempt to propose such a framework.

Keywords: Value chain, design options, preference aggregation, decision making aiding tool.

1. Introduction

Presently, companies evolve in an industrial environment influenced by large technical, economical and social mutations. In addition, they face an increased competition. Therefore, they are continuously in search of new methods and innovative tools helping them to control and improve the performance of their activities and to maximise the value they generate. Managers and designers need not only methods to control and assess the current state of the activities and the outcomes of their firms, but need also tools that help them to forecast the evolution of these performances in the future. Such tools facilitate comparison of different scenarios of evolution in order to evaluate different configurations of processes, and to select between alternatives.

The European standard EN12973 defines value as the relationship between the satisfaction of many different needs and the resources used in achieving so. Being in relation with different kinds of partners and stakeholders, a firm must do its best to satisfy the majority of their needs at the least cost.

Several approaches of performance evaluation and improvement are used by companies. For example, Value Engineering proposes methods and indicators to maximise the value of products, services or processes for their users [1]. Economic Value Added is a value measurement system aiming at maximising the value created for shareholders [2].

Activity Based Costing is an approach that tries to determine the real cost of an object (product, service, project…) by analysing the resources consumed by the activities involved in the fulfilment of this object [3]. Balanced Scorecard attempts to reflect an unbiased view of the different types of performances by adopting four perspectives: finance , customers, business processes, and learning and growth [4]. But each of the available methods doesn't offer a tool for a prospective, qualitative/quantitative value management, and a dynamic vision of value flows. In fact they may be too analytic and precise like Activity Based Costing and Balanced Scorecard and then does not allow to intervene early in a process. Moreover, Balanced Scorecard is based on a static representation of the company performances. Some methods may be dedicated to some specific fields or stakeholders like Economic Value Added dedicated to shareholders' satisfaction. Value Engineering considers the user's value but doesn't draw attention to the company activities and values.

On the other hand, the concept of Value Chain was developed as a tool for strategic analysis of value creation within a firm. Our purpose in this paper is to present an innovative model of value creation in companies, that is based on the concept of Value Chain, and that makes it possible to develop a tool for value improvement. This tool would be more qualitative and systemic than existing methods and would have a better prospective usefulness. By considering the different stakeholders (customers, the firm itself, the society, the ecosystem…) values and adopting an appropriate preference aggregation, this decision making aiding tool would allow designers and managers to simulate and compare the outcomes of different products and services design options, and scenarios of configuration and evolution of their value chains.

Section 2 deals with the value chain concept and presents our model of value chain in a firm, and section 3 shows simulation and optimisation possibilities allowed by the model developed.

2. The value chain model

2.1 The value chain concept

The value chain notion was developed by Michael Porter as a strategic tool for analysing and diagnosing value creation within companies [5]. The value chain decomposes a firm according to its diverse activities of design, production, commercialisation and distribution. A value chain and the manner in which activities are performed result from the firm know-how, from its strategy and from constraints imposed by various economical mechanisms. A competitive advantage results generally as much from the connections between the activities (by coordination or optimisation) as from activities themselves. A firm can adopt this framework to manage simultaneously the performance of the different activities, and the costs generated by these activities [5]. Hence, this framework allows designers to improve and to optimise the value of products during the early phases of their development.

2.2 Modelling the value chain

The value chain represents the set of activities performed in a firm. The level at which a firm's value chain can be defined is the "strategic activity unit", i.e. the level corresponding to activities aiming at serving a precise target: Providing goods and services over some identified market segments. That's why, the majority of firms, especially diversified ones, must simultaneously manage simultaneously a set of value chains serving various targets. Obviously, these chains are not totally independent because they share the firm resources, means of production, and organisation, and because they have interconnections which are the common activities. This paper doesn't treat the simultaneous management of a set of value chains within a firm. It just considers the management of a unique value chain.

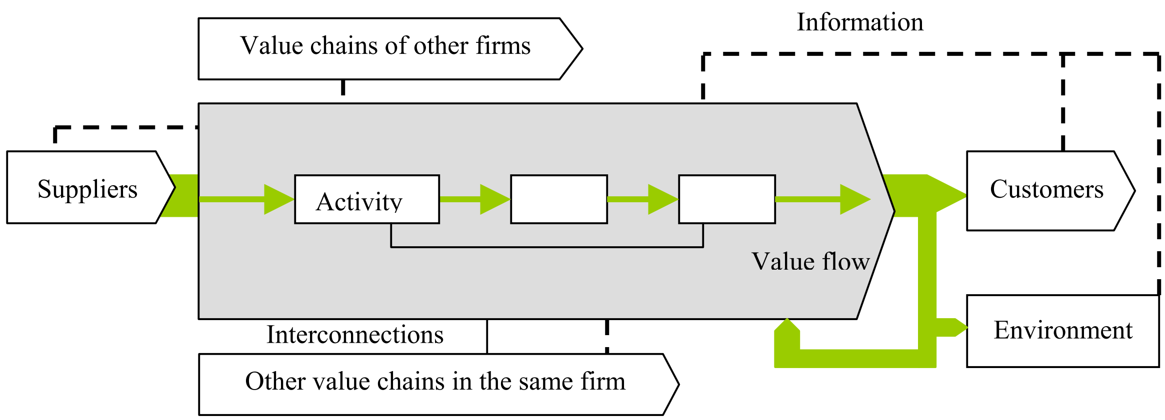

Figure 1. Value chain context

Figure 1 represents the context in which a specific value chain (one of the different value chains of a firm) can be considered. The entities presented in this scheme are the following: The specific value chain, activities making up this value chain, the other value chains of the same firm, suppliers' and customers' value chains, and value chains of other firms. The links between these entities are the following:

- Value flows: In our model, we adopt the hypothesis that the product/service value is built along the different value chain activities. Roughly, one considers that a composite value (composed of different kinds of values: For customers, for environment, and for the firm itself) circulates along flows and is transformed after each step (activity). Value flows help also designers to have an insight of the phases of the development of their products. The firm has to continuously improve the configuration of its value chain in order to optimise the different kinds of values created for the different stakeholders.
- Interconnections: They are links between different activities, that reflect value influences. In fact, in several cases, the manner an activity is achieved may influence the performance or the cost of another activity. For example, the design of a product or a process has an impact on manufacturing and transportation activities.
- Information flows: In addition to internal information flows between activities, the management of a value chain and the design of products and services, especially innovative ones, necessitate to take stakeholders needs and satisfaction criteria into account. This is essential since stakeholders are the value demanders, users, and assessors. Information helps the firm to estimate the value gap registered between stakeholders expectations and their actual satisfaction in order to increase an aggregated value [6].

2.3 Generic modelling of value in companies

In this section, we describe our proposition of a "value-oriented view" of an inner representation of a company. The value components of a company are *value resources*, *value transformers*, and *value flows* interconnecting them. Value resources are value wells representing the wealth on which the different value creation process stages are based. This capital can be either material or immaterial. Material value is incorporated in physical and financial assets possessed by the company. Immaterial value is the intellectual capital reflected by the management and organisation aspects that condition the exploitation of material value resources and that are embedded in members of the company and within the routines of its organisation [7].

Value transformers are the company activities. An activity has input value flows that it transforms into output ones. The capability of an activity to modify, create, increase or decrease some value aspects depends on its "value potential". This potential is defined by intrinsic features of the activity itself, is related to its effectiveness and performance, and results into benefits and costs. It is also modulated by information and controls received through the interconnections this activity has with the other value components of the company.

Figure 2 represents a simplified value chain of a firm producing freezers. Only main resources, activities, and value flows are represented.

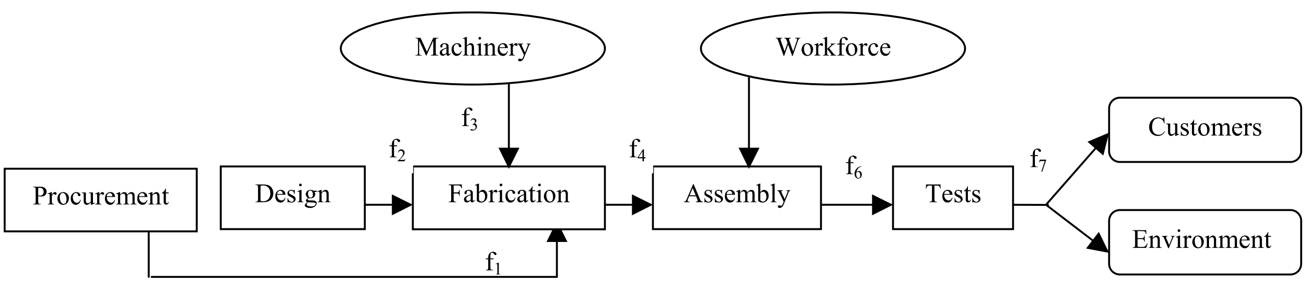

Figure 2. A value chain example

As we try to develop a model that enables us to simulate and optimise value creation, we have to adopt a method for representing and measuring value. Our starting point is the definition of value given by the European Standard EN12973. Value is defined as the relation between the need satisfaction and resources used to attain this satisfaction. In our model, value transported by a value flow is represented by a vector of satisfactions (advantages, services, functions, benefits…) versus a vector of costs (efforts, resources consumed, investments, time…). The recourse to the representation by vectors is due to the multidimensional nature of value, even when evaluated by a unique stakeholder.

The definition of value indicators is guided by the strategy and the objectives of the firm [7]. The stakeholders' satisfaction is evaluated relatively to these objectives. To characterise these objectives, we adopt a functional approach. Every objective is considered as a function that the value chain must fulfil. For every specified stakeholder i, $i = 1..n$, a set of functions reflecting its needs is defined. These functions are characterised by a set of criteria $Cr_{i,j}$ ($j = 1.. k_i$, k_i being the number of criteria relative to stakeholder i).

Therefore, our composite value is, more precisely, characterised by:

- A satisfaction vector whose components are the degrees of closeness between the targeted values of the functional criteria and their current values.

- A cost vector, having the same dimension as the first vector, and whose components correspond respectively to costs spent to reach the satisfaction levels reflected by the first vector.

Then, the value vectors are:

$$\textit{Satisfaction vector} \qquad S = (S_{1,1}, \ldots, S_{1,k_1}, \ldots\ldots\ldots, S_{n,1}, \ldots, S_{n,k_n})$$

$$\textit{Cost vector} \qquad C = (C_{1,1}, \ldots, C_{1,k_1}, \ldots\ldots\ldots, C_{n,1}, \ldots, C_{n,k_n})$$

where $S_{i,j}$ is the degree of closeness between the targeted value of criterion $Cr_{i,j}$, and its obtained value. $C_{i,j}$ is the cost spent to reach this degree. To estimate these degrees of closeness, we adopt the approach recommended by the utility theory [8]: Considering every criterion, we attribute for its possible states appreciation ranks going from 0 to 1. The rank 1 is attributed to the targeted value. Defined so, the appreciation rank of an obtained value of a criterion represents its degree of closeness to the targeted value.

In the case of our example described by figure 2, functions and related criteria are given in table 1.

Table 1. Criteria of stakeholders' satisfaction

Stakeholder	Function category	Criterion
Customers	Usage	Cr_1: Technical effectiveness
		Cr_2: Liability
		Cr_3: Volume
	Esteem	Cr_4: Aesthetic appearance
	Financial	Cr_5: Acceptable price
Environment	Consumptions	Cr_6: Material consumption
		Cr_7: Energetic consumption
	Nuisances	Cr_8: Emissions and waste
		Cr_9: Reuse

Such a representation of value flows allows us to see the contribution of the different resources and activities to value creation for the different stakeholders. We can also analyse the influence of the modification of the features of these components on the value creation process.

A first aggregation of satisfaction and cost vectors elements relative to the stakeholders yields to the following: $S = (S_1, \ldots, S_n)$ and $C = (C_1, \ldots, C_n)$, where $C_i = \sum_{j=1}^{k_i} C_{i,j}$, $i = 1..n$, and $S_i = A_{S_i}(S_{i,1}, \ldots\ldots, S_{i,k_i})$, A_{S_i} being an aggregation function of the satisfaction of stakeholder i. A_{S_i} can be for example a linear weighting by importance coefficients. In this case, one gets: $S_i = \sum_{j=1}^{k_i} I_j S_{i,j}$ with I_j being the importance of criterion j for stakeholder i.

We can go further and represent by a scalar V_i the value created for stakeholder i. Then, our vectors are melted in a unique one: $V = (V_1 , \ldots, V_n)$ where $V_i = R_i (S_i, C_i)$, R_i being the adequate relation chosen to define the value for stakeholder i from corresponding satisfaction and cost. Some specialists, especially value engineering ones, consider this relation as a "functional productivity ratio" (S_i/C_i), whereas some others prefer considering it as a subtraction [9]. This latter relation can adopt one of the two following forms: $V_i = F_i\ (S_i) - C_i$, or $V_i = S_i - G_i\ (C_i)$, where F_i is a function that translates satisfaction into financial terms, and G_i is a function converting cost into satisfaction terms. The use of the subtraction relation is suitable for manipulating notions like added or reduced value, and is coherent with the additive logic of the value chain concept.

We know that the accomplishment of satisfaction targets is performed through the different activities involved in the development and the production of the product or the service. It is also based on the value resources sustained by the company. So, in our model, we suppose that the accomplishment of a target concerning a criterion necessitates and is performed theoretically by an addition of activities and resources *contribution rates*, that are comprised between 0 and 1. We are aware that our model borrows the same strong hypothesis of additive contributions than in the utility theory [8] and that such an hypothesis may be questionable.

If $K_{r,i,j}$ indicates the contribution rate of resource r to the accomplishment of the target concerning the criterion $Cr_{i,j}$, and $K_{a,i,j}$ indicates the contribution rate of the activity a, then:

$$\sum_{r\in\{resources\}} K_{r,i,j} + \sum_{a\in\{activities\}} K_{a,i,j} = 1 \tag{1}$$

Since an activity may have several output value flows, then its contribution rate must be partitioned over these flows. If $K_{a,i,j,fo}$ indicates the activity a contribution that is assigned to the output flow fo, then:

$$\sum_{fo\in\{a\_output\_flow\}} K_{a,i,j,fo} = K_{a,i,j} \tag{2}$$

The contribution rates are theoretical and describe an ideal resource or activity quality. To take practical conditions into account, we define a *quality rate*, comprised between 0 and 1, that describes for a resource or an activity its quality level, i.e. its capability to achieve its theoretical value contribution. So, the real contribution of a resource or an activity to reach an objective relative to a criterion $Cr_{i,j}$ are respectively:

$$T_{r,i,j} * K_{r,i,j} \text{ or } T_{a,i,j} * K_{a,i,j}$$

We consider quality rates as value chain parameters. The trade-off between quality levels and costs they generate can reflect a choice between a set of materials, equipments or processes.

An activity is described by its input value flows, its output value flows, and calculation rules defining the output flows. These rules are of the following form:

$$S_{fo,i,j} = \sum_{fi\in\{Input\_flows\_contributing\_to\_fo\}} S_{fi,i,j} + T_{a,i,j} * K_{a,i,j,fo} \tag{3}$$

$$C_{fo,i,j} = \sum_{fi\in\{Input\_flows\_contributing\_to\_fo\}} C_{fi,i,j} + C_{a,i,j,fo} \tag{4}$$

Equation (3) indicates that for activity a, on the output flow fo, a criterion $Cr_{i,j}$ satisfaction level is the sum of the input levels corresponding to this criterion, to which we add the contribution of the activity that is assigned to fo. Equation (4) indicates that the corresponding cost is calculated in an analogous way.

3. A case-study of value chain simulation and optimisation

Our model being linear, the optimisation of the value chain parameters can be modelled as a linear program. Let us deal with the example given beforehand to show how such a model can be exploited to optimise the configuration of a value chain.

Our case study comprises two value resources R_1 and R_2, five activities $A_1 ... A_5$ and two stakeholders P_1 (customers) and P_2 (environment). We have nine satisfaction criteria and seven value flows. The value vectors transported by every value flow f_l are:

$$S^l = (S^l_1, \dots , S^l_9) \text{ , and } C^l = (C^l_1, \dots , C^l_9).$$

The contribution rates to the achievement of the satisfaction objectives are given in table 2.

Table 2. Contribution rates of resources and activities

	Criteria	Cr_1	Cr_2	Cr_3	Cr_4	Cr_5	Cr_6	Cr_7	Cr_8	Cr_9
R_1	Machinery	0	0.1	0	0.1	0.2	0.1	0.2	0.1	0
R_2	Workforce	0.1	0.1	0	0.1	0.1	0.1	0.1	0	0
A_1	Procurement	0.1	0.1	0.5	0.1	0.3	0.2	0.1	0.3	0.6
A_2	Design	0.2	0.3	0.5	0.5	0.2	0.3	0.1	0.2	0.2
A_3	Fabrication	0.3	0.2	0	0.1	0.1	0.1	0.2	0.1	0.1
A_4	Assembly	0.2	0.1	0	0.1	0.1	0.1	0.2	0.2	0.1
A_5	Tests	0.1	0.1	0	0	0	0.1	0.1	0.1	0
	Total	1	1	1	1	1	1	1	1	1

The composition rules of the satisfaction levels and the costs related to the satisfaction criteria Cr_i, $i = 1..9$, conveyed on the value flows are such as the following:

Flow f_1	$S^1_i = T_{A1,i} * K_{A1,i}$	*and*	$C^1_i = C_{A1,i}$
Flow f_4	$S^4_i = S^1_i + S^2_i + S^3_i + T_{A3,i} * K_{A3,i}$	*and*	$C^4_i = C^1_i + C^2_i + C^3_i + C_{A3,i}$
Flow f_7	$S^7_i = S^6_i + T_{A5,i} * K_{A5,i}$	*and*	$C^7_i = C^6_i + C_{A5,i}$

Quality rates and cost levels for resources and activities are our model variables. For resources, cost levels and quality rates are described by correspondences such as the following ones:

	Cost levels	*Respective quality rates*
$C_{R1,2}$ *and* $T_{R1,2}$	*9, 8, 6*	*0.9 , 0.7 , 0.5*
$C_{R1,6}$ *and* $T_{R1,6}$	*6, 5, 4*	*0.8 , 0.7 , 0.5*

For activities, rules linking cost levels to quality rates are similar to the following ones:

$$C_{A1,3} = 1 + 5 * T_{A1,3}$$
$$C_{A1,5} = 1 + 10 * T_{A1,5}$$

Implemented on the Excel software, our model basically permits to calculate and apprehend value flows subsequent to a fixed choice of quality rates and cost levels of value resources and activities. The second usage of our model is the optimisation of the value chain configuration.

The objective may be the maximisation of a combination of some satisfaction criteria, of the value created for one of the stakeholders, or the minimisation of costs induced to satisfy one of the stakeholders. The constraints may be a maximum budget allowed to a given resource or a given activity, or a maximum limit on costs spent to satisfy a given or a set of stakeholders, or some inferior bounds imposed on some quality rates or on some final satisfaction levels relative to some specified criteria. Then, the decision variables to concomitantly optimise are the quality rates and the cost levels. For example, in our case we have resolved the following problem:

Maximise $$S_{flow7} = \frac{2}{3}\times\frac{1}{5}\sum_{i=1}^{5}\mathrm{S}_{\mathrm{i},7} + \frac{1}{3}\times\frac{1}{4}\sum_{i=6}^{9}\mathrm{S}_{\mathrm{i},7} \qquad (5)$$

Subtract to $$C_{Environment,\, flow7}\left(= \sum_{i=6}^{9}\mathrm{C}_{\mathrm{i},7}\right) \le 150\ € \qquad (6)$$

$$\sum_{i=1}^{9}\mathrm{C}_{\mathrm{R1,i}} \le 80\,€, \qquad \sum_{i=1}^{9}\mathrm{C}_{\mathrm{R2,i}} \le 60\ € \qquad (7)$$

$$\sum_{i=1}^{9}\mathrm{C}_{\mathrm{A2,i}} \le 70\,€, \qquad \sum_{i=1}^{9}\mathrm{C}_{\mathrm{A5,i}} \le 50\ € \qquad (8)$$

Objective function (5) that we want to maximise is the aggregated satisfaction of the customers and the environment. Constraint (6) shows the maximum accepted cost for the satisfaction of environmental needs. Constraints (7) reflect the maximum budgets allocated to resources R_1 and R_2. Constraints (8) reflect the maximum budget allocated to activities A_2 and A_5. Additionally, the problem includes 13 other constraints of the type $T_{A,i} \in [T_{min}, 1]$. These latter constraints reveal lower bounds on certain quality rates.

Table 3. Satisfaction criteria fulfilment

	Stakeholder	Customers					Environment			
Activity	Value flow	Cr_1	Cr_2	Cr_3	Cr_4	Cr_5	Cr_6	Cr_7	Cr_8	Cr_9
Design	f_2	0,00	0,30	0,00	0,45	0,20	0,00	0,08	0,20	0,20
Fabrication	f_4	0,30	0,55	0,50	0,68	0,72	0,37	0,50	0,52	0,80
Assembly	f_6	0,59	0,74	0,50	0,83	0,90	0,56	0,57	0,66	0,80
Tests	f_7	0,69	0,83	0,50	0,83	0,90	0,65	0,57	0,66	0,80
Stakeholder’s satisfaction		0.75					0.67			
Corresponding cost		172					150			
Aggregated satisfaction		0.72								

We have considered as variables only 8 resources cost levels (and their corresponding quality rates), and 13 activity quality rates (and the corresponding cost levels), and we have maintained unchanged the other value chain parameters. To resolve the problem, we used the Excel software Solver, which employs the Simplex method. The optimisation results are an aggregated satisfaction level equal to 0.72. Table 3 shows the progression of the fulfilment of the satisfaction criteria along the value chain, obtained with the optimal configuration.

4. Summary, conclusion and perspectives

Value management is a promising approach to assess and ameliorate both product and process design. It is important for managers to have a clear view of the different value components available in their firms. In this paper, we presented a generic model of value chain.

Describing value with a double vector form, on one hand, we emphasise the multidimensional feature of value especially when we take several stakeholders that the firm wants to satisfy into account. On the other hand, we consider that value is satisfaction levels versus costs spent to achieve these levels. Using a value flow model based on this representation, we can optimise a value chain configuration and therefore the value of a firm products and services.

Comparing our model to the Balanced Scorecard approach, we see that common points are the junction of different perceptions of the created value relatively to different perspectives, and the adoption of value indicators to control the different activities. Our model permits to consider the requirements of as much stakeholders as needed by designers to optimise the configuration of products and services developed and by managers to adequately tune their firms. Besides, our model doesn't regard the different activities independently as can be done by a set of separate Scorecards attached to these activities. In fact, our model tries to consider the value flows linking the activities in order to visualise the different stages by which the value creation passes while the product is treated along the value chain, and the actual contribution of each activity. Moreover, another advantage of our model is the optimisation possibility that it offers. On the other hand, the Activity Based Costing approach aims at determining the real costs of products by analysing the activities performed and the resources consumed to obtain these products. But, this is only one side of value, our model's ambition is to allow designers to manage satisfactions and corresponding costs.

Our first perspective of further development is to better model possible evolutions of activities and their impacts on design and management efficiency. Indeed, when some actions are implemented in the company so as to make evolve an activity efficiency, different variables of our model are impacted in a correlated manner. First, for a given action, the *contribution rates* of the activity may be changed (not considered here). Moreover, any combination of the *quality rates* inside an activity must not be permitted because these *quality rates* are more likely to evolve correspondingly.

Our model lays upon two main simplifying hypotheses that can be limiting and questionable. The first hypothesis is the possibility to split up the value created in an analytical way so that we can compute the contribution of each activity or resource to every satisfaction criterion and to the corresponding cost. Since accessible costs are generally those of activities, the possibility of isolating costs spent to satisfy precisely a given satisfaction criterion isn't straightforward. To overcome this difficulty, we propose to gather the activity managers for assessing the cost contributions to the satisfaction criteria changed by the activity. For such a purpose, a well known technique of Pairwise Comparison is helpful; for example, the *Least Squares Logarithmic Regression* method is adapted [10]. Additionally, the operational deployment of our approach needs to develop appropriate users' interfaces and methods of cognitive extraction to help managers to feed such a system with pertinent required data. If properly implemented, such a system would represent a decision making aiding tool that permits to compare design options in multi-attribute judgement problems.

Another shortcoming of our model stands in the consideration of activities which are the core sites of value creation as additive or linear processors. This concept of value processors requires much additional research concerning the adequate modelling of activities performed in a company. Another focus subject is the possibility of integrating the time dimension and of modelling the value chain dynamics. Since we are interested in the study of the temporal evolution of the value chain's configuration and outcomes, and in considering the value process feedback materialised especially by the value created by the firm for itself which implies changes in value components features and effectiveness, we believe that Forrester's System Dynamics [11] could be a promising research track. An extension of the SD semantics drew our attention: This is the *Kinetic Process Graphs* approach by Lefèvre [12] thanks to its ability to model in a powerful and parsimonious way complex composite flows of conservative materials accompanied by non-conservative value variables.

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