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INTEGRATION OF BENCHMARKING AND BENCHMARKING OF INTEGRATION

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Benchmarking is an approach used for evaluating and improving the company performances, by comparing them with the best performing companies. Benchmarking first studies the process to be improved, finds a best practice process in order to try to match two parts of the processes which have analogies, and then tries to change or modify the interconnections, structures or behaviour of the part to be improved using the analogy with the best trasformation process. In the paper, we try to define different types of benchmarking, and, in particular, organizational benchmarking. The decision making process and its link with the value of a set of performance indicators, suitably depicting the company's behaviour, is a cornerstone of the benchmarking building. In this framework we define the process that can be used to transform performance evaluation into improvement decisions.

Keywords: Benchmarking, performance improvement, optimization.

1. INTRODUCTION

There are several definitions of benchmarking, all based on the idea of evaluating the performance of an organized system by comparing it to exogenous entities.

The Webster dictionary defines a benchmark as: "A mark on a fixed and enduring object (as on an outcropping of rock or a concrete post set into the ground) indicating a particular elevation and used as a reference in topographical surveys and tidal observations. A benchmark is thus a point of reference from which measurements of any sort may be made."

In a business context, D.T. Kearns, executive director of Xerox Corporation, defines it as: "The continuous process of measuring products, services and practices through the comparison with its strongest competitors, with companies leaders in the field".

A definition that tries to include all these different aspects can be:

continuing search, measurement and comparison of products, processes, services, procedures, ways to operate, best practices that other companies have developed to obtain an output and global performances, with the aim of improving the company performances.

The concern about performance evaluation has always existed in corporations, and has traditionally been realized on historical basis (by comparing the performance to the one of the year before) and, sometime, on competitive basis (by comparing the company to a competitor). Only in recent times some attention has been devoted to a comparison made on a functional basis, by comparing similar functions in different companies or, in general, activities, relevant for the company performance, that are similar from a functional point of view, but deal with completely different transformation processes.

The origin of benchmarking can be seeked in different sectors, where these concepts have been developed indipendently, with scarce interactions. Manufacturing processes, data processing systems, accounting systems, and company practices, have had, in this context, a particular relevance.

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1.1 Manufacturing processes

With the beginning of the 20-th century, managerial problems in production became more and more relevant, in comparison to purely technological problems. Prescriptive and planning systems were developed, generating the birth of standard costs, budget, personnel. Taylor's *scientific management* is based on a set of performance indicators, continuously measured, compared and updated. The first manufacturing flow line, the moving assembly line, introduced by Ford in the Highland Park plant (completely operational in 1916, after several years of gradual introduction of conveyor belts and gravity feeders), is credited to be inspired from a visit to a Chicago abattoir plant in 1911. In this plant, the material handling system has been for a long time organized in a flow line, formed by a sequence of dedicated working cells. This layout transfer represents a classical benchmarking process. During the first world war, with the development of statistics, the first set of reliable performance measures are created. These measures introduce the concept of performance standards, emphasizing the importance of comparisons among different productive enviroments contexts. More recently, the development of total quality approach led to a finer performance's measurement system, in order to compare different situations in production and to find adeguate improvements. The growth of integrated and flexible manufacturing systems, characterized by the capacity to adapt to time-variable situations, brought to an increasing complexity in performance evaluation and decision strategies' definition. Conceptual models for evaluation and decision support become more and more complicated and require an always wider technological know how on the system to be used. Thus, synthetic conceptual models like benchmarking help to tackle with complex systems.

1.2 Data processing systems

In order to measure performance in data processing systems, from the very beginning of computer studies, evaluation tools based on benchmarking concepts were developed. In fact, although the value of a computer depends on the context in which it is used, and that context varies by application, by workload and in terms of time, nevertheless benchmarking is the basis of the computer performance evaluation process. The measurements of some main parameters of the machines (such as cycle time, response time, memory size, overall computer speed etc.) and of the way of using them (work charge, throughput, execution of predetermined programs) take place on the basis of predetermined standards and allow detailed comparisons between the efficiency of different machines. More complex is the problem of measuring effectiveness with respect to a given class of applications, that is to say the responsiveness of the processing system to the users' requirements. The performance measurement issue has been studied both for standalone computers, heterogenous systems and networks. More recently the issue of finding significant and comparable measures for machines with massive parallelism has been analysed.

1.3 Accounting systems

Performance indicators actually used by corporations for budgeting refer to standards that are determined on extrapolations of the past. Without a comparative analysis of more advanced industrial practices and a consequent effort to meet those standards, the progress of productivity is gradual, evolutional, pursued only to the level seen as acceptable for the organization. A company's productivity is reached gradually, by improving every time the worst working parts of the processes. In today's more dinamic context, where more and more attention is given to continuous improvement, there is less corrispondence between "measurement for control" and "measurement for improvement". Besides new criteria and tools for performance measurement, defining measures for improvement requires benchmarking studies, to determine the real standards, those which quantify the best practices and the best companies.

1.4 Marketing

In marketing, tools for cross-company comparisons have always existed.Market research traditionally analyses company markets and market acceptance of products, in order to determine how customers' needs are satisfied with products and services. Competition analysis becomes of central importance in this context, studying competitors' strategies to define market activities for products and services. In their continuous search for new arguments to improve competitiveness of their products and services, marketing managers have always looked for parameters to compare their products with the competittors. In many countries ethical codes have been defined on what is fare and what is'nt of publishing results on comparative experiments.

1.5 Business practices

In business activities benchmarking techniques have remained at a larval state. No attempt to have a systematic comparison with other business realities was made: generally also the natural consequences in terms of organizational changes were not performed. One of the first and most interesting benchmarking experience promoted systematically by Xerox involved L.L.Bean as the benchmarking partner.)

In summary, benchmarking deals with *what* (identify analogous process parts, i.e. subchaines), *why* (identify performance indicators) and *how* (identify the new organization: interconnections, structure or behaviour of the part to be improved), practices of leader companies, having conquered leadership positions, can be transferred.

This is represented in the following chart.

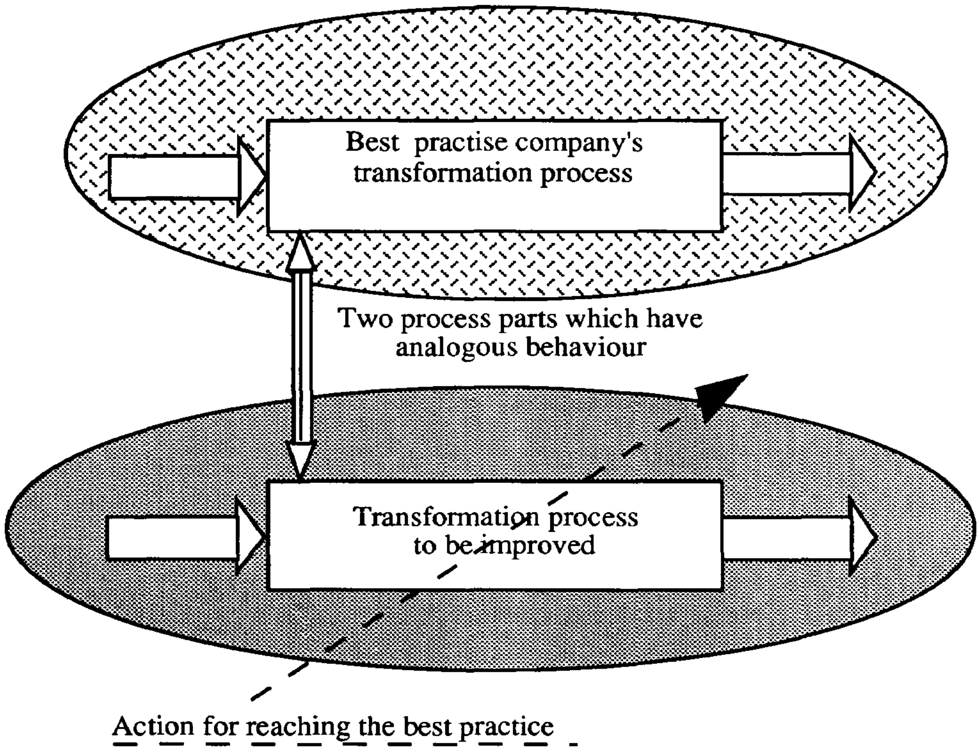

Figure 1: Identification of analogous process parts.

2. THE DECISION PROCESS

Benchmarking is a tool directed to implement change, more then a tool for merely evaluating company performances. The decision making process and its link with the value of a set of performance indicators, suitably depicting the company's behaviour, is then a cornerstone of the benchmarking building.

The field measures are taken in particular points of the system, suitably related to the transformation process considered, and are process quantities (flows and levels). On the other hand, performance indicators are defined on the basis of measures taken in different parts of the systems, at different times or time intervals, and adeguately elaborated. Typical performance indicators are: effectiveness, efficiency, productivity, quality of work-life, innovation, profitability (or budgetability), quality.

In this framework, it is therefore important to define company goals in order to determine what and where to measure, which are the right indicators and how they relate to measurements. To put together goals, measures and performances you need a conceptual model of the transformation process, that can be used to transform performance evaluation into improvement decisions.

In practice, company decisions lie on different levels, and benchmarking focuses only on certain types of decision, that we may call of intermediate level.

These decisions do not concern, typically, basic company strategies, such as market selection, process selection, joint ventures, basic make or buy decisions.

In the same way, these decisions do not concern, typically, operational decisions, such as material routing and operations scheduling.

Benchmarking decisions focus on a tactical level, where you can modify organizational constraints, procedures and practices. We have had examples of this in physical material handling, distribution systems, assembly lines, production layout.

Using decision models' language, we may characterize the three levels, from operational to strategic, as follows:

<u>Operational level</u>
<u>Given</u>: environment, operational conditions, different types of technological and organizational constraints, a univocally defined objective function,...
<u>find</u>: the value of decision variables directly connected to the process,
<u>such that</u>: the performance will be optimized (throughput maximization, lead time minimization, ecc.)

<u>Tactical level</u>
<u>Given</u>: environment, structural constraints difficult to modify, a set of performance indicators,
<u>find</u>: operational constraints, information flows, operational procedures and the value of decision variables,
<u>such that</u>: to obtain good solutions.

<u>Strategic level</u>
<u>Given</u>: environment, some structural constraints, a set of interconnected decision centers, a set of basic resources and one or more strategic goals,
<u>find</u>: how the company should be organized,
<u>such that</u>: the profitability of investiments will be maximized.

A first set of decisions concerning organizational contraints are usually the connections between input resources, activities and output resources. Notice that this is the framework for activity based costing analysis.

At this point we have to define the relations amongst activities, such as precedence constraints, concurrency, etc.

Given the resource/activity connections and the relations amongst activities, we can define the resource allocation process and plan our activities in time.

The activities can either be the output of a decision making process involving men (organized in different decision centers), machines and informations, or the output of an automatic system of decision rules, producing the actions on the ground of a set of measures of the state of the field and, if it is the case, the value of a set of parameters.

The set of decisions produced automatically and the effectiveness of the decision rules are a crucial point for the effectiveness of the whole system.

3. THE OPERATIONS BREAKDOWN TREE AND THE FOUR BENCHMARKING MODELS

An operations breakdown tree is a good model for representing company decisions.

Let P be a given process which transforms, in a suitable time interval, a given input in a given output. P is composed by a set of interdependent operations.

Let U' and U" be the sets of organizational units (*ou*) in charge of performing the process P in two different companies C' and C".

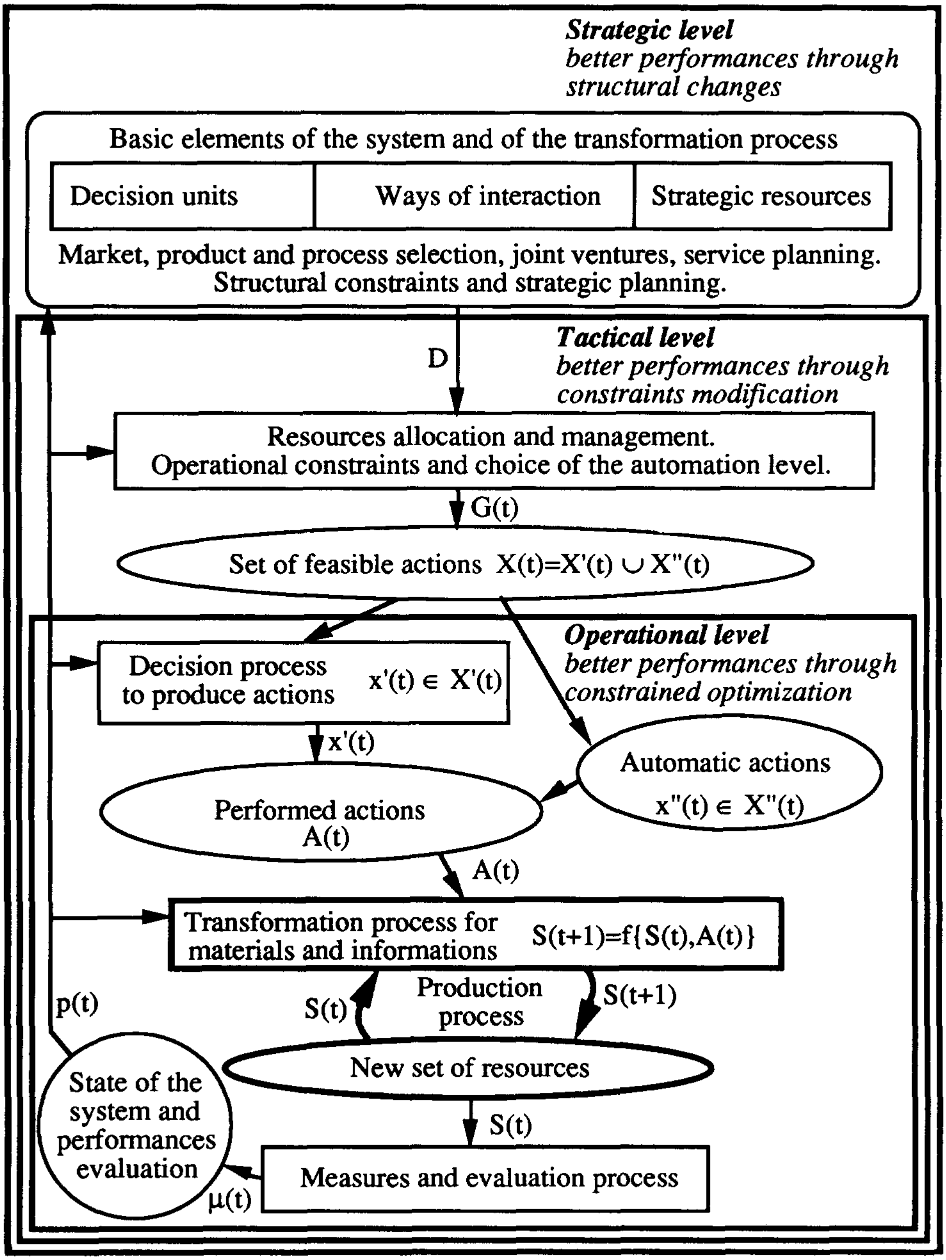

Figure 2: Decision level model

For benchmarking, we assume the point of view of company C' and we will use company C" as benchmarking partner; in fact, benchmarking is not a design from scratch of a process, but a redesign based on the transfer of processes existing in other companies.

The nodes of each tree belong to three different types: process nodes, logistic nodes and network nodes.

Let T' and T" be two operations breakdown trees (*obt*) of P.

Process nodes correspond to all the different phases of the transformation process at different levels of aggregation: the root and all internal nodes are process nodes, the leaves corresponding to *ou* in charge of transformation of materials or informations are process nodes.

Notice that, in order to simplify the presentation, in this paper we assume that, for each *ou* there is a corresponding leaf of the tree, that performs the set of operations assigned to the *ou*.

For some types of organizational analysis a more detailed breakdown, where the leaves correspond to elementary operations, would be more adeguate.

Logistic nodes are always leaves and correspond to activities which perform support operations (such as: manutenability, general services, material handling), enabling process nodes to operate effectively.

The term logistic is here used as a paradigm of all support operations which are in common to several *ou*..

There are no interactions among different logistic nodes, i.e. each logistic node is the unique node producing a given set of support services.

There are interactions between a logistic node and a subset of the set of process and network nodes of the subtree rooted in the father of the given logistic node.

Network nodes are always leaves and each network node corresponds to connection and integration procedures among all its brothers, i.e. the direct (first level) sons of the father of the given network node.

More precisely, each network node induces an interaction graph among a set of process nodes (e.g. precedence constraints, information flows,...).

For each arc, there can be a set of procedures (automatic decisions) and resources which define the system behaviour.

Such procedures and resources, if pairs of process nodes are concerned, are considered embedded into such nodes; if more then two nodes are involved, they are considered part of the logistic node with the same father of the given network node.

There are no interaction among different network nodes.

The roots of the two trees T' and T" both correspond to the whole process P, the leaves that are also process nodes correspond to the *ou* in the two companies, i.e. the number of leaves of this type in each *obt* is equal to the number of *ou* in the corresponding company.

In general, T' and T" will have a subset of equivalent nodes.

By equivalent we mean that input and output (therefore the transformation process) are the same, although the transformation may be obtained with a different set of operations, different decision variables and using a different set of resources.

Notice that, if we consider a transformation process of company C" (node of T") and we try to transfer this process to company C' substituting it to the corresponding node, we must anyway redesign the process and adapt it to the caracteristics and features of company C'.

When we redesign the process, we may either find that the transformation is the same as the original one in company C', or that it is different.

In the first case the two nodes are called identical.

In the second case an opportunity for benckmarking becomes possible.

Two equivalent nodes can be both leaves, both internal nodes, one leave and one internal node.

If a node of a tree has no equivalent node in the other tree, then it belongs to a subtree which have a corresponding alternative subtree in the other tree; the roots of the two subtrees are equivalent nodes, although not identical. In this case a benckmarking opportunity becomes possible, by replacing the whole subtree.

Every time that we find the opportunity of substituting a node or a subtree of C' with a node or a subtree of C", we introduce an *or* node representing this choice.

Let T be a tree with *and-or* branches, obtained as the union of T' and T" (always from the point of view of company C').

The set of *or* nodes represents the set of choices available for the benchmarking. Each *or* is the root of two subtrees (that may also be a single node, the left subtree is a subtree of T', the right subtree is a subtree of T") which perform the same input-output functions (although in a different way, with a different set of decision variables and using a different set of resources).

To better clarify the benchmarking process, we may consider separately meaningful aspects.

The most important aspect is *organizational benchmarking*, which studies the possibility of substituting only subtrees corresponding to different breakdowns of subactivities.

In this case we suppose that company C' has designed at best the elementary tranformation processes, their interconnections and the logistic support; the only constraint in obtaining better performances is a not optimal breakdown.

This aspect is the core of the modelling approach discussed here.

A second aspect is *integration benchmarking*, which studies the possibility of substituting only network nodes.

In this case we suppose that the basic elements of the system (process and logistic nodes) remain the same and only the interconnections among them, i.e. the interactions procedures, can change.

This case is fairly rare on its own, because, in general, only few interconnections are possible.

A third aspect is *implementation benchmarking*, which studies the possibility of substituting only single process and logistic leaves.

We suppose that the functions performed in all the process, logistic and interconnection (i.e. the network) nodes are the same in the two trees T' an T", although the ways to perform the functions in some leaves can be different.

In other words, we suppose that the design of some single units may be modified, e.g. by using a different technology or different procedures.

A fourth aspect is *goal benchmarking*, which studies the possibility, for two trees with all identical nodes and a benchmark expressed in terms of a set of performance indicators, that the actions of company C' does not fit the benchmark.

The goals used by the company to drive the actions do not allow to reach the benchmark.

However, with a different set of goals (in particular the goals of C"), it would be possible to reach the benchmark.

A basic assumption underlying the *and-or* tree is *modularity*.

Only by supposing that a given subtree of T' can be replaced without major problems by a suitable redesign of the corresponding subtree of T", we can use the *and-or* tree as a decision support tool.

In practice, this is seldom true today in manufacturing environments, but the general trend, mainly because of cost and quality assessment, is in the direction of more and more standard subsystems and interfaces.

The *and-or* tree represents the overall set of configurations of the production system.

In fact, for each choice of the *or* nodes a different configuration arises.

Generally speaking, some configuration may prove to be unfeasible, but, if the system is fairly modular and the redesign well done, most of the configurations produce feasible patterns, with different values of the performance indicators.

The choice of the best configuration can be done in different ways:

- by total enumeration (if the number of configurations is small),
- by heuristic search,
- by solving an optimization problem.

For most of the practical applications, the number of alternatives subtrees is small, therefore the number of possible configurations is also small. In these cases total enumeration is more simple and effective.

Notice that, for a given configuration, the construction of an efficient way to operate often requires the solution of an optimization problem, in order to define correctly the nodes' internal organization and interface procedures.

4. OPTIMIZATION AND BENCHMARKING: TWO PROCEDURES FOR INTEGRATION

The following figure represents the two different loops of optimization procedures vs benchmarking procedures.

The optimization process, as shown in the next figure, consists of the evaluation of the state of the system, the evaluation of the system's performance, the optimization of the process itself, and the formulation of improvement decisions to the process.

The benchmarking loop, begins with the redesign of the trasformation process, and continues with the comparison with the benchmarking partner's. A suitable set of performance indicators are therefore needed.

Constraints redesign is then necessary, in order to introduce improvement decisions to the process and then to formulate a new optimization problem.

Notice that, to make the comparison effective, we must compare the performances of our process with the performances of the redesigned partner's process, and not with the original partner's process, not directly comparable.

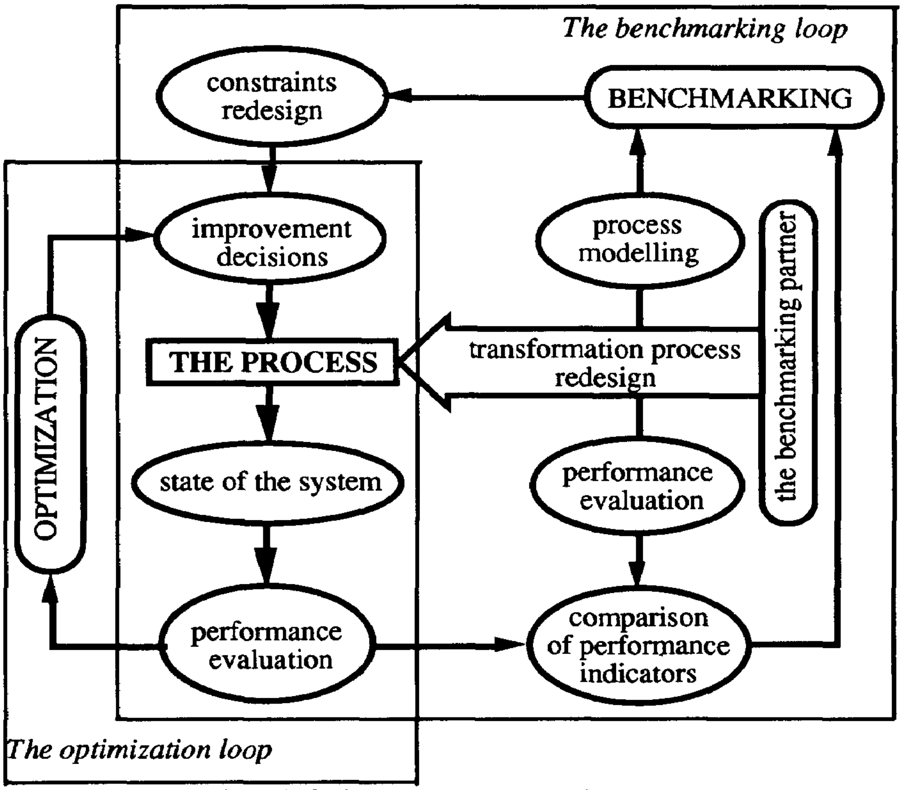

Figure 3: Optimization and benchmarking loops

The following table gives a possible breakdown of the procedures to formulate a decision problem as an optimization problem vs. the procedures for a benchmarking process.

Notice that one step of the benchmarking is the optimization procedure for the new system's configuration.

Table 1
Benchmarking procedures

Optimization procedures	Benchmarking procedures
Preanalysis	
Recognition of problems to face	Recognition of problems to face
Identification of main elements	Identification of main elements
Data and informations gathering	Data and informations gathering
Intervention limits	Identification of benchmarking partners
Decision centers touched by the problem	Data and informations gathering
Preliminary design of the decision alternatives	Performance indicators and preliminary comparison
Short and long term consequences	Intervention limits and modifiable constraints
Risk and uncertainty	Preliminary design of the aggregate and-or tree
Analysis	
Analysis of the decision alternatives	Analysis of the decision alternatives
Quantification of the decision process objectives	Operation breakdown tree
System and decision process representation	Quantification of process nodes
Subsystems and input-output relations	Quantification of logistic nodes
Decision variables and parameters	Quantification of network nodes
System dynamics and transition problems	Identification and redesign of partners' subtrees
System and decision process modelling	Analysis of the subsystem performances
Solution procedures	Modularity and integration problems
Hardware, software and user interface	Subsystems and detailed and-or tree
Prototype and output analysis	Set-up of the benchmarking model
Time and cost of getting a solution	Solution procedures
Decision	
Execute the numerical experiments	Find a set of feasible solutions
Parametric analysis	Integrate the results
Frame the results in the conceptual model	Optimization procedures
Decisions and operational procedures	Find the new procedures and ways to operate
Results validation and assessment	Results validation and assessment
Resources needed	Resources needed
Resources available and acquisition procedures	Resources available and acquisition procedures
Measurement and control tools	Measurement and control tools
On-line management of the transformation process	On-line management of the transformation process
On-line management of the decision process	On-line management of the decision process

5. TECHNOLOGICAL COEFFICIENTS AND PERFORMANCE INDICATORS

Several tools recently developed for organizational analysis may be of help to us for studying benchmarking modelling.

We need a structured methodology to find technological coefficients for resource constraints and to express performance indicators, usually defined in terms of products and final outputs, as a function of the activities in which the process breaks down. To do this we need to associate products to activities and activities to resource consumption..

First of all, the breakdown required by the benchmarking analysis produces a decomposition useful for comparing processes in different companies and may be used to find standards of performance for some types of processes. Functional decomposition may also be a good basis for treating information before their entry in the model.

Activity based costing methodology (*abc*) is, we believe, relevant for our modelling purpose and it is worthwhile to recall here some basics of it to be used in defining the input of the model.

Abc methodologies have not only the goal of giving an accurate assignment of costs, being thus a decision making support tool; *abc* can be used for pricing, inventory assessment, strategic management, activity management and, generally, for a better understanding of the company.

In addition to accurate informations on costs, more recent elaborations of *abc* tend to be used to obtain information in order to make changes in business practices and introduce performance improvement programs, such as benchmarking.

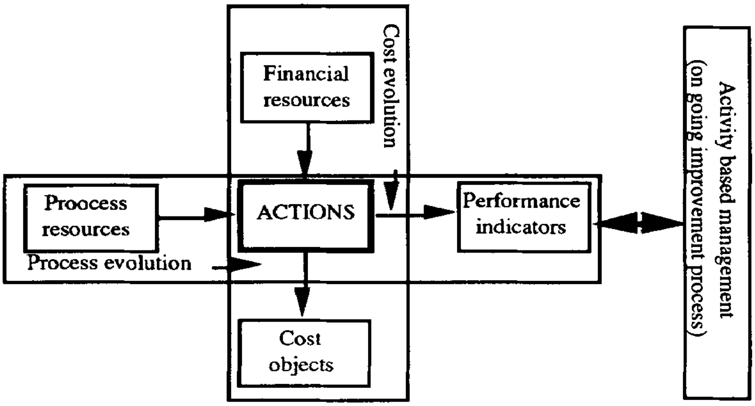

Figure 4: Activity based costing and mamagement

This chart shows the double dimension of the *abc* model. From the cost evolution point of view, you consider the cost of the resources such as salaries, equipment, technology, which you have to disaggregate to the point of reaching the *basic work units*, that is to say the activities, grouped by process or subprocess, and from these activities you are able to determine the cost of the products.This gives a breakdown of the process.

But *abc* methodology give also other informations on the work performed. In the horizontal dimension, we have cost drivers and performance indicators associated to activities. Cost drivers are identified and measured in order to understand why we do the work, which is the primary cause of the effort. The second aspect of the process evolution is performance measurement, that takes into account time, cost, service, productivity, quality and tells us how well the work has been performed. At this point we can perform a benchmarking action to understand, in comparison to other companies' performances, the level of performance of our work, based on the breakdown.

This second dimension, the horizontal process evolution, allows us to understand why money is spent, why work absorbs a given quantity of time, why we use given resources, why do they require a specific effort. Substantially, why do we perform work in the way we do, and how well do we perform it. There are the non quantitative informations also useful for interpreting cost informations.

Activity based systems aim to correct the traditional costing system's deficiences in finding technological coefficients for financial resources constraints, introducing three main goals: assign costs to activities (or actions as we have previously called them in the chart), assign costs to cost objects, and produce (not strictly financial) auxiliary informations about activities.

Conventional cost system presumes that products cause costs. The correct activity based cost assumption is that the cause of cost is not the product as such, but all the activities necessary to manufacture the product (or realize the service).The product does not consume directly money, but consumes resources. The performance of activities needs a series of resources, and these resources cause costs.

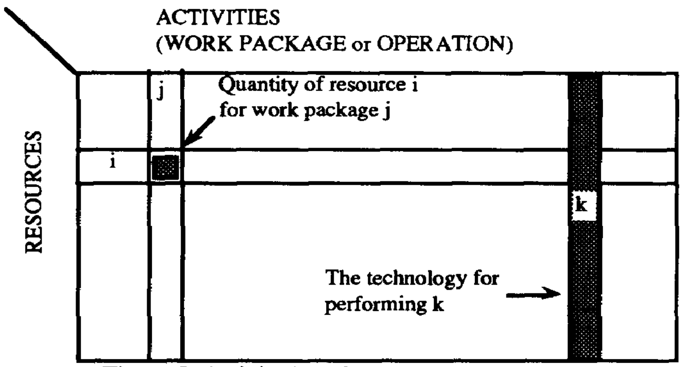

Figure 5: Activity based resource management

An activity i.e. a work unit (product development, part inspection,...) is characterized by a set of attributes.

A cost object is the reason for performing the whole process and its basic activities; it can be either a subproduct or a service of the process object of the analysis, and *abc* has the goal of measuring the real unit cost, resulting from the sum of all the activities that are necessary to produce a good or service. Also important is the definition of *drivers*, to have an accurate and fast measure of the use of different activities. The *driver* is a measure through which cost is allocated to the activity; a measurement unit of a *driver* can be, for example, the number of hours worked, the number of parts produced, etc...

A few activity attributes (for instance, the number of hours of inspections for the first piece inspections) can be *cost drivers*:: the number of moving parts of the dye, the number of colours in printed parts. A *cost driver* represents the causal factor, i.e. it gives the dominant cause of cost.

The process evolution, that shifts the attention from the link between resources and activities, is often represented using the above matrix, having the same meaning of the technological matrix of the linear programming models.

The information given by *abc* can be used to measure performance indicators. A performance indicator is, for example, the number of pieces refused by the client, or not accepted after a quality inspection. They must be related to measures of how well we perform the activity.

Indicators for benchmarking purposes must always be comparable. Thus, an indicator has to be normalized with respect to the complexity of the activity considered, of the tools utilized, of the place where the activity is performed, ecc.

It is important to concentrate on activities that are relevant but also changeable. Their indicators should therefore be either global (and therefore comparable), or ad hoc indicators linked to the different alternatives that exist to perform the activities.

We can suppose that performance indicators can be expressed as function of the decision variables that drive the process. In fact, such variables, together with the initial state of the system, determine the state in all the following time frames (because of the assumption of a deterministic system), the state of the system determines the output and the output determines the performances.

When, in order to find better performances, we incorporate some processes of another company into our company, the decision variables can change, but the performance indicators remain the same (even though, hopefully, with a better numerical value).

6. CONCLUSIONS

The paper tries to produce a structured methodology for benchmarking: four types of benchmarking are put into evidence.

One type of benchmarking is *goal benchmarking*, which studies the possibility, based on the improvement of performance indicators, of trying to get the values of the benchmark.

Even more important, according to our opinion, is *organizational benchmarking*, as we have called it, which studies the possibility of substituting sets of activities of the whole process with other sets of the breakdown activities of the same process in the best practice company.

Another aspect is *integration benchmarking*, which studies the possibility of changing the interconnection pattern for the same activity breakdown (this case is fairly rare on its own, because, in general, only few interconnections are possible).

The last aspect is *implementation benchmarking*, which studies the possibility of redesigning process or logistic units. In this case we suppose that the design of some single units may be improved.

The paper also outlines the differences and the relationships between optimization procedures and benchmarking procedures, and then discusses how tools recently developed for organizational analysis such as functional decomposition and activity based management may help in studying benchmarking modelling.

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