SYNTHESIS REPORT

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SYNTHESIS REPORT

Abstract

Cost engineering methods and tools are presented, focusedon cost estimation in the field of mechanical engineering. The limits and drawbacks of traditional costing practices are the starting point from which a new methodology is developed. This new methodology integrates important connected topics, such as information flows, economical analysis and cost accounting.

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SYNTHESIS REPORT

Introduction

The consideration of cost has always been an important factor in all engineering tasks. As *technology* has advanced, the problems of cost estimation, cost control and cost analysis have assumed even greater dominance in economical and engineering decisions. This increase in importance is attributed to several factors, among which we found:

- the world-wide expansion of markets
- shorter product life-cycles
- increased precision both in design and manufacturing, due to new technologies

As a result, most enterprises face a keener competition and a reduced time scale for decisions and resultant action. Yet, experience in a number of SME's has shown that most of them are facing big troubles to get the necessary data collected and then prepared in the most appropriate manner.

The usual arguments against the creation of a costing system are:

- It *costs* too much
- It does not increase, by itself, the sales nor the turnover
- The company has, since its inception, done without such a system

Dealing with the first objection, it is quite true that to create and then run an efficient costing system *costs* money. But the savings indirectly due to the installation of the cost system should lead to a reduction in the total costs, The second objection shows to be wrong as long as the costing system provides with data which allows a more flexible price negotiation. In this way, sales can be increased in the medium and long terms. Coming to the third objection, a close and unbiased examination shows that it is due to insufficient training, lack of interest or fear to change.

The high degree of complexity involved in all costing activities, where many parameters intervene and a lot of information is needed, explains why enterprises meet difficulties in these activities. On the other hand, practices coming from the beginning of the century still subsist even though they are no more adapted to the present reality, In particular, the increasing importance of indirect activities and the introduction of advanced manufacturing technologies have changed the ratio direct/indirect costs, In other words, the cost structure of products includes progressively a more important part of overheads.

Cost estimation is an unavoidable step any enterprise must pet-form in order to fix its selling prices. The accuracy and credibility of a cost estimation can be the source of the success or the failure of a business, industrial activity or government project. Underestimating costs can lead a company to a loss and, eventually, to bankruptcy, On the other hand, high prices resulting from overestimated costs may put a firm out of competitiveness in the market place. In all cases, cost estimation becomes a strategic activity of any company.

But cost estimation cannot be produced out of nothing. Previous knowledge about costs are necessary for new cases. So, historic cost data must be available somewhere and in an appropriate format in order to be of any use. Our claim is that any costing activity (estimation, calculation, control) must be integrated within a complete and coherent system.

The subject matter of the METACOST Project was primarily cost estimation in mechanical engineering. It aimed at the formulation of 'advanced' methods for cost estimation and at the realization of a software prototype based on these methods. The adjective 'advanced' has been used here to qualify a method which is"

1- quicker than standard or traditional methods
2 - more accurate
3 - easily and rapidly implemented in any company

This goal has been enlarged to a new, more global objective:

create tools and methods that can help to implement a powerful and efficient costing system in a company

This objective is attained through the following milestones:

- a global description of the company structure and order processing
- the identification of the relevant cost sources
- the creation of coherent information flows generated by product or order processing.

Different tools are used at each stage. They are described throughout this paper.

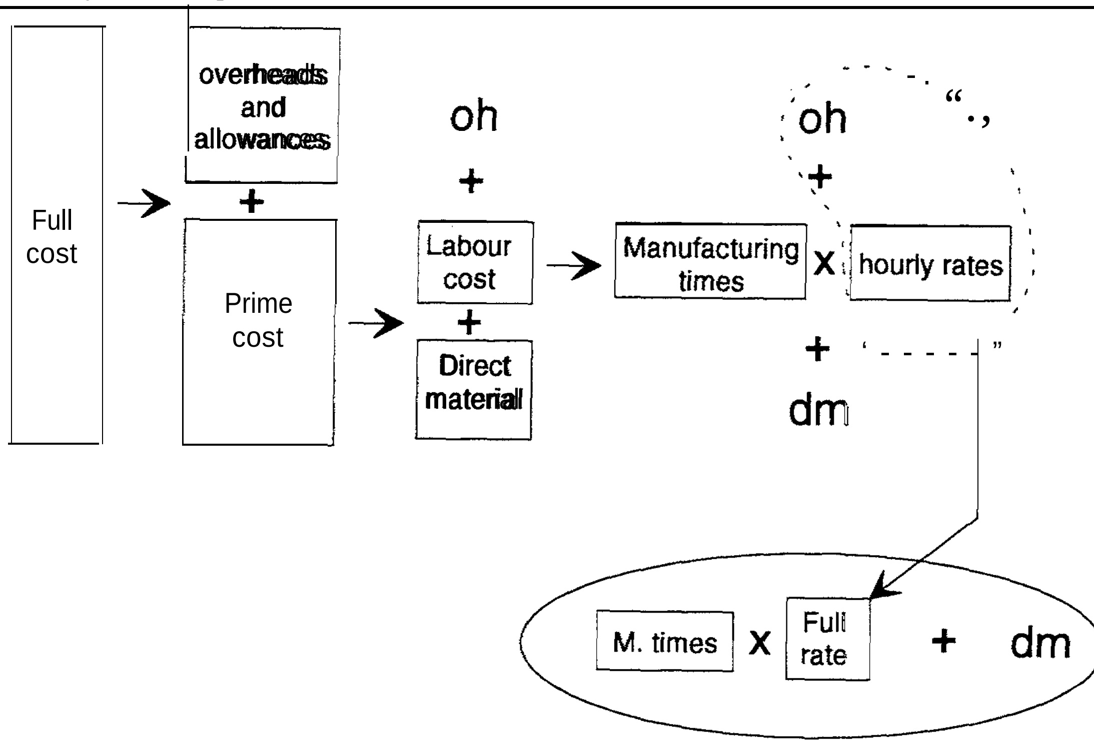
We think that it is important to understand the limits of the traditional costing procedures in order to fully appreciate the need for advanced tools in the field of costing, So, we will begin with a description of traditional costing practices and a critical analysis of them.

1- Traditional costing

The starting point of the project is the analysis of the traditional costing procedures. These procedures were universally spread out at the beginning of the XXth Century with the works of Taylor, Ford, Church and Pent de Nemours' brothers. The practical application of traditional costing procedures may differ from one company to another, but the underlying scheme is always the same. , It is described in the next paragraphs.

1.1- Prime Cost

The (full) cost of a product is derived essentially from prime cost. Overheads and allowances are added proportionally to prime cost {see next figure).



In this figure we can also see that prime cost has two components

- Direct Labour
- Direct Material

Direct Material cost is determined by the suppliers and, *in* a large scale, is independent of the company structure.

Direct Labour cost is calculated from processing or manufacturing times, and one or several quantities, calculated once a year, called hourly rates. Manufacturing times and hourly rates depend exclusively on the production means and the economical structure of the concern,

In order to simplify the calculations, overheads and (direct) hourly rates are grouped in a single factor called full rate.

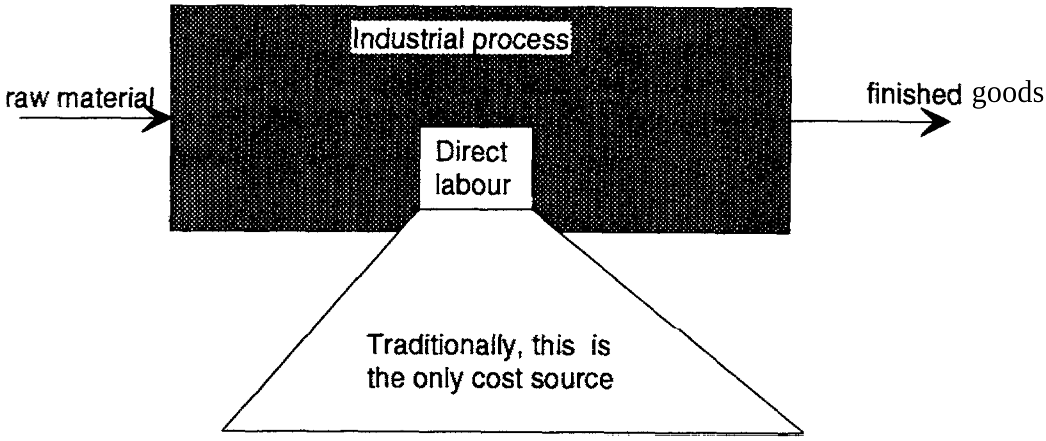
The calculation of the hourly rates is supposed to be the responsibility of the accounting department and material cost is the duty of the purchaser.

According to this scheme, the problem of cost is reduced to the determination of manufacturing times.

1.2- **Critical Analysis of traditional costing**

The preceding costing scheme was adapted to another time, when most companies were labour intensive, where indirect activities and overheads are very reduced. The move in all manufacturing companies is to reduce direct labour and replace it with automation. This is further exacerbated by the number of products each factory is producing.

Nowadays, direct labour is immersed in a lot of activities - not directly connected with material handling - which together form an industrial process. A simple look at any modem company will suffice to convince anybody that in order to treat any customer order, a lot of administrative, commercial and office work has to be done. The economical weight of those activities become in many cases more preponderant that direct labour's.



Behind this traditional approach, there is an implicit hypothesis: the (full) cost of a product is proportional to the dominant production factor. In other words, the cost of a product would be a (linear) function of the manufacturing time,

This approach was set up in a period (from 1850 to 1910) when this hypothesis was, in most cases, well founded. Nowadays it is certainly not. Indeed, the inversion in the pyramid of costs has changed the relative weight between indirect costs and prime cost, the former becoming more and more preponderant,

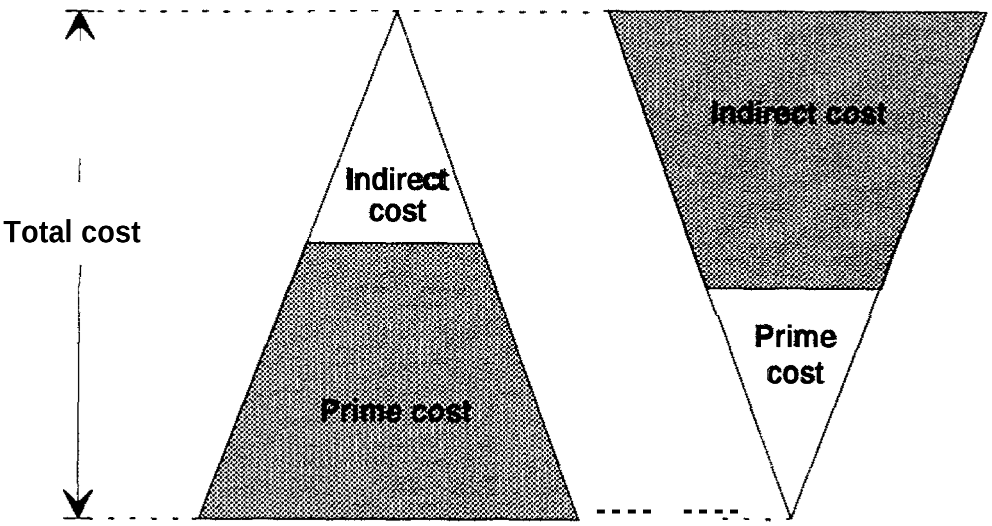


Fig.. 2: Inversion of preponderance between prime cost and indirect cost

Consequently, an important factor of inaccuracy is introduced by the application of heavy overhead rates to the transformation effort. In a sense, this practice amounts to say that if you know the cost of your tires, you can deduce the cost of your car!.

On the other hand, the distribution of the company costs shows that the expenses in the manufacturing area have diminished relatively to other company functions as, for example, the design or technical offices, the sales, the production planning, the administration, etc..

These (indirect) costs are spread over the manufacturing activities in the form of distribution keys which are more or less arbitrary and, above ail, economically senseless. For example, some enterprise will decide to distribute the administration department cost among the machining and assembling activities according to the surface occupied respectively by these two activities. Another enterprise will choose the number of workers and employees as the key to distribute administration cost

2- The basis of a new approach to costing

Having considered the limits of traditional costing practices, we have adopted parts of the Activity Based Costing as the starting point to more realistic costing systems.

The new understanding of the relationship and dynamics of elements of product costs state that:

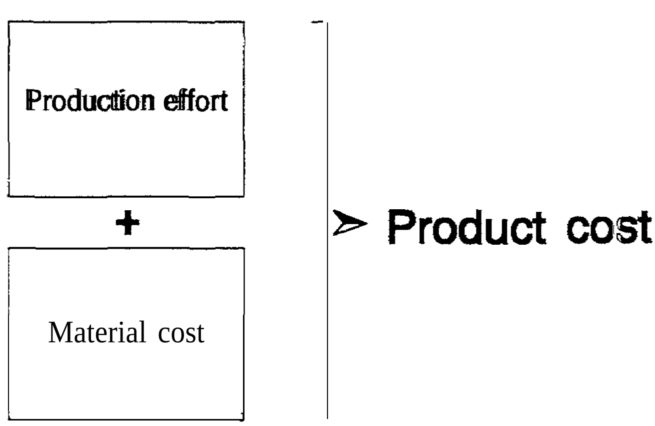
1 - activities consume resources
2 - products consume activities

In other words, the relationship between product and resource (money spent on producing the product) is **activity.**

In our approach, activity is not restricted to direct labour activities. Any activity, administrative, commercial, services or other, will be included in the cost of a product as far as there exist some evidence that the product has consumed some of the activity resources.

So, the first step in the implementation of a costing system is the analysis of the "order processing". From this analysis, the list of all the activities which participate in processing an order is drawn up, The took designed to this end are described in § 2.1

The basis to assign costs to products lies on the decomposition of product cost into two functional and economically different elements: **production effort** and **material cost**.

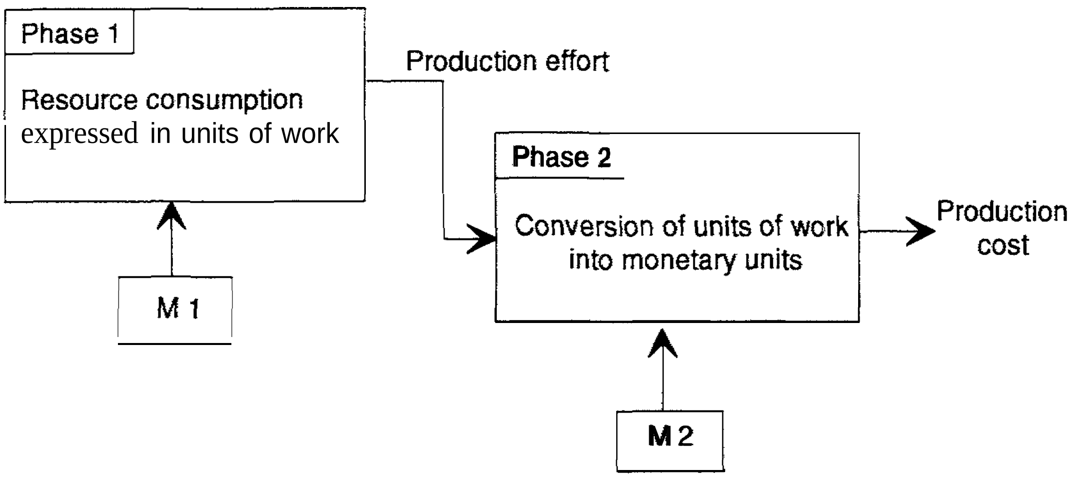


Production Effort is the measure of all resources consumed by an enterprise to deliver finished goods to customers, Enlarging the notion of Direct Labour, production effort includes all kind of product-related activities concerning: material transformation ("hands on"), services, and information or data processing. The money value of Production effort is called *Production Cost* or *Direct Production Cost.*

Material Cost or Direct Material Cost is the sum of all those (variable) expenses incurred in purchasing raw material, components, sub-contracted operations, special tools, etc. Direct Material is integrated in one way or another into the final product.

These two concepts will be further discussed separately in § 2.2 and 2.5.

The costing procedure consists in the evaluation (before or after production) of the production effort. This procedure is composed of two steps or phases:



The first phase, "Resource Consumption", includes all activities chosen and listed in the order processing. We shall call "Module Ml", all methods and tools that can be used to estimate resource consumption.

The second phase, "Conversion of units of work into monetary units", is (or should be) more economically oriented. Traditionally; it is considered that this phase is reduced to the calculation of the hourly rates. We will see later that this phase comprises much more than that. The set of methods and techniques employed in this phase will be called "Module M2°.

The costing procedure is applied in two moments:

- before production and it is called *cost estimation*
- after production and it is called *cost control* (also called 'cost calculation')

In a cost estimation, resource consumption is evaluated mainly from previous experience, as it will be explained later.

Cost control is performed by a *monitoring* system, which records, for each product, actual resource consumption.

Cost estimation and cost control are both necessary and complementary. One cannot exist without the other.

A costing system has two fundamental objectives:

- to perform cost estimations
- to record actual costs (calculation after production)

Because of these objectives, the costing system is connected with almost every company area. In order to understand the place and function of the different components of a costing system, we will introduce the notion of a cost form.

The cost form is a layout in which all relevant cost data related to a product is recorded, The cost form may be a paper sheet or a sequence of computer screens having the following structure:

Region #1		**Region #2**		**Region # 3**			
n°	Activities	Resource Consumption	Units	Rate	cost	Intensity	UPE units
1	Activity 1						
2	Activity 2						
• • •	• • •						
n	Activity n						
		Totals					
		Region # 4					

Region # 5					
n°	Purchases	Quantity	Unit Price	cost	Supplier
1	Material				
2	Components				
3	Sub-contracting				
4	Others				
			Total		

The cost form is divided into several "regions", each one of which will be the subject of the , subsequent chapters.

Region # 1 contains the number and names of the order processing activities which will be the basis to assign costs to products. The procedures, methods and tools used to choose these activities is explained in § 2.1.

Region # 2 contains the values that will be assigned to the resources consumed by the product in the corresponding activity. These values may result from an estimation or from actual values (calculated after production). The methods and tools which can be applied in this region are described in § 2.2 and 2.3, Region # 3 is used to convert resource consumption units into money values. Two methods enabling to perform this conversion are explained in chapter 6. They are ABC Costing (Activity Based Costing) and the UP (Unification of Production) Model. Each one, being complete in itself, can be used independently, or they can be used simultaneously. These methods are presented in § 2.4 and 2.5,

Region # 4 at the bottom of the first block contains the totals of the columns "cost" and "UPE" (Unification of Production Effort units), The first total gives one cost figure for the current product that needs no further processing, while the total "UPE" requires further processing. This will be explained in § 2,6 "UP simulation tools".

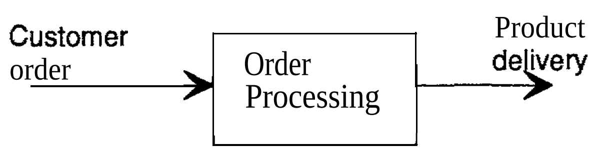
Region # 5 contains the list of purchases corresponding to the product under consideration, The purchasing cost will be the subject of § 2.3.

The set of all cost forms will constitute the historical database of the enterprise, How this database is used, maintained and updated will be the subject of $2.2.1 and 2.4,

.2.1- Order processing diagrams and Pareto analysis of activities

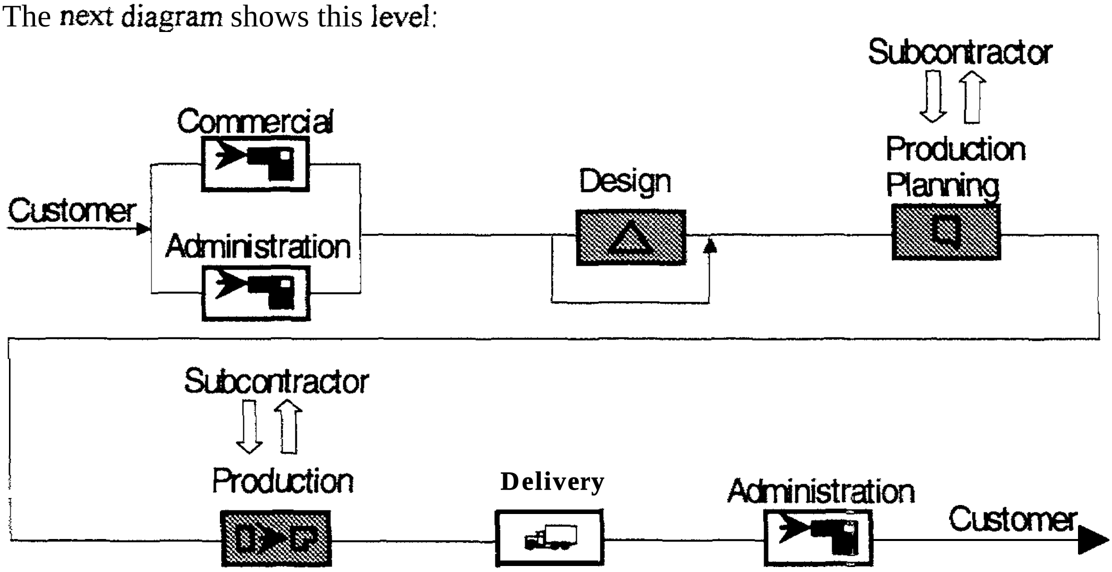
The order processing diagrams are used to describe material and data flows related to an order. They help to understand, organize and trace the path followed by customers' orders, from the moment the order is produced to product delivery.

A top-down approach is used to produce order processing diagrams. At the highest level we have the following black box:



Order processing diagrams are intended to describe, at any desired level, what happens inside this black box.

For example, at the next level, we can use the company department structure to obtain more detail. The next diagram shows this level:



In this example, we can see that

1) there are 6 departments or company areas participating in the order processing (Administration, Commercial, Design, Production Planning, Production and Delivery);

2) the interface between customers and the enterprise are the company areas "Administration" and "Commercial";

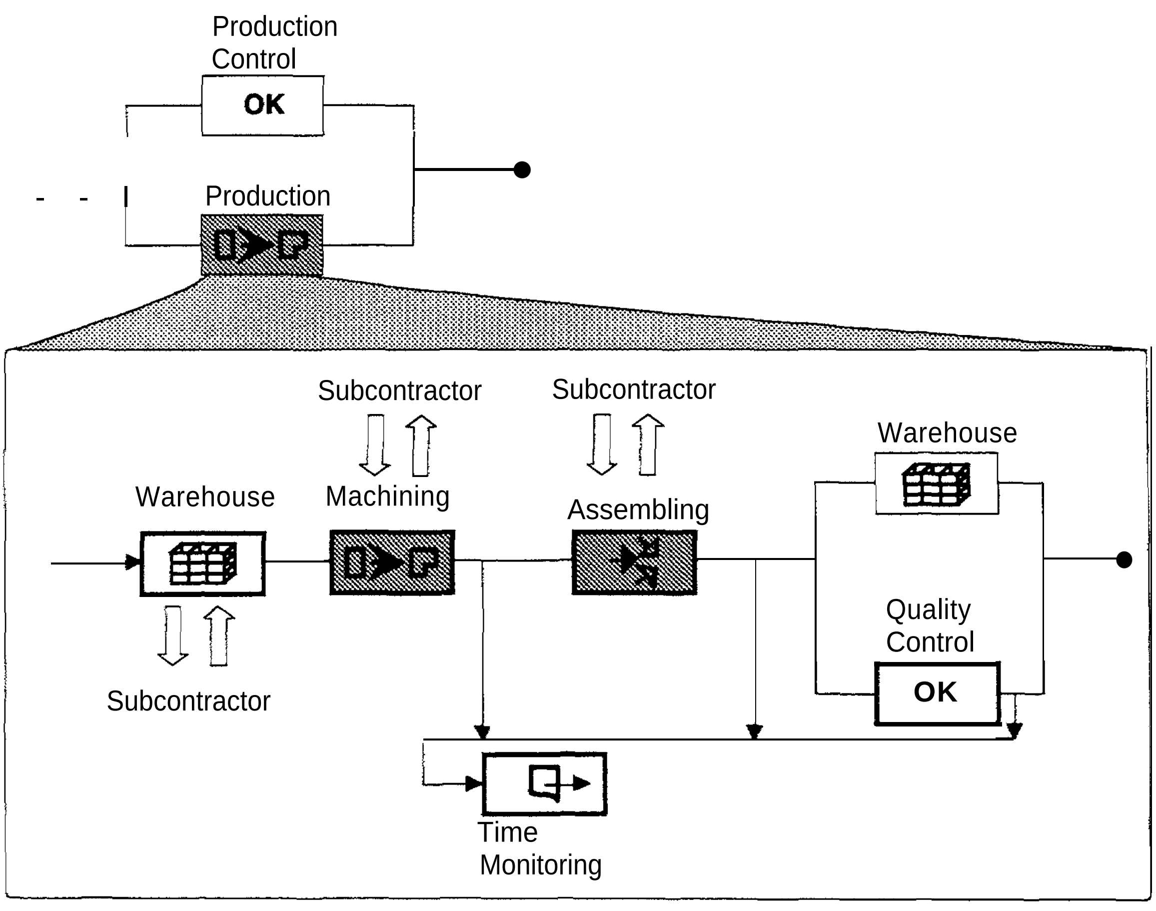
3) some information circulates between these two departments before transmitting the order to the Design Office (which in turn makes advance the order to the Production Planning, etc.);

4) the Production Planning department and Production deal with sub-contractors;

5) the fork before the Design department indicates that the activities in it may eventually be skipped.

6) a library of symbols or icons has been used. The meaning of theses symbols will be given later.

In almost all cases, it is necessary to obtain more detail in the description of the order processing. In those cases, a "zoom" is applied to obtain a more precise definition, The greyed boxes in the previous figure indicate that more detailed diagrams are available in those departments. For example, we can apply a zoom on the box "Production":



Again, more detail could be obtained in the greyed boxes if desired, but we will stop the example here.

Once the exhaustive list of order processing is obtained, in many cases it is convenient to reduce it to those whose economical weight is more important. To this end, a Pareto analysis is performed on the list of activities.

We remind that the hypothesis (adapted to the present case) of the Pareto analysis is based on the fact that 80% of the company resources are consumed by only 20°/0 of the activities, which are called *relevant cost sources*. The Pareto analysis is used to identify these activities.

We will show in a simple example how this is done. We will consider the budget of a fictive company :

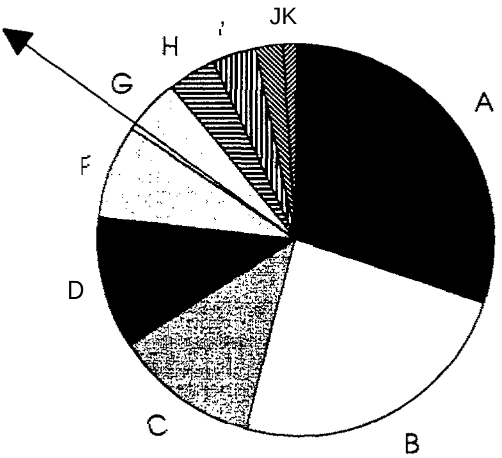
	Gen. Adm.	sales	Production Planning	Design Office	Purchasing	Technical Office	Shopfloor/ Machining	Shopfloor/ Assembly	Quality Control	Mainten./ Shipping
Personnel										
Equipment										
Consumables										
Capital										
Taxes										
Total	3546753	5281423	404031	10624918	1648353	966614	13616487	4611636	1816466	2020180

Total per year	44 736731[

Next, we divide the total cost of each department by the total cost of the company and express the result in percentage:

	Gen. Adm.	Sales	Production Planning	Design Office	Purchasing	Technical office	Shopfloor/ Machining	Shopfloor/ Assembly	Quality Control	Mainten./ Shipping
percentage	7.83%	11.81%	0.90%	23.75%	3.68%	2.16%	3oA4%	10.76%	4.06%	4.52%

Next, the departments are sorted in the decreasing order of the percentage and a graph is produced as shown in the next figure:



A	Shopfloor/Machining	3044%
B	Design Office	23.75%
C	Commercial	11.81%
D	Shopfloor/Assembly	10.76%
F	Administration	7.93%
G	Maintenance/Shipping	4.52%
H	Quality Control	4.06%
I	Purchasing	3.68%
J	Technical Office	2.16%
K	Production Planning	0.90%

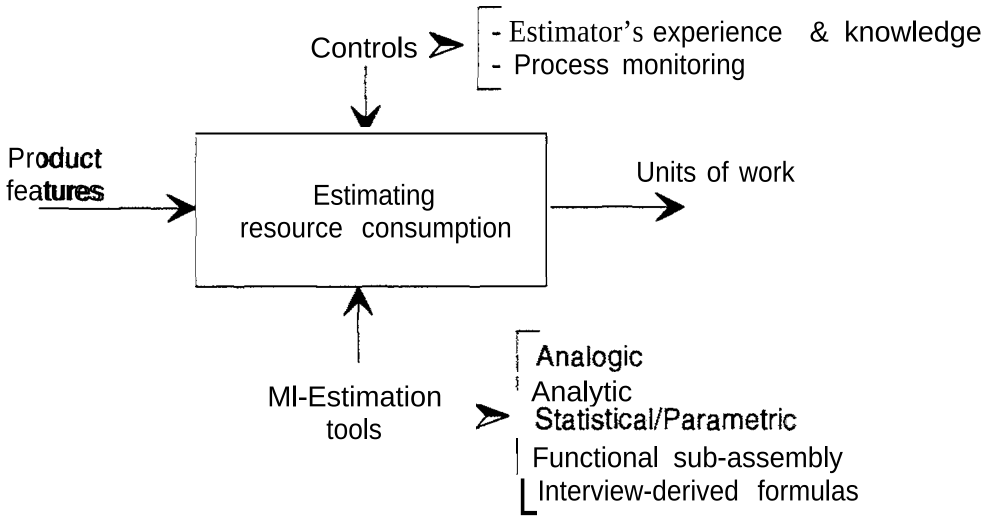
The arrow points to 80% of cumulated expenses. The relevant cost centers are located in the sector going from *midnight* to the arrow, turning clockwise

This means that, in the example shown above, the relevant activities are located in the departments "Shopfloor/machining", “Design Office”, "Shopfloor/assembly", “Administration” and “Maintenance/shipping”. These activities may be used to assign cost to products, because together they amount for more than 80°A of the company expenses.

This choice does not mean that the remaining company areas or their activities are not essential for the enterprise but, rather, that they consume a small part of the company resources,

2.2- Module M_1: Methods to estimate resource consumption

The following diagram shows the role of M_1 -Methods:



In almost all cases, units of work are expressed in time units. Yet, the possibility to use other units exists. For example, in the activity ‘purchasing’, the appropriate unit could be the number of transactions. During the analysis of the order processing, the appropriate units must be identified.

We shall briefly present each one of these methods, but first we would like to warn the reader about possible confusions:

1 - All these methods exploit, in different ways, data that <u>must exist</u> somewhere in the enterprise. If the necessary data does not exist, a method will show to be not applicable, or its results could not be reliable,

2- If a method works fine in a company, there is no guarantee that it will do it in another company, even if there are similarities in these companies,

3- Some vendors assure that their software for cost estimation is universal, and therefore applicable to any kind of products and to any company, We seriously doubt that such a thing might exist, 4 - Any method may progressively improve its results, provided that an appropriate feedback be continuously used to calibrate the method, So, the optimal functioning of a method is reached only after some time of use.

2.2.1- The Analogic Method

The Analogic Method rests on the principle that the effort needed to produce a product is approximately the same for all similar products. Thus, for a new production, the analogic method seeks , in the historical data, those productions that 'fit the best' (provided that comparison criteria exists) with the new one.

In order to estimate the company resources that a product will consume (or the cost it will cause), the application of the analogic method should ideally propose to the user reference values taken out from similar cases previously produced.

Upon reading this definition, we see that the Analogic Method requires two basic elements:

> a historical database, containing reference values
➢ a comparison criteria, allowing to tell when products are similar

At least two solutions are known which fulfil these requirements, they are

➢ classification and coding systems
➢ flexible databases

It is our opinion that the first solution is no more adapted to the present trend in which everything changes so quickly, that a classification of products in a company becomes rapidly obsolete.

We shall therefore prefer the second solution, flexible databases. In order to understand this new approach to the analogic method, it is important to review what functionalities are really needed, and what solutions can be found (a kind of value analysis)

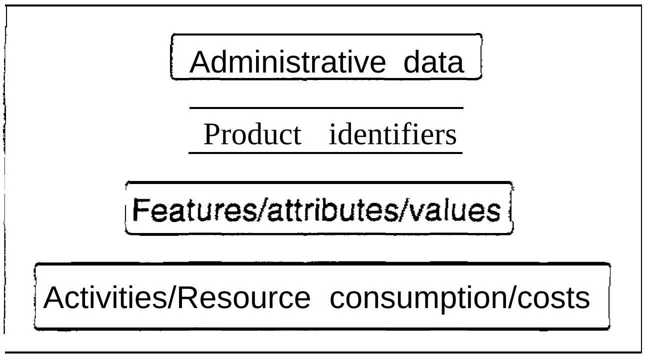
1 - The aim of the analogic method is to recuperate data stored from previous productions in order to transpose it to a new situation.

2- The best solution to retrieve the "similar" cases, is to let the user decide what means similar for him in each particular situation.

Keeping in mind that most geometrical, manufacturing and cost data are contained in outside hard paper files (drawings, process plans, shop floor reports), we propose to create a database intended to become, progressively, part of the company's memory. This database will constitute the guide to its historical archives. In this way, the database will help to locate those hard paper files in an easier an quicker manner.

The search procedures will take advantage of this new formulation, because different criteria, besides the technical ones, may serve to locate old orders as, for example, order date, part name, customer name, etc.).

The database will be composed of, at least, four 'zones'



The type of information that is Contained in each zone is explained next:

Administrative data :

Customer name, address, etc.
Reference dates: offer, order, production, delivery, invoicing, etc.
Offer/order identifiers
Drawing numbers
etc.

Product name

This field identifies the type of product we are dealing with. Its role in the general architecture is fundamental, as it determines the contents of the remaining zones. We shall see later how this is done.

Features/attributes/values

Depending on the choice of the product name, features are dynamically assigned to the current offer/order. For example, in the case of a piston we will have: diameter, height axis diameter, no of grooves, material. In the case of a connecting road, we will have instead: head diameter, foot diameter, length, oil channel, number of bolts and material.

We distinguish between feature/attributes from features/values, the former being applied to *qualitative* parameters and the latter to *quantitative* parameters.

ActivitiesResource consumption/costs

Depending on the choice of the product name, activities (names) are dynamically assigned to the current offer/order. They correspond to the activities that will be necessary to process the order. For example, in the case of a piston, we will have: turning, boring, honing, In the case of a connecting rod, we will have: milling, drilling, boring.

The actual use of this database is through the definition of product structures. A product structure is defined by the assignation of a set of features and activities to a product name. To this end, two tables are supposed to be available:

- a table of features
- a table of activities

For instance, these tables may look as shown next:

Features
Diameter
Length
Head diameter
Foot diameter
Axis diameter
Height
N° of holes
N° of grooves
No of bolts
Material
etc.

Activities
Turning
Milling
Drilling
Boring
Honing
Bending
Shearing
Redrawing
Process Planning
Design
Tooling
etc.

The product structure "piston" will correspond to the following subset of features and attributes:

Features	← piston →	Activities
Diameter		Turning
Axis diameter		Boring
Height		Honing
N° of grooves		
Material		

Now, in practice, the attributes and values corresponding to product features, are known from customers specifications. It remains to know the resources consumed by the activities. There are two cases to consider:

- we are feeding the database
- we are estimating the cost of a potential order

In the first case, the activity monitoring put into place by the company must provide with the actual values of resources consumed. This is an essential feedback without which the method fails,

In the second case, we proceed to look in the database whatever may help to establish reference values, for the complete product or for a particular activity we might be interested in,

To this end, the user has complete freedom to choose product names, features, or even administrative data that may help him to find reference values.

In some cases, when the search has been sharply defined, it could be interesting to have minimum, maximum and average values from the set of 'hits', This could help to produce, at worse, a rough estimation.

METACOST Tool 1 has been designed under this principle,

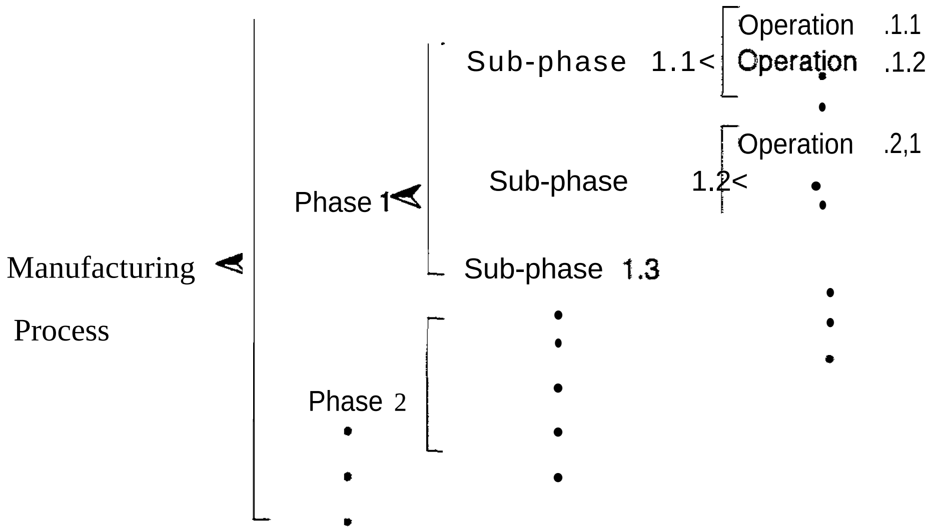
2.2.2- The Analytic Method

The analytic method, as it is used up to now, evaluates the resources consumed by a product in the workshop by breaking down the manufacturing procedure into 'elementary' operations whereby raw material is turned into a finished product. In this context, resources are accounted as machine and operators' working hours.

Consequently, to use this method:

- all the elementary operations making up a process plan must be known.
- there must exist, for each operation, a way (a formula, a table, or other) to assign the time consumed by it.

The following diagram summarizes the principle of the analytic method:



In the first level, the manufacturing process plan is decomposed in *phases*. A phase is determined by a workstation. A workstation is usually determined by the set of operations performed in a single machine (or within a specific company area, where similar and uniform processes are accomplished, for instance, assembling).

In the next level, each phase is divided into *sub-phases. A* sub-phase is defined as the set of operations performed with the same clamping.

Finally, each sub-phase is decomposed into different *operations*, where each operation is performed with the same tool.

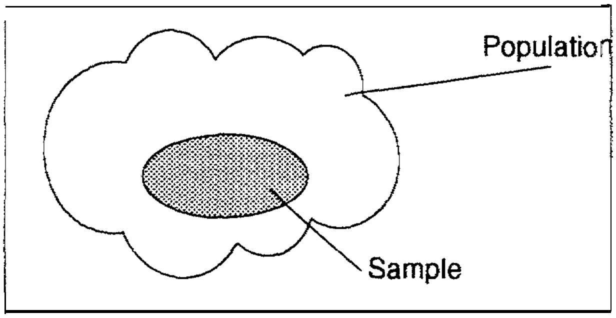
This method has found its best application in machining by metal removal, where technology derived formulas are available for almost every operation,

Nevertheless, in all cases it will be necessary to calibrate the formulas in order to adapt them to each company's manufacturing practices.

2.2.3- Statistical/Parametric Method

The parametric method lies on the hypothesis that a relationship exists between the resources consumed by a product and some of its descriptive parameters. Statistics are used to obtain this relationship from previous experience.

In the more general setting, the statistical/parametric method is based on the idea that the "behaviour" of a population can be statistically predicted from the known "behaviour" of a representative sample of that population. When this is done, a model is created (see next figure):



Three structural elements are defined in this method:

- the population is composed of the set of cases that will be included in the model
- the sample is a representative subset of the population
- the "behaviour" is the set of variables that are taken into account

The statistical analysis performed on the sample aims to extract the following information :

i) The correlations between parameters and the resource consumption (in the example above, the resource consumption is the manufacturing time).

ii) The possible groupings into sub-families

iii) The equations that describe the data matrix

The first two points concern the statistics tools known as Factor Analysis,

The third one, by far the most important, is attained with the so-called Regression Analysis procedures.

2.2.4- The Functional Sub-Assembly Method

The Functional Sub-Assembly Method (FSA Method) has been designed to analyse costs in the special machine field. Its goal is to provide a formal setting and a rigorous frame to the classical decomposition of complex products into smaller, simpler parts,

This method is based on the notion of function (or technological function), which is related to the sub-assemblies of a machine. With the help of this notion, we intend to classify devices or parts of machines which can be quite different but performing the same function.

The underlying idea of the FSA method is that every machine, whatever be its complexity, is composed of a certain number of elementary functions such as motions, support, gripping, clamping, positioning, etc. In other words, a machine can be considered as an *assembly of functions*.

Now, each function is materialized by a specific device which we call *functional sub-assembly*. The cost of a machine is then the sum of the functional sub-assemblies costs, to which is added the *integration* cost, tuning up cost and eventually other service costs.

In this approach, the accent is put on what the sub-assemblies& rather than on which way they are made.

More details on this method are given in the METACOST Guide.

2.2.5- **Interview-derived formulas**

In some cases, when data is not available in a physical support, it is still possible to determine standard consumption values in some activities through the acquired experience of expert people, The technique of specifically oriented interviews can be used to make the expert aware of a hidden knowledge about facts he or she has observed during the execution of certain activities.

In a sense, this technique may be put in parallel to the first stages of a knowledge-based method,

2.3- Estimating Material Cost

Material cost is a variable, non structural cost. As we have said, material cost consists of all purchases carried out to produce a specific product. These purchases should be clearly and exactly identified, then charged integrally to the customer. Indeed, this cost would not exist, had the customer not sent the order to produce.

The manufacturing enterprise plays, in purchasing material and components, the role of an intermediate bridge between customers and suppliers. This role may consume some of the enterprise resources and thus, it is normal to consider the purchasing activity as part of the product cost. But it is important not to confound the purchases themselves with the purchasing activity. The latter is a structural cost but the former not.

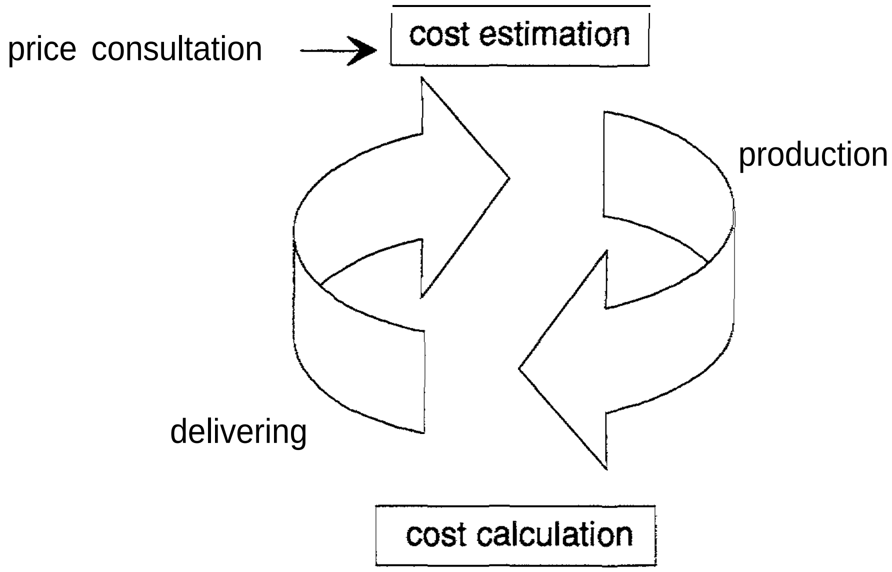
Some companies consider material cost as an activity giving rise to overheads and benefit, but we discourage this practice, Indeed, if this should be the case, the customer will be surprised to learn that the supplier's price is inflated by an unfair manufacturer. In price negotiations, the possibility must be left open to the customer to buy, by himself, the material and components which will compose his or her product. In this case, the price will be different than that in which the manufacturer takes on his charge the duty to search and buy material and components. The difference will come, not from the material cost which, as far as the same suppliers are chosen, should remain constant, but from the purchasing activity.

In some special cases, companies choose to purchase in advance sufficiently big stocks of raw material in order to benefit of discount prices. But even in this **case,** the material cost must not be included in the structural cost. A more rational solution is to consider the enterprise warehouse as an internal supplier selling at preferential prices, and the warehouse functioning cost as forming part of the structural cost.

In a cost estimation, material cost should be evaluated with the highest accuracy, above all in the field of special machine manufacturing, where material cost amount to nearly 45°/0 of the total cost. Now, the only method to do this, is through an information system linking the purchasing department and, whenever it is possible, to suppliers' catalogue list prices, We will deal with this subject again in $2.4.1.

2.4- **Cost Monitoring: Coherence and Feedback**

Cost estimation is only a step in a cyclic process that can be represented as follows:



In this figure, we represent *cost calculation* as the activity which records actual resource consumption of all order (or product) processing activities, during and after production. This activity must provide cost estimators with a **coherent feedback. We** shall explain later in this section what this expression means.

Remark/ Cost monitoring and cost control are expressions also used instead of cost calculation. It seems that the latter is not of wide use, so, we will prefer the first two.

It is essential to understand that cost monitoring not only serves to check the correctness of a cost estimation, but it sets up the basis for any reliable cost estimation.

Indeed, a cost estimation cannot be performed out of nothing Cost estimation is nothing else but the projection towards the future of *previous experience*. This previous experience should exist somewhere in the company and, to be exploited, it must be:

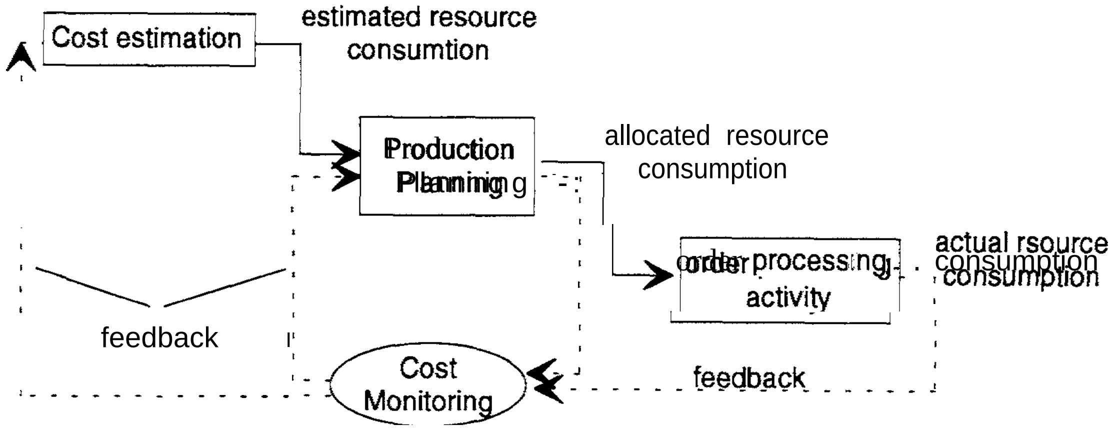
- readily available
- correctly structured
- reliable and updated

Unfortunately, the reality, confirmed by our own experience shows that, in most SME's, this is not the case. Several reasons may explain this situation:

a) bad organization, habits, etc.
b) lack of suitable communication channel exchange (computers, networks, paper,..,)
c) mental inertia

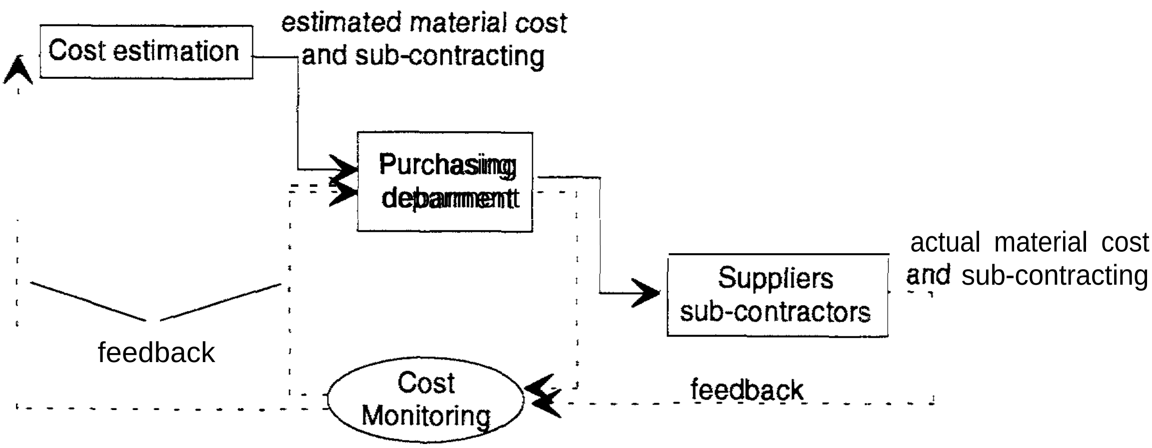
2.4.1- Feedback

Any order or product processing activity in the company should have, at least the following data input and output:



Actual resource consumption is recorded by the cost monitoring system of the company and sends these data back to the Production Planning and to the Cost Estimation departments. This feedback is essential to improve cost estimations, but is also necessary to check performances and to organize the production.

Another important feedback concerns the material and components cost, Usually, it is the purchasing department that is acquainted with these data:



Cost estimators and other people needs, in order to perform their activities, updated prices. These prices concern: raw material, components, sub-contracted operations and other external services (like transporting).

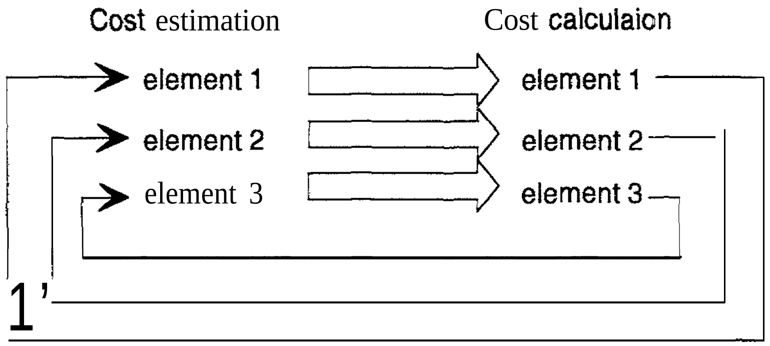
It is convenient to distinguish between figures coming from price consultation and actually purchased items. Indeed, several months may separate the former from the latter and big fluctuations may occur in between.

Also, the origin and destination of purchases must be clearly identified to the product it was intended for. In the case of special machine, for instance, it is not enough to know that a particular component has been purchased for a certain machine, it is also necessary to know the link of that component to the specific fictional sub-assembly it belongs to (see the fictional sub-assembly method),

2.4.2- **Coherence**

A most important requirement of data exchanges is coherence. Coherence means, in this matter, that the same units and the same data structure must be used in the input and in the output.

A coherent feedback means that the same elements are used to estimate cost and to record actual product cost (or estimated and actual resource consumption). Even if this requirement seems to be obvious, we insist on it, because it is far from been understood by many companies.



Feedback is possible

We shall give three examples to illustrate this point

Example 1 - In this example, a sub-contractor of mechanical parts estimates the resource consumption in the following way:

	set up	unit time
milling	2	5
drilling	3	6
boring	4	?

But the actual resource consumption is presented as follows

	set up	unit time
Machining center Mazak	10	24

In this example we have lost detail of operations, Only the machine which executed them is reported.

Example 2- A sheet-metal working company estimates the following resource consumption for a particular product:

	set up	unit time
Shearing	1	5
lasering	2	6
bending	3	7
welding	4	8

The shopfloor reports the actual resource consumption in the following way:

	times
Shearing	7
lasering	9
bending	11
welding	15

In this example, setup and unit times have merged into a single quantity

Example 3- A special machine manufacturer estimates the resources consumed by the 4 fictional sub-assemblies (SA1, SA2, SA3 and SA4) that compose a particular machine X. The figures in the example are not relevant

	SA1	SA2	SA3	SA4
Mechanical design	1	1	1	1
Automation design	2	2	2	2
Machining	3	3	3	3
Assembling	4	4	4	4
Tuning	5	5	5	5
TOTAL			60	

The resources actually consumed are registered as follows:

	Machine X
Mechanical design	5
Automation design	9
Machining	15
Assembling	20
Tuning	24
TOTAL	90

In this example, the notion of sub-assembly is lost, and only global times are recorded,.

With these examples we tried to show that coherence is fundamental to produce useful feedback.

2.4.3- **Information systems**

Any enterprise, in its functioning generates an information flow. The information flow can be defined as the continuous data exchanges from one point called (node) to another; within the company or from the company to its surroundings.

The feedback mentioned above are part of the data that circulates in the information flow.

Information flows have always existed, in paper form or through oral emission. In modern times, the volume of data produced by an enterprise, or circulating through it, cannot be managed only with paper or verbally. Happily enough, nowadays there are computers,

Unhappily enough, though, many enterprises, among small and medium sized, are not sufficiently aware of the possibilities offered by the use of computers, networks and the appropriated so oftware.

In general, many managers and responsible people think that the information flow is created without anybody's effort and reaches by itself its steady state. This belief is the weakest point of almost every company and, when translated to the costing activities it is outright disastrous.

The information flows can only be mastered through an information system. An information system is composed of the data structures, the rules and the physical support for data exchanges.

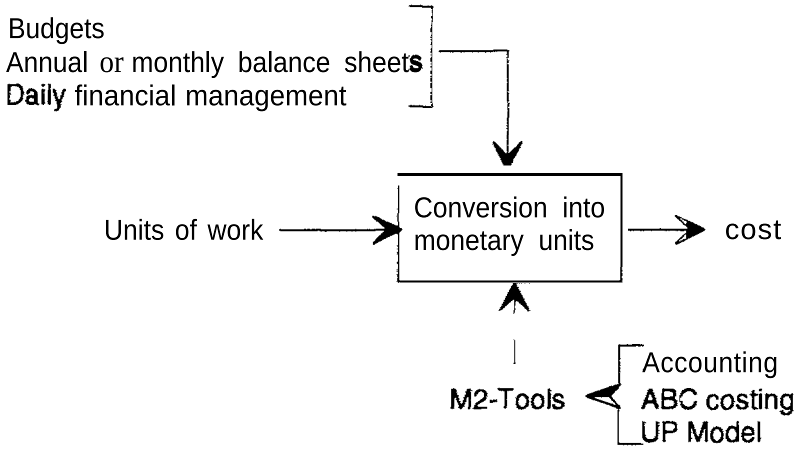
The minimal services an information system must assure are the following:

- Provide any data, to whoever needs it, promptly, accurately and easily.
- Record any relevant data, produced by any activity, in an appropriate format (so that it may be used by other users).
- Produce rules for data exchanges which are clearly understood by all the concerned people. This rules establish when a data exchange must take place, to who it is addressed and in which format.

Any modern enterprise should have an efficient an integrated information system which, among other functions, will provide the costing system with the necessary data to perform its activities (estimation, monitoring, control). Nevertheless, a complete analysis of *integrated* information systems is beyond the scope of this document.

2.5- **Module M2: Methods for converting units of work into monetary units**

Once the resources consumed by each activity are known and expressed in units of work, the next step in the costing procedure is the conversion of these units into monetary units. The methods to perform this conversion are shown in the next diagram:



2.5.1- Classical cost accounting

In classical cost accounting, hourly rates are calculated from a provisional budget, in which direct activities, called cost centers, are separated from other activities. Indirect activities, or overhead cost are distributed over the direct activities using distribution rules (keys), which are fixed by the management. We are not to considering more detail this subject as it is supposed to be known, at least by the specialist. The only comment we need to add, is that classical accounting cannot be used to check the growth of overhead cost in a company.

Because of this reason, two methods have been developed and adapted for METACOST purposes: ABC costing and the UP model.

2.5.2- ABC Costing

Activity Based Costing (or ABC) is a cost accounting method that allows the reduction of overhead cost by a detailed analysis of all processes *or* activities needed to satisfy a customer order.

To this end, the tasks of each department are analysed and divided into individual activities or differentiated processes. Next, the activities are examined in order to determine the *resources* they consume. At the same time, the *capacity* of the activity is evaluated from past experience or from an expected behaviour.

From these elements, resources and capacity, cost rates are determined for each activity. Next, the *assignment* of cost *to activities is* made through the use of cost drivers. Cost drivers are product-dependent reference values that determine the main resource consumption.

This method has been integrated in METACOST Tool 2.

2.5.3- The Unification of Production (UP) Model

The UP (Unification of production) model belongs to Module M2. It is thus a tool serving to the transformation of units of work (usually manufacturing times) into monetary units.

The aim of the UP model is to determine, within an enterprise, a single unit which can be used as a measure of its level of production. This unit is called 'unit of production effort' (UPE). The UP Model is copied from mono-product companies in which the cost of one unit is given by the formula:

Total expenses/Number of units produced

The elements handled by the UP Model are:

- the UPE units (units of production effort)
- the volume of production
- the structural cost
- activity intensity.

These concepts are explained in the next paragraphs.

During a fixed period, an enterprise produces some amount of UPE; this is the volume of production, V. In the same period, the enterprise expenses for its functioning (with the exception of purchases integrated in their products), some amount of money; this is the structural cost, SC. We remind that in the modern factory, the structural cost is, to a large extent, fixed.

The economical rule of the UP model states that the selling of V UPE 's must cover, at least, the structural cost SC. With the help of this rule, one can easily calculate the minimum selling price of each UPE by the formula:

$$\text{selling price of 1 UPE} = \frac{SC}{V}$$

The way of introducing the units of production effort (or UPE) is through the determination of <u>activity intensities</u>. Roughly speaking, an activity A will have a greater intensity than another activity B if, during the same amount of time, activity A consumes more of the enterprise's resources than activity B.

More concretely, the determination of activity intensities is realized through the following steps:

- calculate the economical cost of each activity
- define a standard or reference activity
- divide all economical cost by the economical cost of the reference activity

In the calculation of economical costs, only charges directly associated to the activity are considered. In other words, overheads are not distributed among the activities. The economical costs are grouped into three categories: personnel cost, equipment cost and consumables.

Value 1 is assigned to the reference activity intensity. AU other activity intensities are calculated relatively to the economical cost of the reference activity. In this way, inflationary or monetary fluctuations will have no direct effect on the determination of the productive potential of . the enterprise. Activity intensities change when the economical or the technological means of the enterprise comes to be modified,

The main requirement for the implementation of the UP model, is a well organized and detailed accounting department. This means that the following information is available:

a) A good picture of the cost incurred in each activity. This is necessary to calculate the activity intensities.

b) A complete monitoring of structural cost and volume of work. These entails a work at two levels: the structural cost is managed at a global level, whereas the volume of work is obtained from the activity extension level and thus, it concerns a local monitoring, This monitoring provides, in addition, with excellent crucial parameters for the company's management.

c) The purchasing function must distinguish clearly between material and component cost of products from all other purchases. This is closely related to the required knowledge of the structural cost. In simple words, the purchases originated by an order must be exactly traced and assigned to the corresponding product(s),

d) Frequent communication exchanges must be established between the salesmen and the management in order to keep trace, at any moment, of how many UPE has been sold and at which price. This information will be of utmost importance for the following price negotiations.

The second requirement is more psychological. Almost all enterprises are used to think in terms of productive hours and hourly rates. It takes a certain time to evaluate cost in terms of UPE units, Because of this, it is convenient that a preliminary work of information might be done for all concerned people, in order to prepare them to this change.

Also, it is important to maintain the old costing system during an adaptation period. During this period people may speak of a machine as representing 3000 working hours and simultaneously evaluate its costs at 2560 UPE units.

A major advantage of the UP model is its simplicity, both in its principle and in its implementation,

2.6- **Simulation took**

In almost all cost accounting tools, cost rates are obtained from budgets (of the previous year or provisional). The size and complexity of a budget makes very difficult, if not impossible to perform simulations of the kind "what if". One of the most interesting features of the UP model is its capacity to perform simulations, This feature is a due to the simplified setting on which the UP Model lies.

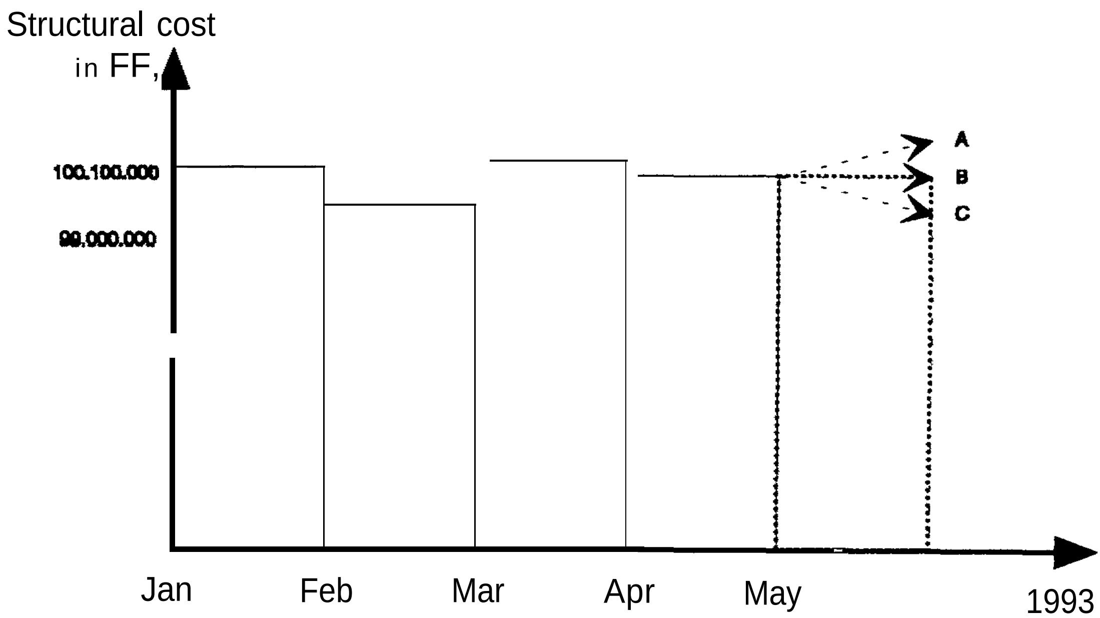
Let's consider an example:

Suppose we are in May, and a price consultation is made for a special machine. The estimator evaluated the production effort (for this consultation) at 6000 UPE. Material cost is ' evaluated at 100000 French francs. The following questions arise:

What will be the cost?
What is the safe interval in price negotiation?
What will be the price if a global 10% profit margin is desired?

In order to answer these questions, we must take into account the time evolution of structural cost and volume of work. Several hypothesis may be formulated as shown in the next figures,

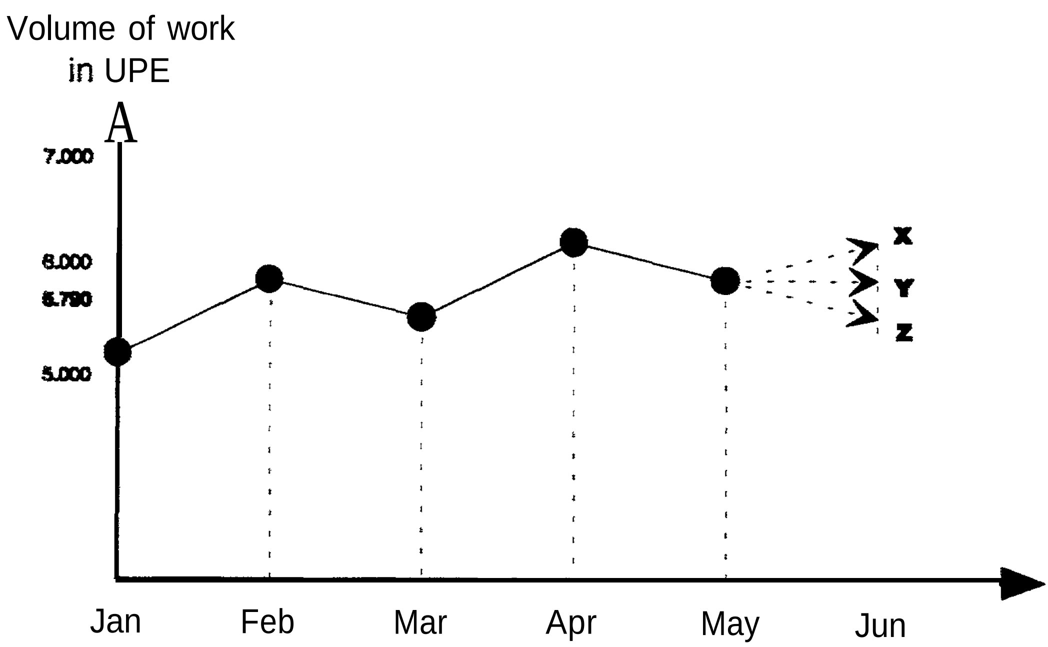
2.6.1- Forecasted evolution of structural cost



In this figure we can see three hypothesis:

Hypothesis **A :** Increase of structural cost (say 5%)
Hypothesis **B :** Status quo
Hypothesis **C** : Diminution of structural cost (say -5%)

2.6.2- Forecasted evolution of volume of work



In this figure we can see three hypothesis:

Hypothesis X : Increase of work volume (say10%)
Hypothesis Y : Status quo (same volume as in the previous month)
Hypothesis **Z :** Diminution of work volume (say -1 5%)

Of course, other hypothesis maybe formulated

We will ***examine*** in which way all these hypothesis can be simultaneously handled in order to formulate a price.

Suppose that in May, the company produced and sold a total amount of 6370 UPE, and the structural cost during this month was of 1022800 FF.

Taking into account these facts, it is possible to *simulate* the different hypothesis and obtain the following results (detail of calculations are skipped);

a) the lowest price at which each UPE can be sold is 138,67 **FF**

b) In the worst case (structural cost increases, volume of work diminishes), the minimum selling price of each UP increases to **198,35 FF**

c) the cost of the machine will fluctuate between 932019 **FF** and 1290071 **FF**.

2.6.3- Profit Margin

Let's consider now the benefit.

We want to know the price of the machine under several hypothesis concerning the profit margin (or benefit) expected. There are several ways to express the benefit:

- a global benefit of 10% over the structural cost
- 9 a benefit of 20 FF by each UPE sold
- a benefit of 5% over the cost of the machine
- no benefit generated in this transaction (marginal cost)

The simulation capabilities of the UP Model enables to give the following answers (detail of calculations is omitted):

a) If a global 10°/0 profit margin (over the structural cost) is expected, the machine must be sold at a price that fluctuate between 1015221 **FF** and **1409078 FF**

b) A unitary contribution of **20** FF is expected for each UPE sold, the price of the machine will fluctuate between 10520119 **FF** and 1410071 **FF**

c) The price of the machine, with an expected benefit of 50/u over its cost, will fluctuate between 978620 **FF** and 1354575 **FF**

3- METACOST software prototypes

A practical realization of the methods presented above are the METACOST software Tools 1 and 2. We will briefly describe these Took

3.1- Tool 1

Tool I is a flexible database that can be adapted to any company -mainly sub-contractors and special machine builders, but also to other industries - and is used to constitute an *historical* database of offers and orders. It allows comparison between estimated and actual costs, and can thus be used as a basis to create a coherent information flow system, Besides, and this is perhaps its main feature, it allows the user to search, in the stored data, *any* element that can be used as a reference for a new estimation. This element maybe a similar product, a machining operation or a functional sub-assembly.

3.2- TooI 2

Tool 2 combines features of Modules M1 and M2. With this tool, it is possible to create one or several company models including activities, resources, different cost types and product structures. It can calculate hourly rates. The approach followed to calculate hourly rates is inspired from the *activity based costing*. *Next,* a formula editor allows the user to enter customized consumption functions according to his or her needs. This formulas can be statistically obtained, technological formulas or derived by interviews with expert people. Another important feature of Tool 2, is that it can give access to Dynamically Linked Libraries (DLL).

4- Conclusions

The methods and tools exposed in this document have been designed to solve the main problems encountered in small and medium enterprises working in the field of mechanical engineering. The majority of the concepts presented here can be progressively introduced, and contribute, in this way, to the implementation of an efficient costing system in the enterprise, The METACOST software took constitute a substantial basis for a complete, integrated offer in cost engineering software.

6. Adresses

Coordinator:

CETIM
52, Avenue Félix Louat
BP 67
60304 SENLIS
FRANCE
TEL : (33) 44.58.35.31
FAX : (33) 44.58..34.00

Other partners:

WTCM
CAMPUS ARENBERG
Celestijnlaan
3-3001 LEUVEN
BELGIUM
TEL : (32) 16.32.25.91 (general)
TEL : (32) 16.32.26.57 (direct)
FAX : (32) 16.32.29.84

WZL
Steinbachstrasse 53 B
D-5100 AACHEN
GERMANY
TEL : (49) 241.807.384
FAX : {49) 241.873.442

GPS
Technologies Park
Kaiserstrasse 100
52134 HERZOGENRATH
GERMANY
TEL : (49} 2407.5069
FAX : (49) 2407.2778

TEKNIKER
Avenida Otaola 20
Apartado 44
20600 EIBAR
SPAIN
TEL : (34) 43.10.67.44
FAX : (34) 43.10.27.57

OPF
6, Rue du Château
80840 PONT-DE-METZ
TEL : (33) 22.95.00.66
FAX : (33) 22,95.76.55

ABc
Wiedauwkaai 43
B-9000 GENT
BELGIUM
TEL : (32) 92.67.00.00 (General)
TEL : (32) 92.67.00.55 (Van de Vijver)
FAX : (32) 92.67.00.67

SERMATI
BP 70
46400 SAINT-CERE
FRANCE
TEL : (33) 65.38.03.80
FAX : (33) 65.38.35.43

ACTIF Industries International
Zone Industrielle des Hauts-Sarts
B-4040 HERSTAL
BELGIUM
TEL : (32) 41.40.07.99
FAX : (32) 41.40.06.86

ETXE-TAR
San Antolin s/n
20870 ELGOIBAR (GUIPUZCOA)
SPAIN
TEL : (34) 43.74.06.00
FAX : (34) 43.74.34.72

Project Technical Auditor:

Mr. PAPON
ARTTIC
5, Avenue de Verdun
94204 IVRY SUR SEINE
FRANCE
TEL : (1) 45.15.24.50
FAX : (1) 45.15.24.60