Global Approach of Quality Management Using GRAI Integrated Methodology

Christine Foucault, Bruno Vallespir, Jean Paul Bourrières

GRAI- Laboratoire d'Automatique et de Productique (LAP)
Université BORDEAUX I
351, Cours de la Libération,
33405 Talence
FRANCE

Abstract: The quality of the product is without any doubt a condition of competitiveness. But to perpetuate the manufacturing system, one needs define in a coherent way what the quality of a product implies for the whole manufacturing system and what the actions to be launched are, in order to improve quality without endangering the system. Actually, a whole bunch of tools is proposed to companies to help them deal with their quality problems. They are efficient for specific problems but do not allow that managers map the whole system. However, this mapping is absolutely necessary to lead the quality system to being a helping tool for the manufacturing system in achieving its objectives by respecting the strategic, tactical and operational decisions without disregarding the triplet (quality, cost, delay).
In this paper we will present the state- of- the- art of various ways and tools dealing with quality. We will also present the concepts developed at the GRAI/LAP in order to model the quality system and to integrate it with operational manufacturing.

Keywords: Quality management, Integrated modelling, GRAI Integrated Methodology.

Christine Foucault was born in 1965 at Mantes la Jolie, France. She is preparing a Ph.D at the GRAI/LAP on Quality Management. She is involved in the ESPRIT project 8991 MULTIMAN (Quality Management in Distributed, Multi-site Manufacturing Environments).

Bruno Vallespir was born in 1960 in Bordeaux, France. He received the Ph.D degree in Automatic Control in 1987. Since 1992, he has been Associate Professor at GRAI/LAP . His research is about enterprise modelling and production management and he wrote several papers on this topic.

Professor Jean Paul Bourrières was born in 1952 in Tarbes, France. He received the Ingénieur degree in Electronics and Automatic Control (ESIEE Paris) in 1976, the Ph.D in Automatic Control in 1979, and the State Docteur ès Sciences degree in 1990. He joined the University of Bordeaux as full Professor in 1993. He is Deputy-Head of GRAI/LAP, where he manages a research team dealing with medium- and short-term manufacturing control.

1. Problem Statement and the State- of- the- Art

Everybody agrees that quality is today one of the main conditions of competitiveness. But it is always difficult to define what the quality of the product implies for the whole manufacturing system and how to act on the manufacturing system in order to improve its quality. It must be kept in mind that the quality system should help the manufacturing system achieve its objectives by respecting the strategic, tactical and operational decisions within the framework of the triplet of performances (quality, cost, delay).

1.1 The State- of- the- Art

Many tools are proposed to companies to help them deal with their *quality problems*. As the evolution of the apprehension of the quality concept is very quick, these tools are presented by grouping them with respect to periods of quality history. It conducts us to group them by functions, the evolution of the quality concept implying the evolution of the quality objectives and therefore the tools achieving these objectives.

The periods will be linked to the dominant growth mode (Gomez, 1994; Hermel, 1989). We can point out three periods.

Taylorism (from 1900 to 1940). All problems can be solved by a scientific approach, a strict application of techniques. Firms deal with a proximity clientele. The work is a planned organization and it is the beginning of mechanization. Regarding quality, we can extract two major ways. Firstly, quality inspection aims at the reaction to situations by detecting defaults. Supervision tools (they can be visual) are found here. Before long, quality gets a regulation role more than a reaction role. It consists in statistical analysis of defects and definition of thresholds of tolerance (metrology). The tools are often mathematical as probability and statistics.

Fordism (from 1940 to 1970). The period is dominated by mass consumption, mechanization and salaried class generalisation, a regulation by the government and a normalization of the working tasks. It is the beginning of quality assurance. The aim is the prevention of defects and the ensurance for the client that he will get what he is expecting to. It is an engagement in order to give confidence. For this purpose, the firms implement organizational and technical procedures which can be shown to the customer. The ISO standards are a guide for the implementation of the quality system and are therefore relevant to this kind of tools.

The' Crisis'. Our period is dominated by the growing of services. The situation is regulated by the market. One speaks of total quality management or world wide quality management. It is a generalization of quality assurance. The client-supplier link is coming into the firm: a process inside the firm is considered as a client of a process and as a supplier for another one. Some methods exist such as the Crosby or Juran ones (Spitz, 1991). They present steps to take when the firm wants to change its way of working for acting in accordance with total quality principles. It helps the firm but there is no real methodology of implementation as the complexity of each firm does not allow a generic method to implement a specific quality system (which would be more efficient).

Beyond these kinds of methods, we can find tools in specific fields belonging to a total quality approach (Ishikawa,1990; Spitz, 1991) such as stimulation and control of creativity (brainstorming, votes), enquiry and analysis (ISHIKAWA cause-effect diagrams, TAGUSHI experience plans,...), comparison and choice (PARETO diagram, decision trees,...), follow- up and measurement (GANTT diagram,...), etc.

We can see that the quality function has moved from an original inspection role with a curative vocation to a more dynamic and preventive role. However, today, we meet all various apprehensions of the quality concept.

1.2. Problem Statement

As the quality concept evolves to a wider concept, the tools get meanwhile fuzzier. A company has to deal with the proliferation of books describing various aspects of the quality concept and associated tools. It leads to a problem which is the difficulty to choose the adequate tool regarding the specific problem which the firm wants to focus on. But the first concern remains the identification of the specific problem worth being solved.

However, many companies are faced with the fact that they must implement a *quality system* to follow new strategic objectives set by today's economic context. Then, several problems come up.

The first one is a bureaucracy effect. A first symptom of it is the consequent paper handling that the quality assurance system leads to. But a deeper aspect is that the *quality system* frequently evolves on its own, inducing inconsistencies that can make the system act against its own purpose of existence by working against the evolution objectives of the manufacturing system itself.

The second problem is that the quality system is too heavy to handle, the costs involved are important and the benefits are not clear: everything that is involved is hardly quantified.

In conclusion, traditional tools are efficient for specific problems. Thus the fact is that there is no tool allowing managers to map the system so that to understand it as a whole and to structure it in a consistent way for defining their requirements in terms of software but also in terms of management methods.

2. GIM: GRAI Integrated Methodology

The term *methodology* employed within GIM[1] (Doumeingts et al, 1992, 1995; Vallespir et al, 1991, 1993) refers to a consistent set of components which are:

- a reference model, globally and generically showing the structure of the system to be studied,
- one or more modelling formalisms, enabling models of the system to be built up in order to study and evaluate it,
- a structured approach, leading step- by- step from an existing system to a future one, taking into account evolving objectives and specific constraints, and
- a set of evaluation criteria, to allow the system to be evaluated from various points of view (control consistency, reliability, etc.).

2.1. Reference Model

A reference model aims at modelling the invariant parts of the manufacturing system and the links between them. It is an a priori model which may be used as a basis for design and implementation. The GRAI model (Figure 1) aims at giving a generic description of what a manufacturing system is, focussing on the control part of this system. The sub-systems appearing in the GRAI model are:

- The physical sub-system (machines, workers, techniques, etc.) transforming the material flow.
- The decision sub-system, split up into decision-making levels, according to several criteria, each composed of one or several decision centres. The *operating system* dedicated to *real-time* control can be distinguished.
- The information sub-system is the link between the decision and physical systems, and the environment; it also aims at transforming and memorizing information.

1 GIM was developed by GRAI, mainly within two ESPRIT projects: 418 (OCS) and 2338 (IMPACS).

On focussing on the decision sub-system, these considerations yield a two-dimension decomposition. A functional decomposition (horizontal), defining the various functions of such a system, and a hierarchical one (vertical) in accordance with time criteria, instituting decision-making levels characterized by the concept of horizons (time intervals within which the result of the decision is relevant) and the concept of periods (time intervals after which the result of the decision must be questioned). These notions generalize the classical levels: long- term, middle- term and short- term.

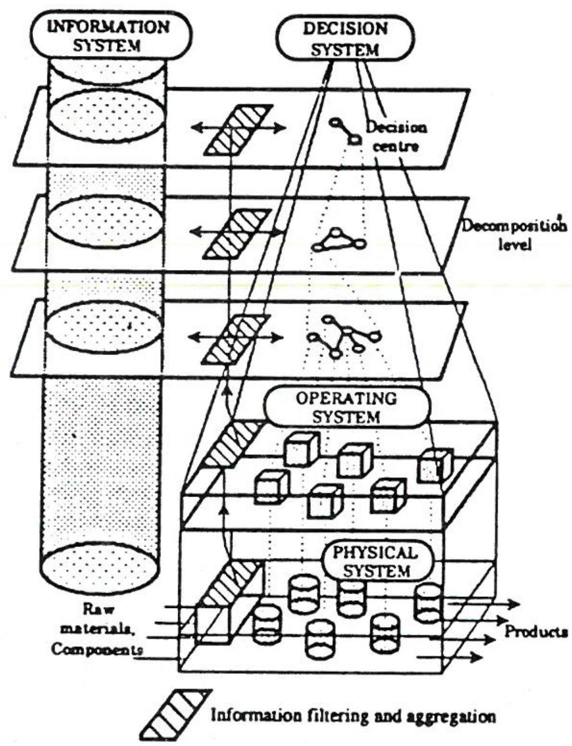

Figure 1. The GRAI Model

This two-dimension decomposition enables the decision centre to be defined: a decision centre contains, as a whole, decisions made within one function and at one hierarchical level. These concepts support the GRAI grid (Figure 2) that aims at the instantiation of the GRAI model on particular cases.

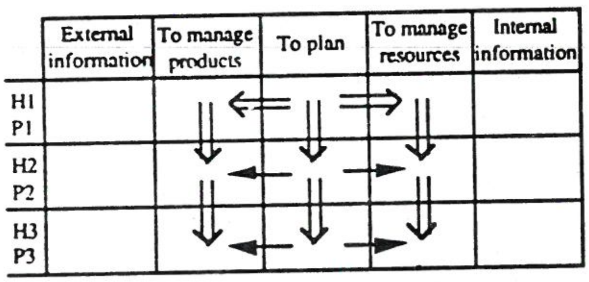

Figure 2. The GRAI Grid: Support for the Translation of Concepts of the GRAI Model on Particular Cases

With the GRAI grid several other concepts can be explained.

Three functions are considered as basic functions in the sense that they are always present: *To manage products* within which any decisions dealing with products are found, *To manage resources* for decisions about resources and *To plan* dealing with both products and resources and aiming at co-ordination and synchronization of *To manage products* and *To manage resources.*

Decision centres are linked by information flows (single arrows) and are linked the same way to environment (through external information) and to the physical system (through internal information). They are linked too by decision frames (double arrows) providing the decision centre which receives with the frame within which the decision must be made. A decision frame is mainly composed of an objective that must be matched thanks to the decision to be made and several decision variables indicating what the decision centre can act on.

2.2. Modelling Framework and Modelling Formalisms

Given the high complexity involved in designing a CIM system, an initial structuring is needed. Various concepts and models therefore need to be defined and built. In order to ensure completeness, consistency and integration between concepts and models, it is proposed to define a modelling framework within which all the models needed for the analysis, design and implementation of manufacturing systems find their places. The modelling framework has two dimensions: view decomposition and abstraction levels.

View decomposition. According to the GRAI model, any manufacturing system may be split up into three systems: the physical system, the decision system and the information system. These three systems provide three views. A *view* can be defined as a selective perception of a manufacturing system which concentrates on some particular aspect and disregards others. To these three views, a fourth one is added: the functional view. The functional view enables a very simple model to be built, showing the main functions of the manufacturing system and the flows (of any nature) moving between these functions. Another interest of this view is to define exactly the boundary of the study domain.

Abstraction levels. The modelling activity implies a simplification of a too complex reality. So, a model retains only concepts and elements which will be necessary at the time of the use of the model. The introduction of abstraction levels allows a *stratified description* in the sense that the model is in fact constituted of several models which integrate specific concepts. In practice, three abstraction levels are proposed in GIM. *Conceptual level,* made up without any organisational or technical consideration, is the most stable level and aims at asking the question *What? Structural level* integrates an organisational point of view and aims at asking the questions *Who?, When?* and *Where?. Realization level* is the most specific level because it integrates the technical constraints of the case studied and enables the choice of real components to be made. Combining these two dimensions gives the GIM modelling framework.

About formalisms, the focus here is on the conceptual level in which we are interested for the purpose of this paper. The needs and formalisms for each case of the modelling framework are as follows.

Conceptual Information Model. This model is a description of all stable and *natural* data of the organization, of their attributes and of the links between them. The formalism used here is the entity / relationship model.

Conceptual Decision Model. This is a description of the decision- making structure, links between decision levels,analysis of links among objectives, analysis of constraints, and a description of decision variables. The formalisms used here are the GRAI grid at the global level and the GRAI nets at the detailed level.

Conceptual Physical Model. This model is a description of the process and routes, with physical flows between operations. The formalism is the IDEFO actigram (also used for the functional model).

2.3. GIM Structured Approach

According to the user requirements of the future system, the goal of GIM is to provide specifications in terms of organization, information technology and manufacturing, which will allow this new system to be built. The structured approach of the method has four main phases: initialization, analysis, design and implementation.

The techniques used to build new manufacturing systems are currently very difficult for the users of future systems to understand, in particular for the information technology domain. In addition, according to the amount of investment necessary to build a new manufacturing system, users need be sure that the design of the new system meets the objectives defined in the user requirements. Thus the design of the new system must be validated by the users before any developments or implementations are started.

Because of these remarks, the design phase has been split up into two sub-phases: the user-oriented design, which provides user-oriented specifications understandable by users, and the technically oriented design, which provides the technical specifications necessary for the development and implementation of the future system. Users validate the user-oriented specifications in order to ensure that the design phase provides efficient solutions appropriate to their requirements.

3. Quality: Definitions and Points of View

3.1. Definition

There are various interpretations of quality, depending on the context of the activities to be considered. Basically, any decision and consecutive action lead to a material or immaterial result whose quality can be discussed. In the field of manufacturing, quality refers directly or indirectly to products.

The notion of product is today often extended to the couple, <product associated services>. For instance, is the quality of a product not delivered in due date good? So for many today's companies, the product means always a product and all services around sold(or provided) with it.

Thus, the definition given by the ISO standards is a common base for everybody: quality is "*the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs*" (AFNOR, 1992).

In this framework, the product is judged by the customer regarding two points: its characteristics (technical quality- criteria quantifying services it provides, fluctuation of characteristics, etc.), and its selling conditions (economical quality-price, delivery and paying conditions, warranties).

But, to reach a convenient level of manufacturing quality clearly involves the whole product development chain in the enterprise: marketing, product design, manufacturing. Quality is therefore a final sanction which results from continuous quality tracking from the initial virtual product (product concept) to the final object delivered to the client. Thus, the previous minimal definition of quality is extendable to the relationship to each step of the process.

However, a practical definition of what the final user really expects is sometimes very difficult to make. In fact, the flow linking raw -materials suppliers to the user of the final product can be long and complex. The customer can be an individual, a firm or local communities. The customer is not always the user: it is the case for a lot of products bought by local communities or dispatched through distributors.

Quality could also mean a search for excellence. In this second case, objectives could be pursued such as to nullify the scrap during manufacturing, reduce inventories in coherence with a minimum of flexibility of the manufacturing system or security requirements, reduce paper manipulation, suppress machine breakdowns, suppress contempt in hierarchical relations, etc.

These objectives are relevant to the enterprise way of running and are not directly linked to the customer's satisfaction. Thus, in our understanding, two views do appear. The first one is customer oriented and is related to quality, the second view is firm oriented and is related to productivity.

But, for many companies, quality means today adequation of final products to user requirements and search for productivity at the same time. Most of the companies are in between those two extremes. What we can see is that the commitment of the company differs a lot depending on the objective chosen.

In the field, quality still remains a wide and fuzzy domain that led ISO to clarifying the subject by identifying different topics for quality mastering. ISO 8402 defines Quality Control, Quality Assurance, Quality System and Quality Management (AFNOR, 1992).

Our aim is not to get a common and unique definition of quality. The objective is more to analyse it and obtain a frame so that most of the companies could recognise and position their way to quality in it. But even though our aim is not to define *Quality Management* in a strict way, we can describe the main activities implied in *making quality*. It will be for us the first step on the way to analysing the management of these activities.

3.2. Quality from An Operational Point of View

The starting point for analysing quality management is to understand what it represents for a company, what actions are launched and what means are used in order to achieve the *quality objectives*. With this view, a characteristic comes out: however managing quality is dealt with, it is a search for matching one or several performances.

If we go deeper into what implies the search for performance within the manufacturing system, two aspects come up: the performance must be measurable and the management parameters of the manufacturing system have to integrate the objectives the company relates to quality.

Thus the main point is that such an environment for decision could only be efficient if the triplet <Objective, Performance to be measured, management parameters> is consistent.

This way of understanding the operational point of view on quality is consistent with the GRAI approach. Within this framework, the following notions come out (Figure 3):

- the objective indicates to the decision-maker the performance which must be reached and comes generally from an upper level of the hierarchy,
- the main management parameters are the *decision variables* (parameters the decision-maker can act on in order to make his decision),
- the decision-making can also be supported by procedures,
- a performance indicator is built up by aggregating information coming from the physical system (follow-up), and

- the triplet <Objective, Decision Variables, Performance Indicator> must be consistent for each decision centre[2].

This leads to the following requirements in order to efficiently take quality into account:

- integrating quality objectives into operational manufacturing objective,
- making performances indicators available thus enabling to follow in real-time performances the company links to quality,
- defining decision variables enabling to efficiently act on aspects linked to quality by the company, and
- providing procedures for decision support (if necessary).

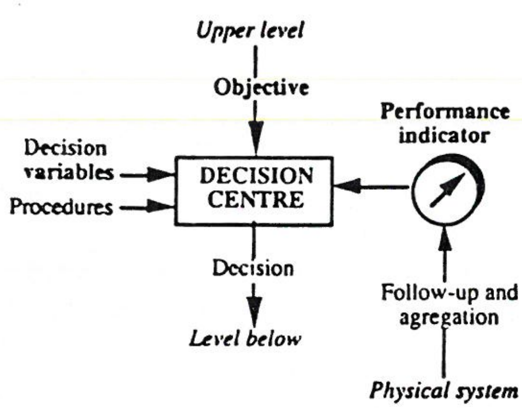

Figure 3. Quality Operational Point of View Through Triplet <Objective,Decision Variables, Performance Indicator>

2 This approach is more developed within the ECOGRAI method the purpose of which is the definition and implementation of performance indicators consistency with the GRAI approach. Doumeingts et al,1995.

3.3. Quality from A Management Point of View

The permanent evolution of the manufacturing environment leads to the necessity to allow the management parameters to live and evolve so that they should fit into the performance needs of the moment. The approach we have shown right before does not allow to take quality into account in that way.

Thus quality must be put into a dynamics of progress and evolution. This statement implies a set of activities such as processing and exploitation of the quality information, checking results, getting knowledge about new performances to be achieved, identifying manufacturing defects or organization weaknesses, and so on.

The basic principle is that this evolution is based on a comparison between the current performances of the manufacturing system and the performances the company wants to achieve. The difference will be the input of a process of evolution of the structure (Figure 4). Two main activities come up: measurement and improvement.

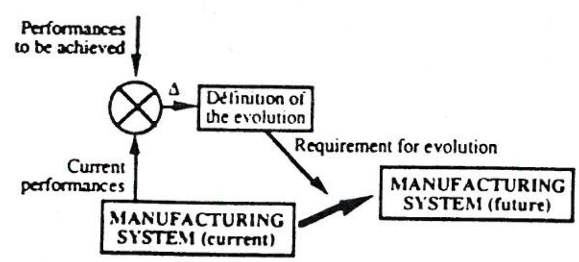

Figure 4. Evolution Principle

Measurement. Measurement can be done at different levels: product, process and control.

The product must be measured at any level: inside the physical system but also as an input and an output. In this way, we come to evaluate suppliers' capabilities (product as an input) and customers'satisfaction (product as an output). All these levels are complementary to obtain the final quality. At the customer level, quality will be measured, for example, with satisfaction indicators or the rate of favourable answers to a questionnaire. At the product level, the measures are defined regarding characteristics to reach such as disfunction indicator, rate of product sent back,... At the process level, the indicators can be the scrap rate, mistakes, machine breakdowns,... The objective of measurement is to find a way to get a realistic view on the status of the manufacturing system. The knowledge of the status will lead to launching actions in order to improve the system.

Improvement. The knowledge of the status of the system will allow to act on specific parts of it in order to prevent problems or to improve these parts. To do so, the necessary actions must be defined and data analysed to correct or to improve processes at specific stages. Various functions of the company are to be concerned with improvements. They will be able to define the actions to be launched. That evolution may be asked to each of the three sub- systems of the manufacturing system:

- physical: replacement of a machine, enhancement of operators'capabilities (teaching), etc.,
- information: re-definition of information flows, modification of technical data (bill of materials, routes), etc.,
- decision: modification or change of procedures, decision variables, etc.

The following up of the actions launched through the quality system should also be part of the quality system.

Quality management. Our model should have the capability to show the management of these activities. As we have shown above, there is a tight link between manufacturing control and quality management. One of our concerns is the integration of the manufacturing control and the quality management.

On the other side, the concepts specific to the generic model of manufacturing (GRAI model) are usable to define a generic structure of any control system. Our idea is so to use the same approach for the quality system.

So far, the GRAI model is dedicated to systems transforming products. An immediate activity different from a transformation of raw- material, belonging to the quality system, is the writing of quality procedures. Companies concerned with quality assurance or having to answer security standards as with nuclear power stations, are familiar with the writing of procedures. This activity takes quite a lot of means but there is no raw -material transformation: the result is informational. This establishment takes us to generalize the notion of physical system to the notion of quality process.

As a conclusion, the quality system owns a management system that aims at the control of a quality process, that is of a set of activities. These activities use two main inputs: current status of the manufacturing system and new performances to achieve. They lead to an output which is global and asks for evolution.

Strategic issue. The need for integration of quality system and manufacturing system leads to an upper level of control assigning the global manufacturing objectives to the manufacturing system and the performances to be achieved (cf. Figure 5) to the quality system. From this point of view, we see the need that the strategic level (business planning) co-ordinates both systems in order to have a coherent decisional structure for the whole system.

Figure 5 summarizes these notions within a global model. In this Figure, two loops appear. The first one (1) is relevant to the operational point of view while the second one (2) is relevant to the quality management point of view. It must be kept in mind that this model is conceptual and so the splitting of quality and manufacturing systems leads to nothing at all about people involved. We can find people involved only in quality in some cases or involved in both systems in other cases.

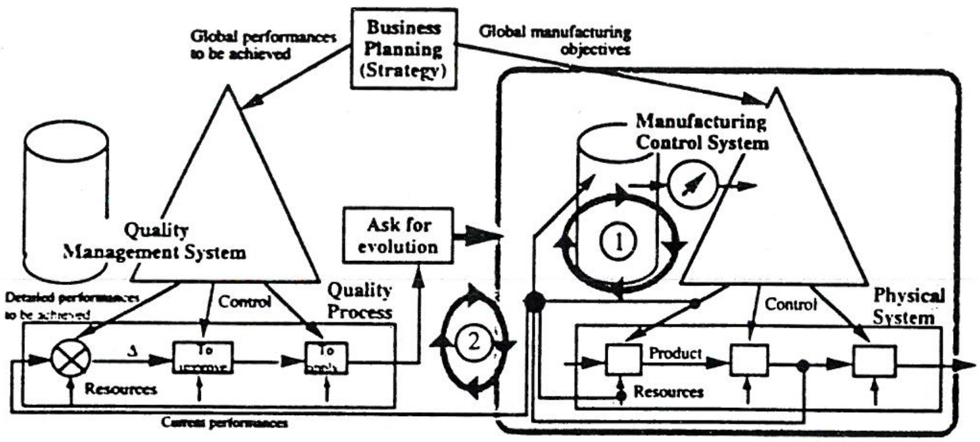

Figure 5. Generic Model

4. Structures Positioning Quality Management

In the previous chapter, the quality system was introduced as an autonomous system (Figure 5). The main reason is that the quality system has its own dynamics. In fact, the same way the dynamics of the manufacturing system is related to the throughput time, the dynamics of the quality system is the time the quality process lasts. Thus, if we want to represent the control of this general situation by using GRAI grids, two independent ones are obtained (Figure 6).

However, a simpler structure can be imagined. This structure puts quality management and manufacturing control together in one control system. This structure assumes two aspects: quality management and manufacturing control must be synchronized and the evolution of the manufacturing system led by quality decisions must be only qualitative, i.e. the evolution must not have an impact on the structure at the level of

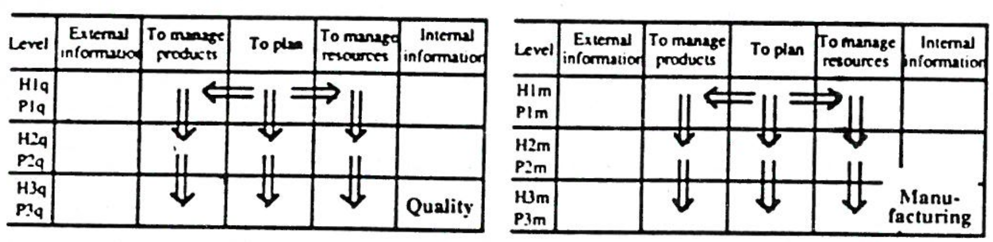

Figure 6. Quality Management Independent of Manufacturing Control in the General Case

the concepts the GRAI grid deals with.

With these assumptions, a structure such as that in Figure 7 is possible.

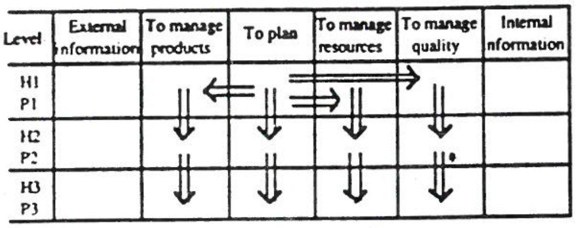

Figure 7. Structure with Quality and Manufacturing Systems Synchronized

Another structure is also possible, closer to the first one (Figure 6) but it is related to cases where the quality system implements its decisions through large projects. In this case, the upper part of the control is dedicated to the global quality management, the control part related to shorter terms is dedicated to specific projects. Each project has its specific control system co-ordinated by the common upper part (Figure 8). This structure assumes that each project owns specific resources. On the contrary , the first structure is more relevant (Figure 6).

5.The ESPRIT MULTIMAN Project

The overall aim of MULTIMAN is to provide an integrated IT based solution for the support of quality management in multisite manufacturing environments. As such, MULTIMAN intends to meet the needs of industrial Europe which is faced with an ever increasing quality-based competition from the world market. Consequently, the industrials involved in the project belong to distributed multisite manufacturers: PIRELLI and VALIO which are representatives of dominant discrete industries and dominant process industries respectively.

So far,the objective of the work being done is the identification of the information flows and decisional processes relevant to quality management at individual factory level. Just from the beginning of the project, the need appeared for better conceptualization of quality management.

First based on the analysis of the quality management problem as seen by the industrials involved in the project, in their respective manufacturing system, tasks have so been oriented towards a triple perspective: better explanation of the quality management strategy and procedures in both industrial cases, extrapolation towards reference structures of quality management, in order to provide a reference frame for the modelling of site-level quality systems and better correlation of quality tracking, as a medium - and long- term task, and tracking of other manufacturing goals.

The first step of our approach was to obtain a functional model of the quality activities (using the IDEFO formalism). This functional model is built with a conceptual view (the activities can be dispatched to different services or persons, they can also be grouped depending on the organisation of the company). The functional model (Figure 9) has been obtained.

To follow. It aims at obtaining the current status of the manufacturing system (as-is status): real time physical process control, internal audits, control of the measurement equipment,...

To collect/understand customer's requirements. The goal is to know what the status of the manufacturing system required is (to-be status): the use of specific software in order to collect and store customer's complaints, launch special questionnaires on some products,...

To develop. The main activities here are re-thinking of the existing system and searching for solutions: to develop a software (for instance access database) able to collect customer's complaints, change parameters in the physical process, change quality procedures,...

The activities presented are related to the quality process of the quality system. In order to identify the functions of the quality management, we have defined what are the necessary means , what is to be processed, what actions to launch so that to make sure that the means are there in time and when we must launch these actions.

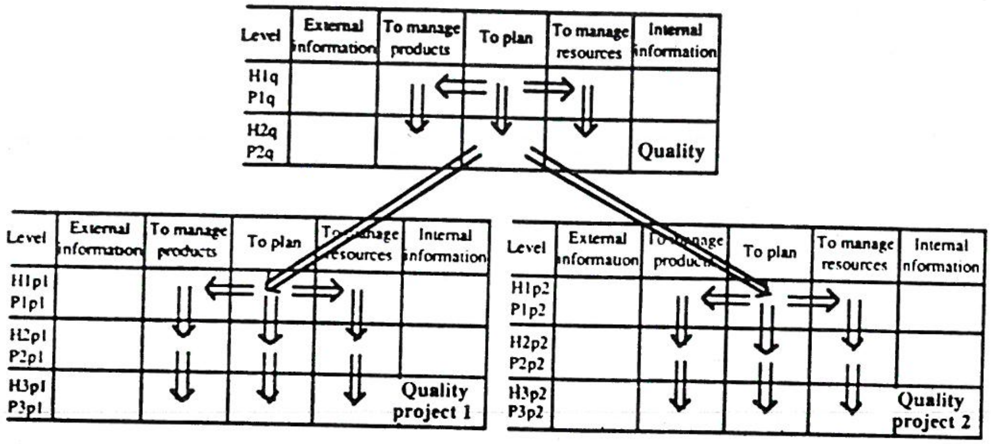

Figure 8. Quality Management and Specific Project Controls

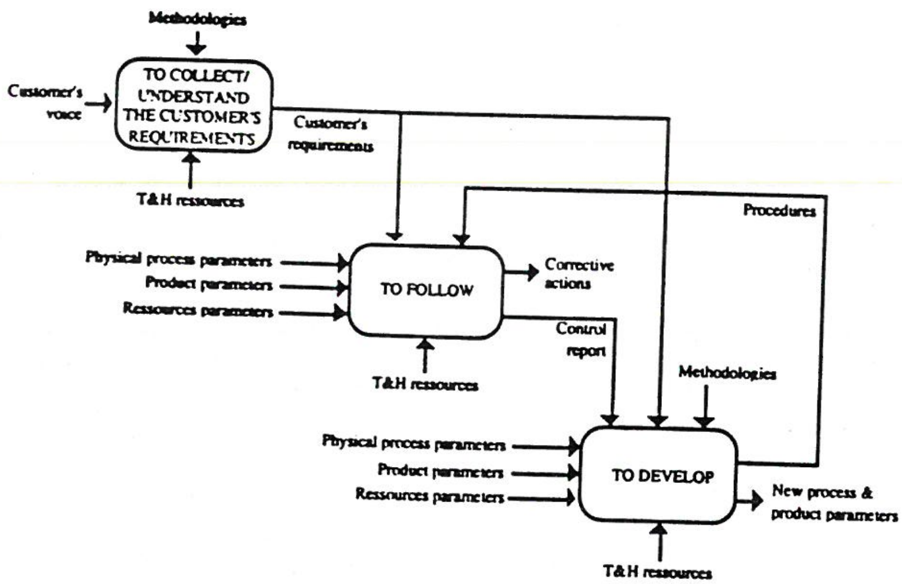

Figure 9. Functional Model of Quality Activities

Thus we have searched for products and resources in order to obtain the functional decomposition described in the GRAI model: *To manage resources. To manage products* and *To Plan.* The latter ensures that the means needed for the quality process will be there in time. Our aim was also to identify the quality management activities and to classify them according to functional and temporal (when possible) criteria.

In a top-down approach, with a GRAI grid, we have identified the main decisions on manufacturing control and quality management (Figure 10). The decisions of both sub-systems (quality sub-system and production sub-system) being synchronized, we have used the same grid to model them both. This way, the integration of the two sub-systems appears more clearly.

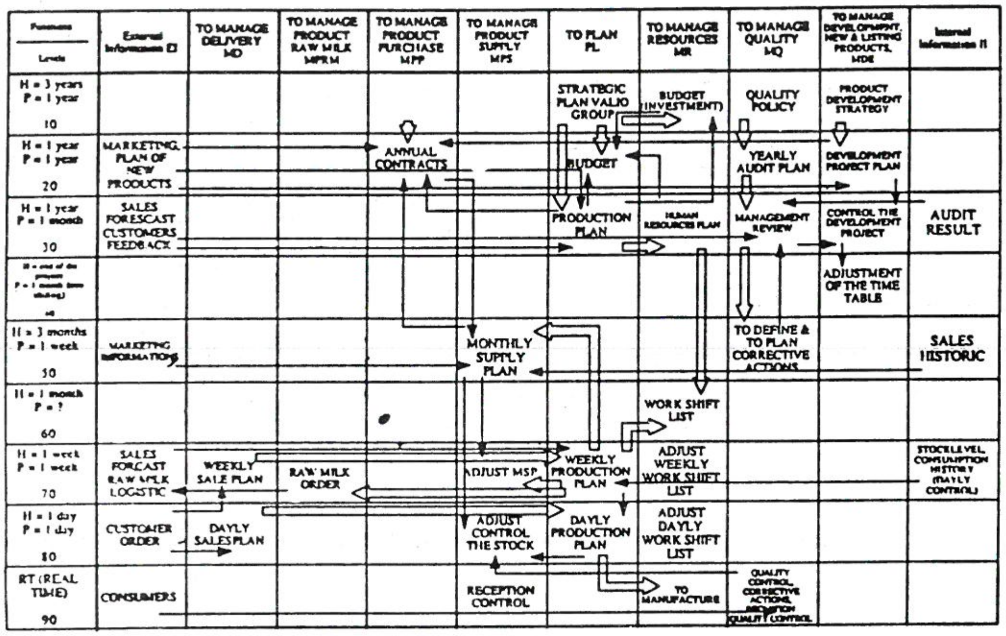

Figure 10. GRAI Grid of Manufacturing Control and Quality Management

6. Conclusion

Our work on the quality concept has reinforced us on the complexity of the subject. Depending on the objectives of the company, improvement of the global performance or punctual action on a specific problem, the impact of the quality activities is hardly foreseeable on the whole production system. Our approach of the problem is motivated by the following objective: to model quality management by integrating it with the production management system. The use of the GIM methodology has allowed an integrated view. However, questions still remain. The evaluation of the expressed and implied needs, which is a starting point for the evaluation of quality, raises many questions. And they imply other ones if we generalize the supplier-customer relationship to relationships inbound the company. Regarding the structures presented, other studies with industrials are needed to validate and enrich the models.

REFERENCES

AFNOR (1992-1). **Gérer et assurer la qualité-Tome 1: concepts et terminologie, recueil de normes françaises,** AFNOR normes, 1992, 394 p.

AFNOR (1992-2). **Gérer et assurer la qualité-Tome 2: management et assurance de la qualité, recueil de normes françaises,** AFNOR normes, 1992, 376 p.

DOUMEINGTS, G., VALLESPIR, B., ZANETTIN, M. and CHEN, D., **GIM, GRAI Integrated Methodology- A Methodology for Designing CIM Systems,** Version 1.0, University of Bordeaux I, LAP/GRAI, 1992, 62 p.

DOUMEINGTS, G., VALLESPIR, B. and MARCOTTE, F., **A Proposal for An Integrated Model of A Manufacturing System: Application to the Re-engineering of An Assembly Shop,** CONTROL ENGINEERING PRACTICE, Vol.3, No. 1, Pergamon Press Ltd, 1995, pp. 59-67.

DOUMEINGTS, G. and VALLESPIR, B., **A Methodology Supporting Design and Implementation of CIM Systems Including Economic Evaluation**, in P. Brandimarte and A. Villa (Eds.)Optimization Models and Concepts in Production Management, GORDON & BREACH PUBLISHERS, 1995, pp. 307-331.

GOMEZ, P.-Y., **Qualité et théorie des conventions**, ECONOMICA, 1994, 270 p.

HERMEL, P., **Qualité et management stratégique- du mythique au réel**, Les éditions d'organisation, 1989,160 p.

ISHIKAWA, K., **La gestion de la qualité-Outils et applications pratiques.** DUNOD ENTREPRISE, 1990, 242 p.

SPITZ, B., **Forces productives et qualité totale-Approche systémique**, ESF éditeur, 1991, 250 p.

VALLESPIR, B., CHEN, D., ZANETTIN, M. and DOUMEINGTS, G., **Definition of A CIM Architecture Within the ESPRIT "IMPACS" Project**, CAPE'91: the Fourth IFIP Conference on Computer Applications in Production and Engineering, Bordeaux, France, September 10-12, 1991, Amsterdam, NORTH-HOLLAND, pp. 731 - 738.

VALLESPIR, B., MERLE, C. and DOUMEINGTS, G., **GIM: A Technico-economic Methodology To Design Manufacturing Systems**, CONTROL ENGINEERING PRACTICE, Vol.1, No. 6, Pergamon Press Ltd, 1993, pp. 1031-1038.