STRUCTURAL ANALYSIS WITH THE MICMAC METHOD & ACTORS' STRATEGY WITH MACTOR METHOD

by[1]

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I. INTRODUCTION: THE SCENARIOS METHOD AND THE PROSPECTIVE TOOL-BOX[2]

For the last thirty years, impact matrices have become one of the most commonly used tools of the futures field. With the objective of investigating systems and their dynamics, impact matrices can be divided into three categories: structural analysis, actors' strategies, and probabilistic cross-impact matrices. In structural analysis, these impacts deal with variables (Kane's KSIM or Godet's MICMAC, both in the early seventies). With actors' strategies, they concern actors and their objectives (Ténière-Buchot's chart of powers, Godet's MACTOR, in the late eighties). In probabilistic models, developed from the late sixties and improved in the early seventies, they combine events and hypotheses (original model by Gordon and Dalkey, Battelle's Explor-Sim, Godet's Smic-Prob-Expert or Martino's Maxim) and sometimes trends that seem to be variables (Enzer's Interax).

Within the framework proposed by Michel Godet in his scenario method (see Figure 1), this paper will present more precisely the first two families: structural analysis and actors' strategies.

Scenarios and the prospective[3] tool-box: the place of structural analysis and actors' strategies

Mostly based on impact matrices, the prospective tool-box developed by Michel Godet and French prospective research and consulting teams since the mid-seventies, is a scenario-oriented combination of techniques.

The strategic prospective process comprises three major stages: construction of the basis, identification of major issues at stake, and construction of scenarios.

1) Construction of the basis and identification of essential variables

At this stage, the method consists of laying down and analyzing the system under study. The purpose of this step is to identify focal points and questions which represent stakes for the future and around which the actors could build their strategies. Structural analysis is the main tool at this stage of the process.

2) Identification of major issues at stake and key questions for the future

At this second stage, the point is to decipher the actual mechanisms regulating the existence and evolution of certain variables. Taking into consideration the actors' strategy at this stage allows one to better understand the evolutions noted, and to widen the range of future evolutions. Certain issues at stake can appear to be potentially generating alliances or conflicts. They will be determinative in the future. Therefore the formulation of key questions relevant for the long-term

[2] See also *A Tool-Box For Scenario Planning*, Chapter 26, on this CD-ROM

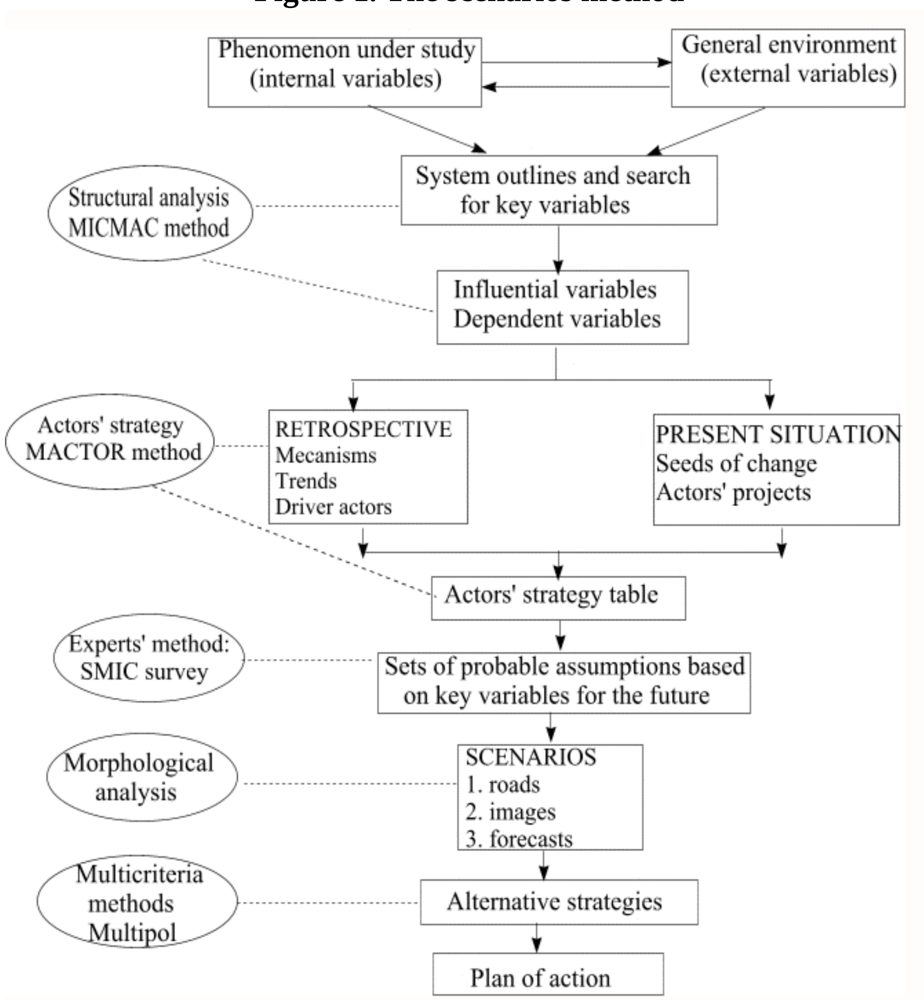
[3] "Prospective" is used in this version where "prospectif" was in the original French; "foresight" or "future studies" are close translations, but not exactly synonymous, since prospective or prospectif in the French and Latin-based languages also implies the state of awareness resulting from the research that stimulates action.

evolution of the system under study is vital.

3) Elaboration of exploratory scenarios

A scenario is made up of a set of plausible hypotheses for each of the key questions. The objective will be first of all to explore, and then reduce the "space of scenarios" (morphological analysis), taking into account the exclusions stemming, for example, from possible incompatibilities between certain hypotheses. The question arises, then, of how coherent are the scenarios thus preselected. The method used (SMIC Prob-experts) consists of asking the participants about each hypothesis's probabilities of simple and conditional occurrence. Their answers will allow deducing the various scenarios' global probabilities. Consequently, exploratory scenarios will be chosen from
among the most probable ones.

Figure 1. The scenarios method



Source: Godet M., *From anticipation to action*, UNESCO Publishing, 1994.

These scenarios are thus built with no a priori objective. However, they will allow marking out the long-term freedom space of a major actor such as the one who leads the study. So, they will be crucial for the elaboration and determination of strategic options. On the other hand, the strategic options will convey an intention – some objectives – as well as the pursuit of a wished-for future.

One must bear in mind that to each stage of the process correspond specific tools. First of all, they act as a medium for the process's development. In addition, they have a modular character and can be rearranged and applied (or not) depending on the circumstances.

The present document is focused mostly on the method and on the tools associated with the first two stages: structural analysis and actors' strategies.

II. IDENTIFYING THE KEY VARIABLES: THE MICMAC METHOD

1. Historical background of structural analysis

Structural analysis is, besides the method of scenarios, one of the most used tools in futures studies. Claiming to have its inspiration in the systemic approach, structural analysis experienced a real boost no earlier than the late 1960's. It is probably Jay Forrester, through his works on models of industrial dynamics, and then urban dynamics (1961), who was the originator of the first justifications of structural analysis. This approach was at its peak with the publication of the "Club of Rome" reports, and in particular "Limits of growth." At the same time, the necessity of taking into account multiple and homogeneous, qualitative and quantitative variables, induced the pioneers of structural analysis to use other modes of representation based on matrices and charts. In this perspective, Wanty and Federwish (in "Global Models for Business Economics") applied this approach in the cases of an iron and steel company and an air transport company. A little later, Ténière-Buchot (1973) analyzed under Wanty's supervision the "water" system and published an article about a model concerning a Policy of Water Pollution. In the same period, Kane introduced the KSIM model which, although closely related to Forrester's industrial dynamics, is nevertheless a structural analysis method.

For his part, Roberts led work for the National Science Foundation in the USA designed to bring indirect relationships to light, with applications in energy and energy-related pollution in transports.

It was in 1974 that Godet and Duperrin suggested an operational method to rank a system's elements, in the framework of a futures study on nuclear energy in France. The method makes up most of the art as far as structural analysis is concerned. It also led, despite the profusion of studies started since then, to a certain standard in the field.

Structural analysis experienced since the middle of the 1980's an increasing number of applications in various domains, within businesses as well as on society-related topics.

2. Presentation of the method

2.1. Objective and stages

Structural analysis is a tool designed to link up ideas. It allows description of the system thanks to a matrix which links up all its constituent elements. By studying these relations, the method enables emphasizing of the variables that are essential to the system's evolution. It has the advantage of stimulating reflection within the group, and leading it to think about certain aspects that are sometimes counterintuitive. It applies to the qualitative study of extremely different systems.

The system under study presents itself in the form of a group of interrelated elements (variables/factors). The web of these elements' interrelations,, i.e. the system's configuration (structure), constitutes the key of its dynamics and remains quite permanent. Structural analysis, which aims at bringing this structure to light, takes place in three stages:

1) the inventory of variables / factors
This stage, which is the least formal, is crucial for the rest of the process.

2) the description of relationships between variables
During this second stage, the point is to reconstitute and describe the web of relations between variables / factors.

3) the identification of essential variables
This last stage consists of identifying essential variables and key factors to the system's global dynamics.

2.2. The inventory of variables

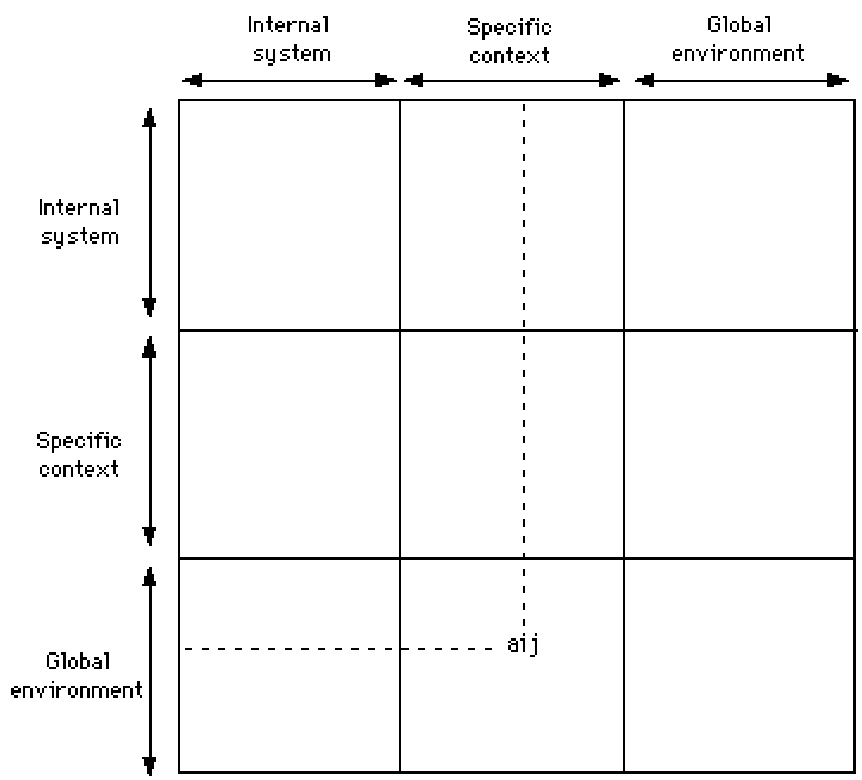
The first task must be to define the study's scope, and therefore that of the system to be analyzed. The second stage then consists of making an inventory of all variables and/or factors, internal or external, that characterize the system. It is advisable at this stage to be as exhaustive as possible, taking care to avoid leaving anything in the dark while describing the system. Besides meetings for reflection and brainstorming, it is advisable to fuel and consolidate the determination of variables through non-directed interviews with experts. Other interviews should be held with professionals possessing an outstanding knowledge of the players who presumably take part to the system. In a second stage, one must set up the list of variables, complete it if needed, and possibly group, split, or even eliminate some of them so as to get a homogeneous list. This list should not normally extend beyond 80 variables. After a first classification of variables into categories allowing the drawing of a closer distinction between internal and external variables, one must establish a glossary. The latter is designed to formalize the variables' consensual meaning within the group. Although the designations must be simple enough to avoid any wrong interpretations, they must also be easily understandable for people outside the group. For each variable, the glossary must finally include: its definition from the group's point of view, a mention of the problems it raises, and some indications of its evolving tendencies in the past and possibly in the future, as well as an assessment of possible breaks in the tendencies assumed, wished, or feared.

Although the elements describing variables are essential before dealing with the later stages of the process, it is important to stress that the list is not yet frozen at this stage, since the glossary's elaboration lasts until the end of the futures study, and even more so because any discussion of problems arising during the listing of variables can enrich the glossary. This stage is fundamental in the sense that it represents an exceptional opportunity to build up within the group a common reference to represent, and then understand the system. Moreover, it encourages a valuable breakup of partitions, as well as a cross-fertilization of the participants' points of view. The identification of relationships between variables will be considerably improved, thus stimulating the appropriation process within the group.

2.3. Description of relationships between variables

The method consists of linking up variables in a double input chart, the structural analysis matrix (see figure 2), specially prepared for the case. The rows and columns in this matrix correspond to the variables stemming from the first stage. For didactic purposes, they can be arranged, for example, according the three subgroups, respectively corresponding to: the global environment, the specific context, and the internal system.

Figure 2. The structural analysis matrix



The distinction among these three subgroups is indicative. It reveals different blocks within the matrix, allowing us to understand it and fill it up easily. Thus:

- diagonal blocks include the relationships of each subgroup's variables with themselves (intragroup influences). These blocks therefore represent the description of the subsystems concerned.
- Non-diagonal blocks correspond to the relations between different subsystems' variables (intergroup influences).

The work consists of taking into account only direct influences between variables taken in pairs. One will endeavor, not only to detect the influences' existence, but also to grade their intensity through qualitative evaluations such as : strong (grade 3), average (grade 2), weak (grade 1) or potential.

More exactly, each a_{ij} element in the matrix is specified as follows:

- with a grade (from 1 to 3) in the square located at the intersection of row i and column j, if variable i has a direct influence on variable j.
- if not, the square remains empty. By convention, therefore, diagonal squares must remain empty.

Filling up the matrix is done line by line. For example, for variable number "i" (row number "i"), one will systematically assess whether it acts directly on each of the other variables. This implies, for a matrix with 70 variables, raising a total number of almost 5000 questions, some of which would probably have been overlooked had not such a systematic and exhaustive reflection taken place.

Before concluding that a relationship between two variables exists, the strategic prospective think group must avoid in particular:

the specification of direct relations from variable i to variable j and also j to i. In this case, the group will have to favor the relation which seems most direct and/or most operational (i.e. in an inductive rather than deductive way); the double direct relationship can only be kept in the final analysis

recording a direct relation from i to j, when the influence from i to j rather goes through another variable on the list

considering a supposed influence from i to j, or vice versa, if these two variables' apparent colinearity (correlated evolution) is due only to the fact that a third variable acts at the same time on both of them.

This interrogation process allows not only the avoidance of mistakes but also arranges and classifies ideas by creating a common language and a shared understanding within the group. It also offers the possibility of redefining certain variables (if needed), and therefore refining the system's analysis.

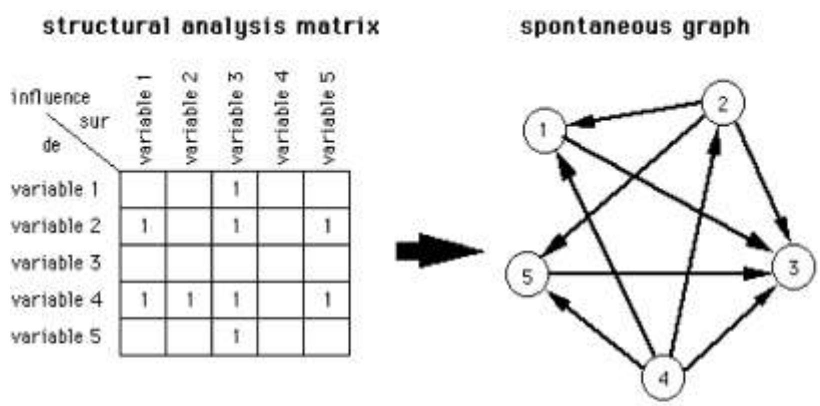
Experience shows that a satisfactory average ”filled in” value for the matrix is around 20%. However, this value is quite a bit higher for diagonal blocks in the matrix, and in particular for that one corresponding to the internal system.

2.4. Structuring the web of interrelations

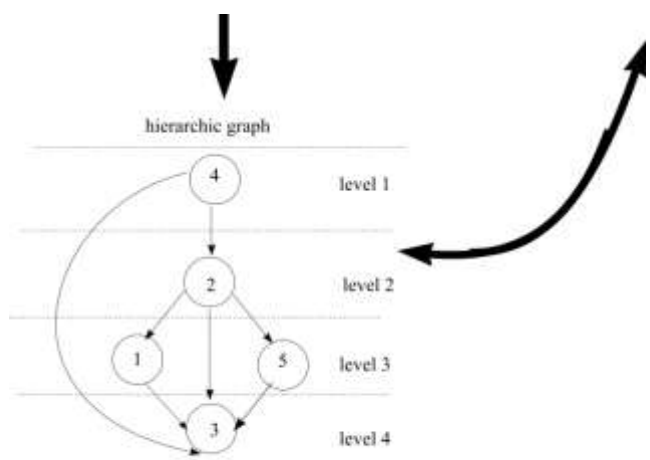
Any chart describing the logic behind interrelations (structural analysis matrix) can be put in the form of a graph whose nodes correspond to the variables and whose arrows correspond to the filled-up cells in this matrix, as indicated (spontaneous graph) in figure 3 below.

But this graph's presentation should improve understanding of the system. So, this graph must be constructed in such a way that it can contribute, in a flash, to untangling the interrelations web: i.e. it must communicate more than the original matrix. From this perspective, it must be able in particular to show the structure in the influences web, if possible through a ranking of variables by successive levels of propagation (hierarchic graph).

Figure 3. The structural analysis matrix and its graphs



In this framework, one can use a simple algorithm to turn a graph into a hierarchy in the shape of a tree.



This algorithm, whose stages are described in frame 1 hereafter, can moreover be realized without necessarily using information processing tools.

Frame 1: Process to organize the variables into a hierarchy

The algorithm proposed hereafter is based on the exploitation of the structural analysis matrix.

1. Determination of variables/factors which receive no influence (empty columns in the structural analysis matrix)
2. Graphic placement of symbols representing the variables concerned, which will constitute the roots of the trees to be drawn
3. Removal of the variables concerned by deleting rows and columns corresponding to them in the matrix
4. Repetition of the process until no variables are left
5. Transcription of direct influence relationships in the matrix in the form of arrows, and perfecting of the resulting diagram

However, organizing a graph into a hierarchy is not always possible. In fact, if the graph contains a cycle, i.e. any variable is at the same time a cause and a consequence of other variables included in the graph, that variable cannot be assigned to any level and the so-called tree cannot be built.

To bypass this difficulty, it is advisable to try and neutralise the cycles, under the condition, of course, that they have been systematically identified. Another algorithm (see frame 2 hereafter) provides for answering this concern.A cycle’s variables are interlinked, which means any influence exerted on one of them affects the whole of the others and vice versa. For this reason, one may consider these variables as closely interwoven and thus rather homogeneous. This homogeneity goes as far as the role they can play in the system's dynamics or the evolution of the question studies are concerned. Therefore the name of "closely related component" is given to such a subgroup of variables.

Frame 2: Process to partition a graph into closely related components

This algorithm can also be carried out on the basis of the structural analysis matrix. The stages are as follows :

1/ choice of any variable in order to initiate the process. It will be considered as the initial root.

2/ setting up two lists of all variables respectively influent on, or influenced by, the initial variable

3/ identifying variables of the component which are closely related to the initial variable, by picking those which belong at once to both lists mentioned above.

4/ removing variables (rows and columns) of the component thus identified

5/ repeating the process until no variable is left

6/ closely related components including more than one variable correspond to cycles in the graph. These circuits are replaced by macro variables.

Then, the cycles neutralization method consists in replacing all variables of each closely related component with a macro variable. A clear designation of these macro variables is all the easier because they include variables which are closely interrelated and therefore functionally homogeneous.

What is most interesting in the theory of graphs is that the simplified graph thus achieved after integrating macro variables can still be organized into a hierarchic tree.

However, this result is not always so interesting since, if most variables are grouped in one same "major strongly related component", then this hierarchy is no longer important. In the extreme, all of the issue's studied variables would be part of one same related component. This would mirror an extremely entangled nature of the system studied.

2.5. Visualization of variables in the influence × dependence plane

In a very intuitive way, a variable's direct influence is evaluated by considering the lines in the structural matrix (action of a variable in a row on all other variables in the columns). A variable acting only on a small number of variables exerts its direct influence on a rather limited part of the system. Equally, direct dependence on a given variable is obtained by considering the columns in the matrix: i.e. the whole of the direct influences exerted on it by the system's other variables. Thus, by systematically adding up the elements in each row, and then in each column in the structural analysis matrix, one gets for each variable indications as to its potential influence and dependence (respectively) in the overall system.

All variables in the system and in its environment can be visualized through their positioning on a perception graph (or influence-dependence plane). According to this form of perception (see chart 3 below), each variable is visualized in the shape of a point identified by its sequential number. This point has for an ordinate the variable's indicator of influence, and for an abscissa its indicator of dependence.

However, a variable can exert influence on a limited number of other variables/factors, which in turn strongly act on the whole of the system. Although its direct influence is weak, it can be increased manyfold through particularly strong variables dependent on it. In order to take this type of relation into consideration, it is advisable not only to try and evaluate direct relationships stemming from one variable,,but also to consider relationships featuring indirect propagation of the variable's influence through a feedback effect (through paths and loops) in the web of interrelations characterizing the system studied.

The MICMAC method, finalized by Michel Godet and consisting in raising the structural analysis matrix to the power of successive values (from 1, 2... up to n), aims at solving this problem.

Let us suppose, to make things clear, that structural analysis matrix A comprises only zeros and ones, i.e. that the intensity of relationships is not taken into account. Generic term a_{ij} of this matrix allows identifying the existence of an arrow of influence (path of length 1) from variable i to variable j. We can demonstrate, by analogy with the previous remark, that the generic element situated at the intersection of line number i and column number j in matrix A raised to the power of n, is equal to the number of paths of length n linking these two variables. The MICMAC software thus calculates the matrix raised to successive powers (1, 2,... up to n) of A. At the end of this process, we obtain a new matrix in which each element corresponds to the number of propagation paths (whose length is less than or equal to n) and thus the direct and indirect influence from variable i to variable j.

Thousands possibly millions of paths are thus identified and explored in the case of most concrete systems. This goes far beyond our mental capacity. This way, the sum of elements in the rows and columns in this new matrix indicate, as for the initial structural analysis matrix, corresponding variables' respective capacity of influence and of dependence. However, this time, they allow taking into account not only direct relationships (simple arrows) but also indirect ones (feedback effects through paths and loops).

Generally, the ranking of variables according to influence or dependence indicators is becoming stable by the time paths of length 4 to 5 are taken into account. This is the reason why matrix multiplications made by MICMAC do not go beyond the power of 9.

2.6. Interpretation of the influence × dependence chart, and typology of variables

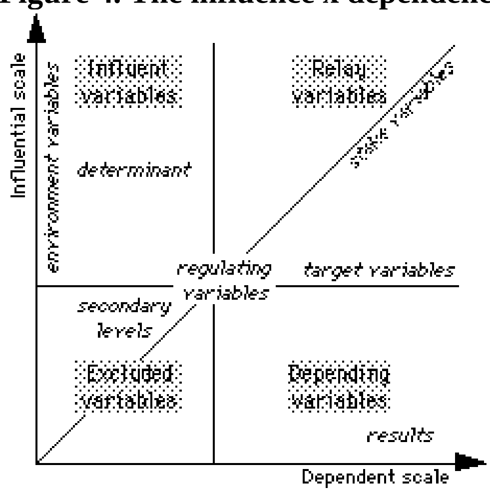
The variables characterizing the system under study and its environment can be projected on the influence × dependence chart. The cloud of points' repartition in this plane and in particular with respect to the various frames set around their center of gravity allows determining four categories of variables. These categories differ from one another depending on the specific role the variables they include can play in the system's dynamics.

- Determinant or “influent” variables. They are altogether very influent and little dependent. Most of the system thus depends on these variables, located in the north-west frame of the perception chart. The influent variables are its most crucial elements since they can act on the system depending on how much we can control them as a key factor either of inertia or of movement. They are also considered as input variables in the system. Among them, there are most often environment variables which strongly condition the system, but in general cannot be controlled by it. They will act rather as a factor of inertia.

- Relay variables. They are at the same time very influent and very dependent. These variables situated in the north-east frame of the chart are by nature factors of instability since any action on them has consequences on the other variables in case certain conditions on other influent variables are met. But these consequences can have a boomerang effect which either amplifies or forestalls the initial impulse. Moreover, it is advisable to distinguish within this group among:

- the stake variables, more precisely located around the diagonal, which will have strong chances to arouse the lust of major actors, since, given their unstable character, they are potential fracture points for the system ;
- the target variables, situated under the diagonal rather than along the north south frontier, are rather more dependent than influent. Therefore, they can be considered, to a certain extent, as resulting from the system's evolution. However, a willful action can be conducted on them so as to make them evolve in the desired way. Thus, they represent possible objectives for the system in its entirety, rather than wholly predetermined consequences.

Figure 4. The influence x dependence chart



- Depending variables, or rather, result variables. These variables, located in the south-east frame of the chart, are at the same time little influent and very dependent. So, they are especially sensitive to the evolution of influent variables and/or relay variables. They are exit variables from the system.

- Autonomous or excluded variables, which are at once little influent and little dependent. These variables are situated in the south-west frame, and appear quite out of line with the system since they act neither to stop a major evolution undergone by the system, nor to really take advantage of it. However, a distinction must be drawn within this group between:

- disconnected variables situated near the axis's origin, whose evolution therefore seems to be rather excluded from the system's global dynamics.
- secondary levers which, although quite autonomous, are more influent than dependent. Variables concerned are located in the south-west frame, quite above the diagonal, and can be used as secondary acting variables or as application points for possible accompanying measures.

Finally, one last type of variables deserves being quoted, less for its intrinsic definition than for its original situation with regard to the other types presented above. They are the regulating variables, situated mostly in the system's center of gravity. They can successively act now as secondary levers, now as weak objectives, now as secondary stakes.

It is particularly advisable to compare the positions of variables stemming from the direct and indirect (MICMAC) classifications, for example by superimposing them on a single causal-function × dependence plane. This presentation has the advantage of qualifying the global, but quite superficial, evaluations made of variables (direct classification).

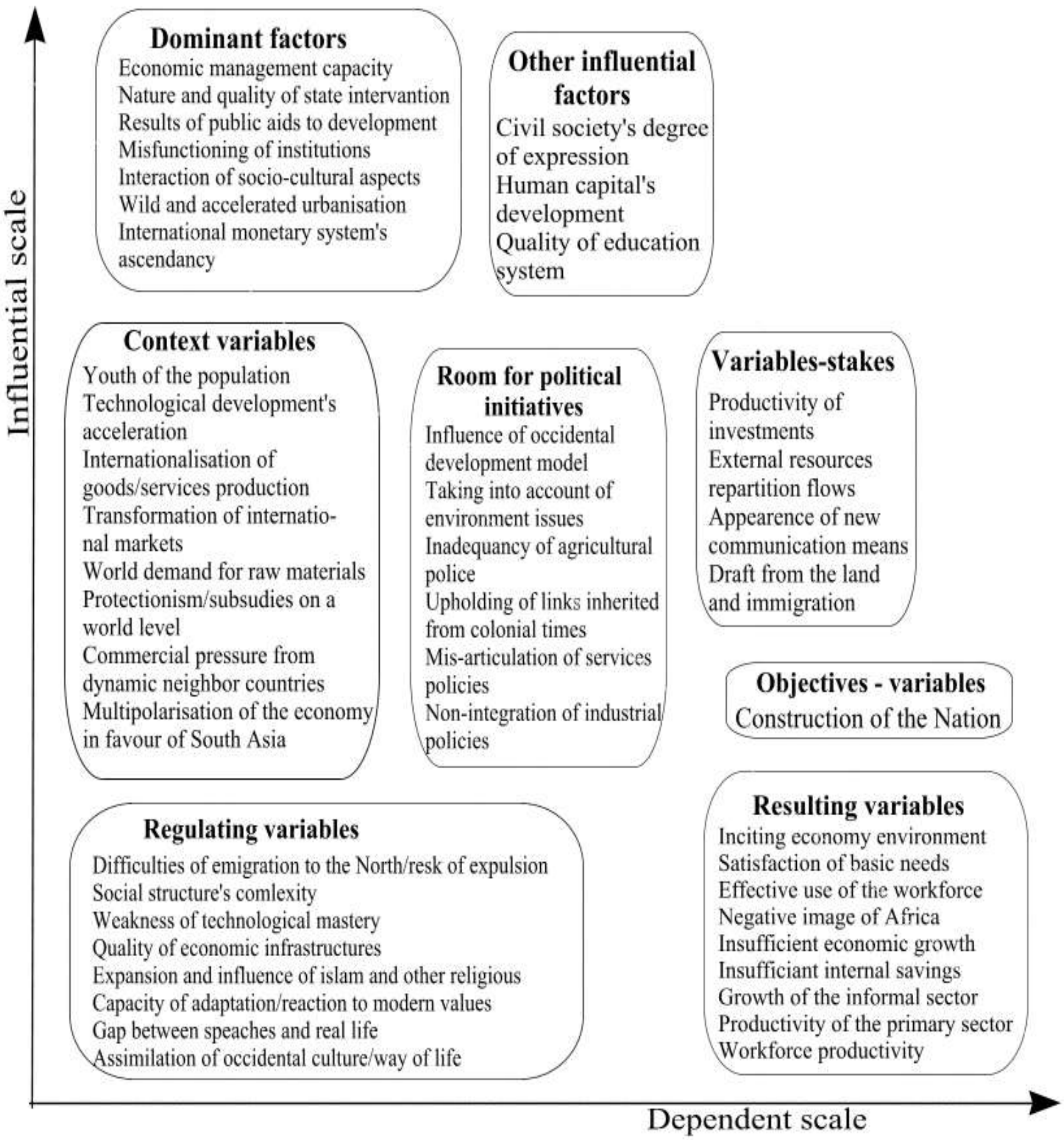
It allows, among other results, bringing hidden variables to light. The modification of the variables' hierarchy (in terms of causal functions) when going from direct to MICMAC classification, is illustrated in the chart below through the example conducted by the "African Futures/NLTPS" project on the case of an African country in its environment.

Figure 5. The major re-rankings between direct and MICMAC treatments

Direct ranking Names of variables/ factors	Rk	N	N	Rk		MICMAC ranking (direct and indirect) Names of variables/ factors
Economic management capacity	1	15	15	1		Economic management capacity
Wild and accelerated urbanization	2	4	33	2		Nature and quality of State intervention
Investments productivity	3	12	55	3		Results to public aid to development
International monetary system's ascendancy	4	56	32	4		Misfunctioning of institutions
Human capital's development	5	22	31	5		Civil society's degree of expression
Inadequacy of agricultural policies	6	17	25	6		Interaction of social-cultural aspects
Interaction of social-cultural aspects	7	25	4	7		Wild and accelerated urbanization
Nature and quality of State intervention	8	33	56	8		International monetary system's ascendancy
Misfunctioning of institutions	9	32	22	9		Human capital's development
Results to public aid to development	10	55	12	10		Investments productivity
Non-integration of industrial policies	11	18	34	11		Quality of education systems
Mis-articulation of services policies	12	19	63	12		Influence of occidental development model
Civil society's degree of expression	13	31	40	13		Taking into account of environment issues
Taking into account of environment issues	14	40	3	14		Youth of population
Quality of economic infrastructures	15	10	57	15		Technological development's acceleration
External resources reparation flows	16	54	51	16		Internationalization of good/services production
Technological development's acceleration	17	57	17	17		Inadequacy of agricultural policies
Drift from the land and immigration	18	2	54	18		External resources reparation flows
Quality of education systems	19	34	30	19		Appearance of new communication means
Internationalization of good/services production	20	51	59	20		Upholding of links inherited from colonial times
Youth of population	21	3	2	21		Drift from the land and immigration
Weakness of technological mastery	22	13	19	22		Mis-articulation of services policies
Inciting economic environment	23	14	50	23		Transformation of international markets
Protectionism/subsidies on a world level	24	48	18	24		Non-integration of industrial policies
Influence of occidental development model	25	63	49	25		World demand for raw material
Appearance of new communication means	26	30	48	26		Protectionism/subsidies on a world level
Inadequacy of land management	27	35	27	27		Construction of the Nation
Difficulties of emigration to the North/risks of expulsion	28	46	46	28		Difficulties of emigration to the North/risks of expulsion
World demand for raw material	29	49	26	29		Social structure's complexity
Transformation of international markets	30	50	13	30		Weakness of technological mastery
Upholding of links inherited from colonial times	31	59	10	31		Quality of economic infrastructures
Construction of the Nation	32	27	45	32		Expansion and influence of Islam and othereligion
Assimilation of the occidental culture/way of life	33	64	28	33		Capacity of adaptation/reaction to modern values
Demographic growth	34	1	43	34		Commercial pressure from dynamic neighborcount
Absence of population policy	35	5	29	35		Gap between searches and real life
Insufficient economic growth	36	6	64	36		Assimilation of the occidental culture/way of life
Uncompetitive secondary sector	37	8	60	37		Multipolarizaton in favor of South Asia
Satisfaction of basic needs	38	23	14	38		Inciting economic environment
Social structure's complexity	39	26	53	39		Weight of international trade regulations
Capacity of adaptation/reaction to modern values	40	28	65	40		Internationalization of drug dealing
Gap between searches and real life	41	29	5	41		Absence of population policy
Commercial pressure from dynamic neighbor countries	42	43	44	42		Sources of ethnic conflicts
Expansion and influence of Islam and other religions	43	45	23	43		Satisfaction of basic needs
Over cost of external factors (transports,inform)	44	47	47	44		Over cost of external factors (transports, information)
Multipolarizaton in favor of South Asia	45	60	1	45		Demographic growth
Hypertrophy of services industries	46	9	58	46		Worldwide perception of humankind problems
Effective use of work force	47	21	35	47		Inadequacy of land management
Sources of ethnic conflicts	48	44	21	48		Effective use of work force
Weight of international trade regulations	49	53	9	49		Hypertrophy of services industries
Internationalization of drug dealing	50	65	6	50		Insufficient economic growth
Entrepreneurial spirit, mostly in trade	51	16	52	51		Growth of world economy
Workforce productivity	52	20	62	52		Negative image of Africa
Deforestation/over exploitation of natural resources		53	37	8	53	Uncompetitive secondary sector
Growth of informal sector		54	41	41	54	Growth of informal sector
Worldwide perception of humankind problems	55	58	16	55		Entrepreneurial spirit, mostly in trade
Productivity of the primary sector	56	7	20	56		Workforce productivity
Under-estimation of inter-state trade	57	42	61	57		Evolution of former colonizer's weigh
Growth of world economy	58	52	42	58		Under-estimation of inter-state trade
Negative image of Africa	59	62	39	59		Under-exploitation of mining resources
Quality of soils and cultivation methods	60	36	7	60		Productivity of the primary sector
Quality and degree of water resources mastery	61	38	37	61		Deforestation/over exploitation of natural resources
Under-exploitation of mining resources	62	39	11	62		Insufficient internal savings
Evolution of former colonizer's weigh		63	61	38	63	Quality and degree of water resources mastery
Quality of the welfare system,	64	24	36	64		Quality of soils and cultivation methods
Insufficient internal savings	65	11	24	65		Quality of the welfare system

Excerpt from the exercise led by PNUD/"African Futures" NLTPS Project

Figure 6. African country-environment, a complex and unstable system

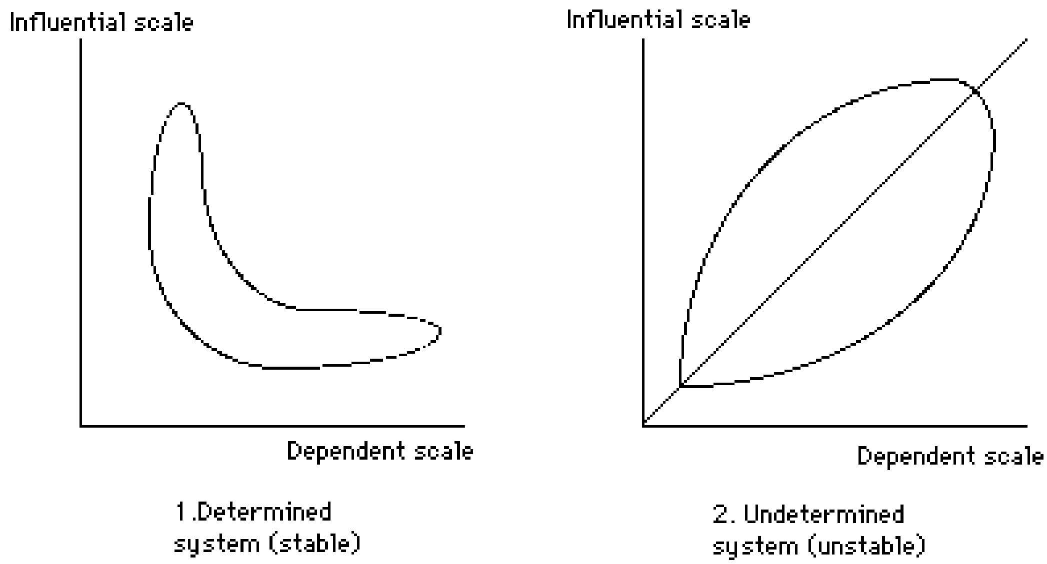


Excerpt from the exercise led by the PNUD / "African Futures" project on "the case of an African country in its environment".

2.7. Assessing the system's degree of determination

The set of variables-points configuration allows completing this analysis, depending on the system's more or less determined (stabilized) state.

Figure 7. The shape of the system



As illustrated in the chart above, the more the cloud of points spreads along the axes (L shape), the more it can be considered as quite determined (stable). This means that the system's response (in terms of evolution) to a given impulse of determining variables can be anticipated with a certain degree of assurance.

On the other hand, when the cloud spreads along the first bisecting line, the system can be considered as quite undetermined (unstable). This is all the more so when the points are located in the north-east frame. The variable points, characterized by their strong influence and dependence, will play an ambiguous role in the system. They are factors of uncertainty in anticipating its evolution as regulated by the variables considered determining.

The system of the African country-environment as studied by the "African Futures/NLTPS" is rather unstable.

However, it is important to stress the fact that this notion of structural determination or stability does not imply that the system won't evolve. It only implies that influent variables' impact on its dynamics will prove, in similar conditions, less unpredictable. In particular, there should not be many boomerang effects.

3. Limits of the method and recommendations for its implementation

3.1. Composition of the experts group

As with any method favoring the team approach, structural analysis greatly depends on the choice of participants. In fact, the results can be strongly biased by dominating competencies within the group. Therefore, it is necessary to set up as multidisciplinary a team as possible. One must also seek to benefit from external points of view through interviews and talks by experts in the fields where the group does not have enough competencies or information. On the other hand, validation of the list of variables by a steering committee including members of the managing team, who should be scientific and professional experts, is especially useful. It can help in checking the understanding and the meaning of variables, as well as highlighting missed spots in the system's coverage. Finally, one must admit, as Michel Godet stresses, that the group can always make collective mistakes. Obtaining a consensus does not mean there is no mistake. However, a collective and participative method greatly limits the risks of incoherence and at the same time offers an invaluable opportunity to build up together a common experience, a common knowledge.

3.2. The operation's massiveness

Implementing a structural analysis is a rather big operation, requiring adequate human resources (experts' availability) and logistics.

In fact, to make things clear, it is important to realize that such an analysis's complete cycle may extend over a three to six months period, taking into account an acceptable pace for the meetings of top executives. In addition, the structural analysis matrix's filling stage requires, for a system of about 70 variables, the organization of a two- to three-day seminar. There are, of course, simpler methods to identify essential variables. That is precisely the objective of the workshops set up by the GERPA (Groupe d'Études Ressources Prospective Aménagement) team. They are based on a brainstorming process designed to identify factors of change, get rid of generally accepted ideas, etc. In addition to stimulating mobilization, these workshops allow the reaching of interesting results when prospective thinking must take place in less than three months. They may not substitute for a complete structural analysis, since they are generally its starting point.

3.3. The need for a small group

Structural analysis, and in particular the establishment of relationships between variables, requires that the participating team not include more than 12 people. Otherwise, animated interaction becomes difficult and possibly boring to such an extent that the work's quality, if not its result, can be at stake. When the group is made up of more than 20 people, it is advisable to avoid the problem by creating two subgroups. The variables' intersection seminar takes place as follows. One morning spent in a plenary session is necessary to discuss together some five variables, so as to build a common reference in terms of working method. One and a half days are spent working in subgroups with the sole purpose of identifying existing relationships between each group's variables (relations between intragroup variables: filling up of the matrix's diagonal blocks). Of course, variables in each subgroup will have been previously gathered in the final list. In the end, one or two days are spent in plenary session in order to identify simultaneously the relationships between variables belonging to different blocks (intergroup relations located in the structural analysis's non-diagonal blocks).

3.4. Originality of the results

Finally, it is important to mention that around 80% of the structural analysis results only confirm the intuitions and viewpoints developed within the group on previous occasions. This contributes in a way to validation of the method. On the other hand, the remaining 20% raises questions with the participants because of their counterintuitive character. Therefore it is these results that one will have to decipher, criticize and explore more deeply. Indeed, they make up the major added value stemming from the process, beyond mutual immersion in the system under study.

4. Usefulness and uses of structural analysis

4.1. Identification of prospective scenarios

Structural analysis allows determination of a core of essential variables: i.e. these that are causes rather than consequences of the studied system's evolution.

In order to build up prospective scenarios, it is advisable to divide this set between two subsets according to the more or less mechanistic or deterministic character of variables and/or of their sensitivity to the actors' moves.

Regarding so-called environment variables, whose evolution is of a deterministic nature and is not very conditioned by the actors' moves, the method used roughly consists of extrapolating the tendencies, taking into account existing correlations between certain courses of evolution. Rather, they correspond to what can be called a variant.

On the other hand, considering variables especially sensitive to the actors' moves, specifically prospective approaches integrating the actors' strategies and leading to the issues at stake, seems to give satisfaction. In this case the scenarios' construction is based on the exploration of all possible combinations of qualitative hypotheses on possible outcomes of each issue at stake (on the horizon studied). This leads to a wider, more varied range of scenarios/combinations, which, through construction, does not include breaking or discontinuities.

The universe thus defined is at once more intuitive and more complex. It is a field where classic forecasting methods are not in use.

4.2. Strategic watch and prospective vigilance

Before setting up a strategic watch force in a company, the question arises of what has to be looked after, and in particular which variables and parameters, because, as in the case of an instrument panel, everything cannot be watched and a selection must be made. Such a choice is all the more difficult in that the list of non-variants shrinks when the time horizon is far away. Therefore, it is important to organize properly the role of the future's factors into a hierarchy. Does it make more sense watching technological innovations or consumer attitudes? Answering this sort of question is all the more difficult because these factors are very interdependent. Clearly, most important factors, which must be permanently under close watch, are those identified by the structural analysis as most influential. Following such variables, especially when they are classified in the category of issues at stake, requires a complement in the form of an analysis of the actors' moves; this analysis finds a primary justification in this framework, independently from its use in the prospective scenarios' construction. Nevertheless, one must note that strategic watch is by nature a permanent activity and thus must be integrated in the company's culture so as to remain permanent. This calls for an at least periodic updating of the process's intermediary results. These results consist of the actors' moves matrix and in the detection of major stakes and key questions. Indeed, beyond the evolution of variables and indicators, it is important to keep in mind that the graphical representation allowing one to analyze situations can be modified or brought into question.

4.3. Qualification and pertinent horizon of strategic prospective

Focusing on mostly macroeconomics and financial variables in order to anticipate evolutions amounts to considering that the sphere of actors is rather stable. In fact, the importance of actors' strategies and reactions, their consequences on the evolution of key variables and on the system's transformation get out of proportion with macroeconomics tendencies. Isn't there a danger that forecasting, by limiting itself to only those variables whose evolution is mainly deterministic, would lock itself in a field whose shrinking weight could bring into question this method's very foundations? An increasingly complex and strategic universe calls for the use of prospective-inspired methods. These methods, while encompassing most techno-economic aspects, enable integrating other aspects of the social and political environment.

The actors’ moves’ increasing role and the recession we are going through are such that the horizon for deep changes has gotten much closer. In fact, who could imagine a year in advance such a major change as the collapse of the former Soviet Union? It would have been interesting, as Jacques Lesourne recommends, to carry out retrospective exercises, in particular on the short run picture. Among other things, they would have allowed evaluating the ability of prospective-like methods to detect the likelihood of such a breakup, especially when the confrontation of such objectives, interests and balance of power between actors becomes essential.

Forecasts that aroused such passion during a 30-year period after World War II are increasingly useless in understanding the future. The basic reason is that, now, most of what is considered as "equal in other respects" varies in the same proportion as factors known to be variable. Therefore, not only is the evolution's estimation unsatisfactory, but the choice of a variables' subgroup to which the forecast applies is also brought into question since it is less and less relevant. In this context, a global perception of the phenomena involved, taking into account the balance of powers' recomposition, becomes essential in order to understand the long-term and short-term futures.

Thus, prospective-like scenarios' scope of validity is increased in terms of both application field and period covered. They are increasingly qualified, including the anticipation of short term futures. For this reason, a strategic prospective's objective cannot be limited to the long term's analysis. In the end, the relevant horizon for strategic prospective could well be one of breakup.

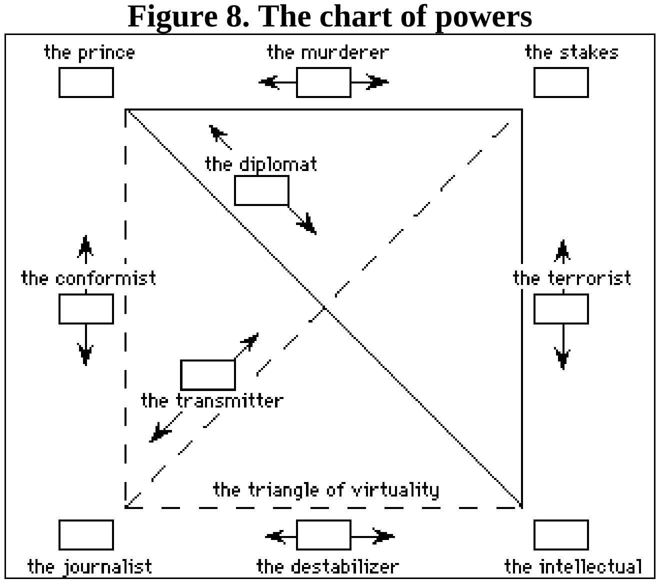
4.4. The chart of powers

The chart of powers was proposed by P.F. Ténière-Buchot in a book called "The ABC of Power". This chart is an original and stimulating graphical representation for the structural analysis influence × dependence plane. It is inspired both by Machiavelli's chessboard and by the Djambi game board. It allows using structural analysis for mostly decision purposes, and, according to its author, "overcoming or managing crisis".

The chart is a chessboard with four corners, each corresponding to a piece, respectively:

- The Prince, which can be associated with influential variables in structural analysis. It represents power and legitimacy and should normally get the upper hand since it is in a strong position ;
- The Stakes, corresponding to relay variables (at once influent and dependent), which is ambivalent in the sense that it contains opportunities as well as threats ;
- The Intellectual, which is associated with most dependent variables, makes a judgment and assesses the result ;
- The Journalist, which represents autonomous variables (at once little influent and little dependent), whose power is based on speech.

Figure 8. The chart of powers



Source : Ténière-Buchot P.-F., l'ABC du Pouvoir, Les Editions de l'Organization, 1991.

In addition to these master pieces, there are intermediary ones such as, for example, the Murderer between the Prince and the Stakes; the Terrorist between the Stakes and the

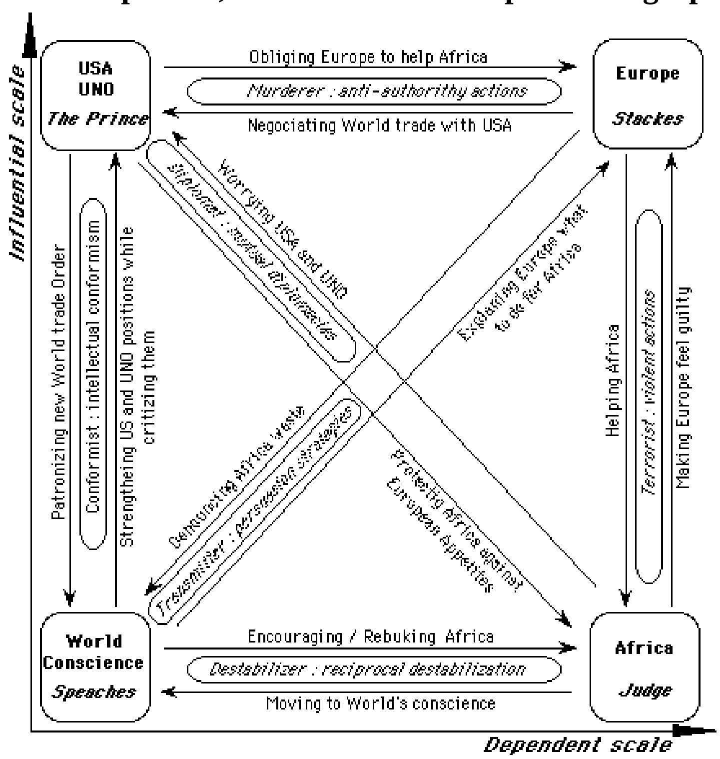
Intellectual; the Destabilizer between the Intellectual and the Journalist; the Conformist between the Diplomat and the Prince; the Diplomat between the Prince and the Intellectuals.

These pieces' variety leads to qualifying the structural analysis classic interpretation which states on the one hand that anonymous variables have no importance, and on the other hand that influence and dependence should be opposed to one another. For Ténière-Buchot, autonomous variables are topics for communication and speeches above all. In addition, causal functions (legitimacy) and dependence (judgment) articulate with one another in a "reversed proportionality" dialectic relationship. Moreover, legitimacy lies mostly on the past, whereas judging results lies mostly in the future: revealing them can constitute a certain weakness. As for stakes, they would call for quite immediate actions.

The author proposes different ways of setting up the chart so as to understand evolutions in the actors' role and the changes in values they can provoke within the system.

One of the recent applications for the chart of powers concerns the Europe-Africa geopolitical system, whose chart states the main results in a purely illustrative way, without taking a stand on the core of the problem.

Figure 9: the chart of powers, the case of the Europe-Africa geopolitical system



This chart is based on the article of Teniere-Buchot P.-F. , "Europe-Afrique: vers de nouveaux pouvoirs", in *Strategique*.

4.5. Simulation models

As seen in J.W. Forrester's works on systems' dynamics, other uses for structural analysis are possible. In France, there was in particular the studies by Ms. Karsky (1984) on oil markets' evolution, and also Gonod (1990). These applications favor a simulation of influences, taking into account, beyond the existence of relationships, not only their intensity but also their signs (positive or negative), as well as the time factor (propagation time). Other refinements, based on the fact that most relationships are not linear, go so far as proposing, for each relationship, various type curves governing the effects' propagation in time: exponential growth, threshold effects (saturation) or breaking (rupture of growth), etc... Despite the fact that they allow pointing out positive retro-action loops, system's amplifiers, negative retro-action loops, regulators, etc, such exercises never proved of real interest. There are three reasons for this. First of all, these systems require difficult to get information, especially when one wants to grasp qualitative factors. Second, such systems' inherent complication grows exponentially and hypotheseis made on the many parameters quickly become unmanageable: therefore the necessity, in order to remain credible, of not going beyond about 20 variables. Finally,although these systems are quite convenient for understanding kinetics of their internal flows of influences, they are on the other hand less suited to pointing out their structural transformation's true determinants, i.e. not the flow's distortion but distortions of their influence network, even though that is one of the prospective approach's fundamental aspects.

Moving back to structural analysis's more classic applications, contenting oneself with considering the relations' intensity through simple attributes (nil, weak, average, etc.) deserves certain comments. In fact, experience shows that a better knowledge of the relationships' intensity supposes a second degree of precision, as compared to taking into account the very network structure through which they propagate. This remark is all the more justified when the network's configuration is complex, because the expected gain through a higher degree in precision quickly becomes out of proportion with the effort made.

4.6. Structuring of objectives and relevance charts

When the structure of a complex strategy or project is unclear and cannot be directly split into increasingly precise levels, the structural analysis approach allows one to try and reveal it, as well as its underlying logics of action. To this end, one must build the matrix of supports between objectives. It will be filled, in a first stage, with zeros (0) or ones (1) conveying the existence or not of direct support relations. In accordance with the graphs' formation methods explained above, and provided that the matrix is not too complex (no strongly connected major components), several levels of objectives can be identified one after another. This may require grouping some of them into the form of macro objectives.

Without predicting the actions which will eventually influence most specific explanatory factors, this generic tree of objectives deserves being presented, beyond the discussions necessary to set it up.

The graph's various levels are interlinked with contribution arrows. Each level logically corresponds to a step in the course of the reasoning, which goes in an increasing direction from the most operational objectives located at the bottom of the tree (they will be used as the actions' application points), to the global objective located at the top. Schematically, the structure of objectives has a pyramid shape in which every level must be homogeneous, objectives in the same level are independent, and all incidence arrows go from the bottom to the top.

The contribution arrows of objectives in a given level, are evaluated by local analyses reflecting their relative contributions (in %) to the objectives above them in the pyramid, which they directly support.

Thus, a lower objective's overall contribution to the global objective (at the top of the tree) is obtained first by constructing the path from it that reaches the final objective, and then by multiplying the local evaluations determined for the arrows which constitute this path. In particular, one obtains in this way the relative contribution (evaluation) of each operational objective (situated at the bottom of the tree) to the final objectives' realisation. This sort of tree allows comparing different modes of attack for the whole strategy, and assessing how relevant alternative projects can be when compared to it. This is why it is labeled a relevance tree. This relevance is obtained in particular through the analyzed sum of the actions' direct contributions to the various objectives.

However, as mentioned above, the objective chart is sometimes too confused to be structured in the shape of a tree. In this case, it is advisable to come back to the initial matrix of the objective's structural analysis in order to better exploit it. The method, inspired from the relevance tree's logic but generalizing it, consists of determining for each objective its alteration (in %) of the contributions it directly receives from other objectives. This amounts to replacing non-empty squares in the columns of variables with appropriate percentages (with the column's sum equal to 100%). In this case, assessing a project's global impact on the strategy amounts to applying a "closed Leontief model". However, according to this model, the repartition of the various objectives' induced contributions (direct and indirect) is converging towards a balance repartition through a Markovian type process. This balance repartition corresponds to considerations which must be granted to the different objectives in order to assess the global impact of any alternative project's various actions. The frame below describes an application of this approach:

Structuring a food strategy's objectives and prioritizing rural development programs.

The exercise took place within a Sahelian country's Inter Ministries Commission in charge of food strategy. It was in the framework of a financial backers' round table preparation. This food strategy could be summarized through a particularly entangled set of around 50 generic objectives: results, leitmotivs, displays, etc. The recommended approach consisted, through a structural analysis, of reconstituting and clarifying the web of support relationships among these many objectives. Beyond awareness of the strategy's configuration, and of its own dynamics, the exercise allowed the core team in charge of its implementation to identify the most interesting modes of attack and shed a new light on measures taken until then.

Another result of this exercise was the setting up of a nominal system for the relative weight of the strategy's various objectives. This system had to reflect the objectives' structural capacity to contribute in terms of direct or indirect net supports to the implementation of the strategy in its entirety. Thanks to this result, it was possible to lead a multi-objective evaluation (qualitative and aggregated) of the performance expected from certain rural development programs. The result was a rather counterintuitive hierarchy as compared to the food strategy which was the keystone of the financial backers' round table. This ranking, in fact, greatly eased the adoption of a negotiated compromise that the first priority must go to a decentralized program of hill weirs development. This program was considered until then as secondary as compared to the more classic program to rehabilitate the hydroagricultural Development Office.

III. UNDERSTANDING THE ACTORS' STRATEGIES: THE MACTOR METHOD

This stage is essential. Proper *prospective* thinking cannot be carried out unless there is an in-depth retrospective study. Notably, this means considering all the key variables and questions identified earlier, and building up a database (both quantitative and qualitative) that should be as extensive as possible. All sources of statistical information should be drawn upon to identify the major evolutionary trends, to analyze past discontinuities, the conditions under which these came about, and the role played by the main actors of this evolution.

As in the case of structural analysis, the above information should be supplemented by qualitative interviews with the actors themselves; this approach enables one to identify the main events which pointed the way to the future, to gain a better overview of the interplay of events and a better understanding of the relationships among the actors. It is only when a solid database is available and there is a thorough knowledge of future challenges that the MACTOR method can be usefully implemented.

The future is never totally predetermined - however influential past trends may be, the future remains open to several possible scenarios. The actors in the system under examination possess various degrees of freedom which they will be able to exercise, through strategic action, in order to arrive at the goals they have set themselves, and thus successfully to carry out their project.

From this, it follows that analysis of these actors' moves, confronting their plans, examining the balance of power between them (in terms of constraints and means of action) is essential in order to throw light on the strategic issues and the key questions for the future (which are the outcomes and consequences of foreseeable battles).

If we focus our attention on energy, for example, these key questions will be concerned mainly with the price of oil, the demand for energy, the maintenance or collapse of solidarity among OPEC member countries, and so on. To take another example, in a 1976 futures study of cosmetics consumption up to 1990, analysis of actors' strategies showed that the existence of companies with specialised distribution was threatened by the moves of other actors (such as mass distributors, consumer movements, and trend-setters).

In the field of prospective there is general consensus on two points regarding analysis of actors' moves.

On one hand, everyone concurs in recognizing it as a crucial - and perhaps the most important - step in constructing a basis for thought that will enable scenarios to be built. Without careful analysis of actors' moves, scenarios will lack relevance and coherence.

On the other hand, the same people lament the notable lack of a systematic tool for analyzing actors' behavior. This lack is all the more remarkable in that analysis of actors' behavior is so often preceded by a rather clumsy structural analysis, using tools (the MICMAC method) to help identify the key variables and ask the right questions - in other words, to improve the pertinence of the thought process.

We recall that this is a matter of focusing on those actors who directly or indirectly control the key variables identified by the structural analysis. We then construct an "actors' strategies" table, presented in the form of a square matrix (actors × actors) in which:

- each diagonal cell contains the aims and objectives of each actor, insofar as these can be identified

- the other cells contain the means of action which each actor may use against the others in order to achieve its aims

Filling in this table is a group discussion activity, sharing the information gathered on each actor and its relationships with the others. This information on actors' behavior can be collected or complemented by conversations with experts who are representative of each group of actors. Given that it is generally difficult to ask an actor to reveal his own strategy and his own strengths and weaknesses, it is much easier to get him to talk about the other actors. By sifting through sets of partially true information, a more or less coherent picture of the whole situation emerges.

It is often said that it would be good to take advantage of information derived from game theory, in order to make intelligent use of the near-complete data collected in the actors' strategy tables. We support this view, and have no doubt that one day young researchers will propose significant ways forward. In the meantime, to our knowledge, the available tools have hardly developed at all over the past few years.

In 1985, however, we outlined a path that seemed to us promising, and by taking up this idea once again we have now created and developed the MACTOR method (Matrix of Alliances and Conflicts: Tactics, Objectives and Recommendations). Our aim is to create an analytical tool that will allow us to make better use of the informational added value contained in actors' strategies tables. Although the 'game theory' path still appears to be of interest, we did not pursue it rigorously in creating MACTOR. Others will certainly do so, but we would suggest that they bear in mind the following recommendation: develop tools that are sufficiently simple to be appropriable (understandable) by the users and which lend themselves easily to multiple and varied applications.

Analysis of actors' moves, as we propose with MACTOR, proceeds in the following six stages:

1. Note down each actor's plans, motivations, constraints, and means of action (construct the "actors' strategy" table).

2. Identify the strategic issues and objectives associated with these battlefields.

3. Position each actor on each battlefield and note the convergences and divergences.

4. Rank the objectives for each actor and assess possible tactics (interaction of possible convergences and divergences) in terms of their objective priorities.

5. Evaluate the relationships of power and formulate strategic recommendations for each actor, in keeping with the actor's objective priorities and available resources.

6. Raise key questions about the future - i.e. formulate hypotheses regarding the trends, events and discontinuities which will characterize the evolution of the balance of power between actors. It is around these key questions, and hypotheses as to their answers, that the scenarios will be constructed.

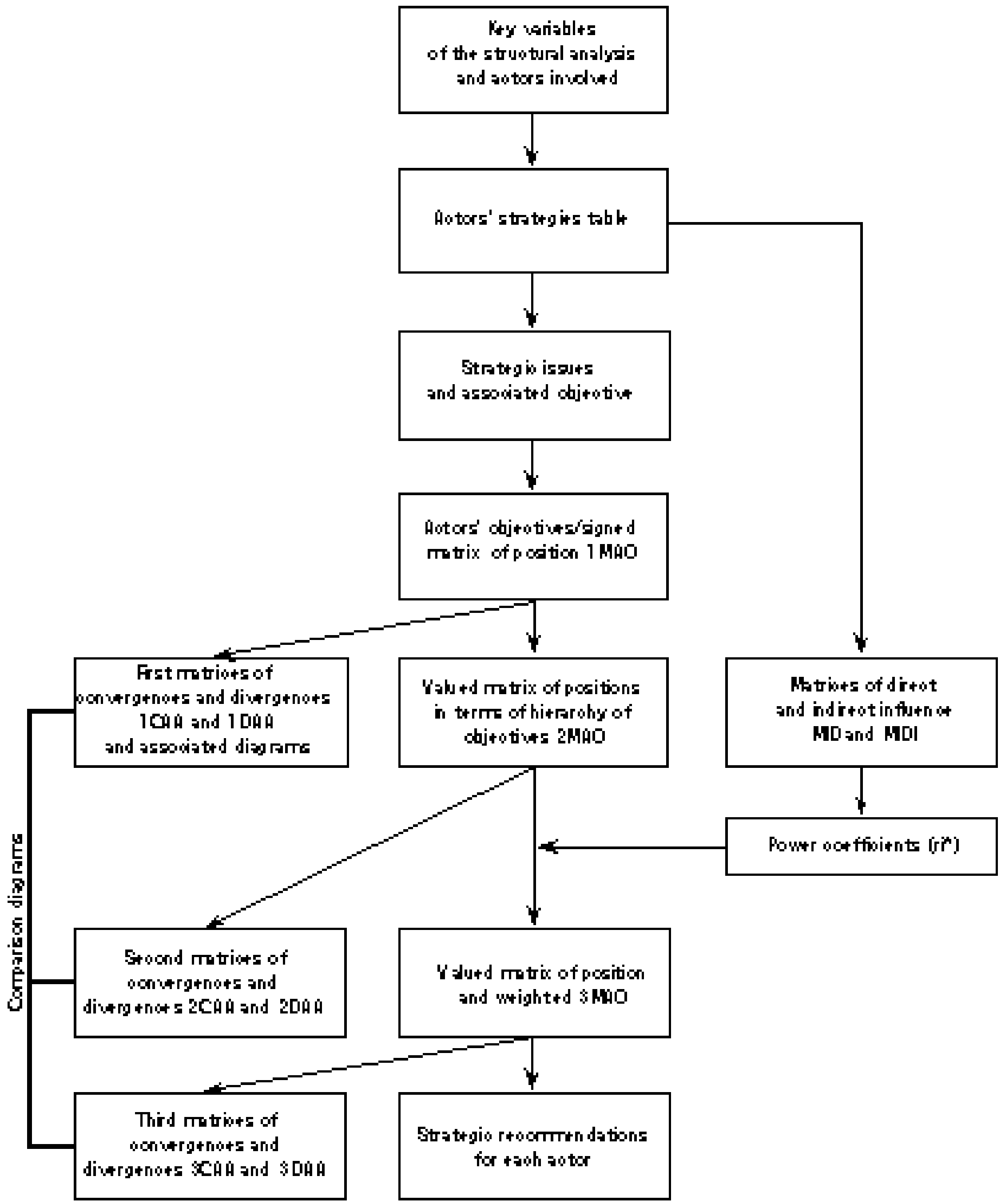
The added value created by the MACTOR method derives primarily from stages 3 (positioning actors in relation to their objectives) ; 4 (tactics for possible alliances and conflicts) ; and 5 (strategic recommendations). In the future, more attention will be devoted to these stages, for until now we have too often passed rather quickly from stages 1 (constructing actors' strategy tables) and 2 (strategic issues) to stage 6 (key questions for the future).

How do we conduct this analysis of actors' behavior in six stages? What exactly does the MACTOR method consist of?

To answer these questions, we have once again chosen to illustrate the method with an example which relies on material collected while carrying out several prospective studies in the field of air transportation. Most of these studies were carried out in the 1970s (at the time when we ran SEMA prospective), for Aerospatiale, for the Directorate General of Civil Aviation (DGCA) in France, and especially for the Paris Airport Authority.

An example like this is not dated - it is now that it is most valuable, for we can check whether or not the conjectures made about the future (which is now the present) were well founded. Moreover, more recent analyses of actors' moves, relating to futures yet to arrive, are almost systematically confidential. The example of air transportation is currently one of the only ones that can be made public. Other examples, relating to the Post Office or other firms, may perhaps emerge from their wraps of confidentiality after a longer prescribed period. The directors of the Paris Airport Plan have confirmed to us that this example of 'retrofutures' retains a certain topicality. Furthermore, a new study of actors' moves in air transportation up to 2010, using the MACTOR method, has been set up - naturally its results cannot be published, whether they are relevant or not. If an actor reveals to others the nature of the questions he is asking himself, and the way in which he is formulating them, he has already said too much about his strategy... unless of course part of his strategy is to use the effect of declaring his hand, as in poker.

Figure 10: MACTOR method; sequence of stages



1. Constructing the actors' strategy table

We are focusing, then, on the behavior of actors in air transportation in the Paris region up to 1990, as analysed in 1978. The first question concerns the number of actors to take into account. Should we consider the airline companies as a single actor, or should we subdivide them according to a particular characteristic (size, legal status, nationality...)?

Similarly, the state is generally a polymorphous actor - there is the DGCA, but also the Ministry of Finance, the government, and so on. These actors, which together make up the state, differ in their objectives, their behavior, and their criteria for decision-making. A complete analysis would have to integrate other actors such as the trade associations, the European institutions, and the international air transportation organizations. One could thus multiply the number of actors at will, and almost inevitably run the risk of making analysis of the system impossible. Experience shows that a total of 10 to 20 actors constitutes a realistic and operational compromise.

The actors' strategy table is constructed in a square matrix (actors × actors), similar to the following table, which we have redrawn from memory. The cells on the main diagonal are generally the fullest, for in these cells we are setting down in black and white each actor's identity card. In contrast, many of the other cells (actions of one actor towards another) are almost or totally empty.

In order to simplify this account of MACTOR, we shall consider only six actors: aircraft manufacturers (A1), scheduled airlines (A2), charter airline companies (A3), the state (A4), Paris Airport Authority (A5), and the local residents' associations (A6). In the case analyzed on behalf of Paris Airport in 1990, 12 actors were considered, as well as seven strategic issues and over 30 associated objectives.

Table 1: Actors' strategies

Action of ↓ on →	**Manufacturers**	**Airlines**	**State**
Manufacturers	**Objective :** To survive and avoid crisis **Problems :** Plan for higher ▪ performance aircraft ▪ specific noise and fuel consumption standards to meet **Means :** Association between constructors Military orders Diversification of activities	Pressure on airlines to purchase new aircraft Diversification of needs and aircraft Standardization of the fleet for each constructor Availability of entire range No significant technological progress	Exercise "blackmail" in regard to jobs Demand finance for new projects
Airlines	Demand aircraft better suited to their needs Dominant criterion : Cost per passenger mile per ton effectively transported Reluctance to use large aircraft	**Objective :** To maintain market share **Problems :** Financial investment and salaries To maintain high frequency and occupancy **Means :** Cooperation between airlines (ATLAS) Increased use of branches Standardization and operating flexibility of the fleet Development of freight Concentration at the tertiary level (feeder lines)	Seek protection from competition in the form of discriminatory rights in relation to long-haul traffic
State	To protect the national aeronautical industry Military and civil aircraft order Finance for new projects Export credits Approaches to foreign governments Appeal to private finance	Protectionism Pressure on airlines to purchase Mercury Airbus with financial aid State protects airlines provided they develop and improve their section	**Objective :** Prestige and a French presence in the world **Problems :** Unemployment Inflation **Means :** Sustained growth

Source : Godet M., From anticipation to action, UNESCO Publishing,1994.

2. Identifying the strategic issues and associated objectives

Through group reading and discussion of the actors' strategy table, the strategic issues - i.e., the battlefields on which the actors will confront each other- are brought to light fairly easily. Here we concentrate on five strategic issues regarding which the six actors have converging or divergent objectives (convergences or divergences). These five issues concern the following:

E1 : *Definition of aircraft*. The aircraft manufacturers want to impose their own new aircraft designs on airline companies and on Paris Airport. For example, Boeing 747s were developed at a time when the existing runways were too short for them.

E2 : *Aircraft market*. National aircraft manufacturers rely on the state to develop their share of the national and international market. The other actors under consideration are not concerned with this objective.

E3 : *Allocation of traffic rights*. Here the scheduled airlines rely on the state to curb the aspirations of the charter companies, who favor deregulation. For its part, Paris Airport supports the opening of new lines that would allow an increase in the number of flights to Paris.

E4 : *Market for ‘organized’ flights*. The interests of charter companies regarding the ‘organized’ flights market are opposed to those of the scheduled airlines. The main concern of Paris Airport is to avoid having to turn traffic away, and from this point of view it is an objective ally of the charter companies.

E5 : *Noise pollution and disturbance near airports*. This issue is at the crossroads of actors’ strategies, for it involves all of them. Residents demand less noisy aircraft, are opposed to the authorization of night flights, and their concerns are naturally echoed by the state (residents are also voters). Aircraft manufacturers represent an objective ally of the residents, in that more restrictive noise-control standards could lead to the abandonment of old aircraft in favor of new, less noisy craft. Scheduled or charter airlines and Paris Airport are naturally opposed to anything which could curb traffic.

Each of these strategic issues (battlefields) can be presented in the form of one or more precise objectives over which actors are in convergence, in divergence, or neutral.

For ease of exposition, we shall limit our analysis to the battlefields (01, 02, 03, 04, 05), which constitute only part of the objectives associated with issues E1-E5. A complete analysis of actors’ strategies would have to take all objectives into account.

Table 2: Issues and objectives

ISSUES (BATTLEFIELDS)	ASSOCIATED OBJECTIVES
E1 Definition of aircraft	01 - Impose aircraft specifications (size, performance) - Define aircraft specifications together
E2 Market for aircraft	02 - Defend and increase the national manufacturers' market share
E3 Allocation of traffic rights	03 - Maintain allocation of traffic rights - Partial deregulation - Total deregulation (free opening of new lines)
E4 'Organized flights' market	04 - Develop 'organized flights' - Control 'organized flights' - Avoid turning traffic away
E5 Noise pollution and disturbance near airports	05 - Regulate and reinforce noise standards

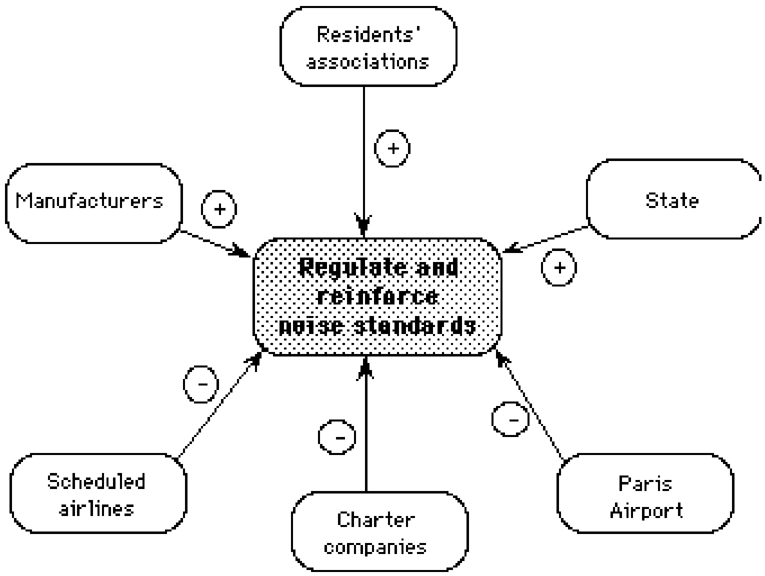
3. Positioning each actor in relation to the strategic objectives (signed position matrix)

The relationships between the actors on each battlefield can be represented in the form of a diagram of possible convergences and divergences. Of course, in order to understand the strategic situation as a whole, it is necessary to construct all the diagrams of possible convergences and divergences associated with each strategic objective, as well as diagrams of corresponding resources.

We soon see that strategies of convergence and divergence between actors vary from one objective to another. In order to maintain coherence, there can be no question of fighting against a certain actor on one battlefield while counting on his support for another, and vice versa.

For any given actor, the question is therefore to identify and evaluate possible strategic options and a coherent selection of objectives and alliances. Visual comparison of the diagrams of convergences and divergences is not easy; however, a matrix representation (MAO - Matrix of Actors and Objectives) enables all these diagrams to be summarized in a single table. Below we see the positioning of actors towards the objective of regulating and reinforcing noise control standards.

Figure 11: Positioning actors towards the objective of regulating and reinforcing noise control standards



Objective : regulate and reinforce noise control standards
+ = in favour of objective
- = opposed to objective

Table 3: MAO ; signed matrix of positions (actors × objectives)

	01	02	03	04	05
A1- Manufacturers	+1	+1	0	0	+1
A2- Scheduled airlines	-1	0	+1	-1	-1
A3- Charter compagnies	-1	0	-1	+1	-1
A4- State	0	+1	+1	0	+1
A5- Paris Airport	-1	0	-1	+1	-1
A6- Residents' associations	0	0	0	0	+1
Σ+	+1	+2	+2	+2	+3
Σ-	-3	0	-2	-1	-3

01 - Impose aircraft specifications
02 - Defend and increase national manufacturers' market share
03 - Maintain allocation of traffic rights
04 - Develop 'organized flights'
05 - Regulate and reinforce noise control standards

The MAO matrix (actors × objectives) is filled in as follows:
(+1) Actor i in favor of objective j
(-1) Actor i opposed to objective j
(0) Actor i neutral in relation to objective j

So, for example, we find the fifth column represents the diagram associated with objective 05: regulating and reinforcing noise control standards.

Commentary:

Simply examining the positive and negative totals of the lines and columns of the MAO matrix provides a wealth of information. Thus we see, on one hand, that the residents' associations (A6) are only concerned with one objective (noise, A5), while all the other actors are involved in four out of five battlefields. On the other hand, objective 05, noise pollution and disturbance near airports, is the one which most divides the actors and involves them all. Defining aircraft specifications (01), allocation of traffic rights (03), and to a lesser extent the development of the 'organized" flights market (04), are also highly contentious objectives.

<u>4. Ranking the objectives for each actor (valued position matrix) and assessing the range of possible convergences and divergences</u>

For each pair of actors it is interesting to note the number of objectives over which they are in convergence or divergence. This can almost be picked out visually from the MAO matrix. But for larger tables incorporating about 10 actors and 20 or so objectives, we must make use of a classic property of binary matrix calculation: by multiplying a matrix by its transposition we obtain the number of factors in common for each pair of rows in the original matrix (to transpose a matrix all we have to do is to place in columns the factors which were previously in rows). The transposed form of MAO (actors × objectives) is called MOA (objectives × actors). The product of matrices MAO × MOA, respectively (6,5) and (5,6) in format, gives a matrix Actors × Actors (6,6) in format.

In order to be able to distinguish which of the factors common to two actors (two rows of the MAO matrix) correspond to motions in favor of certain objectives (indicated by +1) or opposed to others (indicated by -1), the matrix calculation MAO × MOA gives two matrices:

- CAA is obtained by the matrix product that retains only positive scalar products. This is also the number of objectives towards which actors i and j have a convergent attitude, either favorable or unfavorable (number of convergences).

- DAA is obtained by the matrix product that retains only negative scalar products. This is also the number of objectives towards which actors i and j have a divergent attitude (number of divergences).

For example, CAA_{23} = +2, means that scheduled airlines (A2) and charter companies (A3) take up the same position on two objectives (in this instance 01 and 05). DAA_{23} = +2 means that they are in opposition on two other objectives (03 and 04) (cf. in the MAO matrix, rows 2 and 3).

Table 4: CAA ; matrix of convergences (actor × actor)

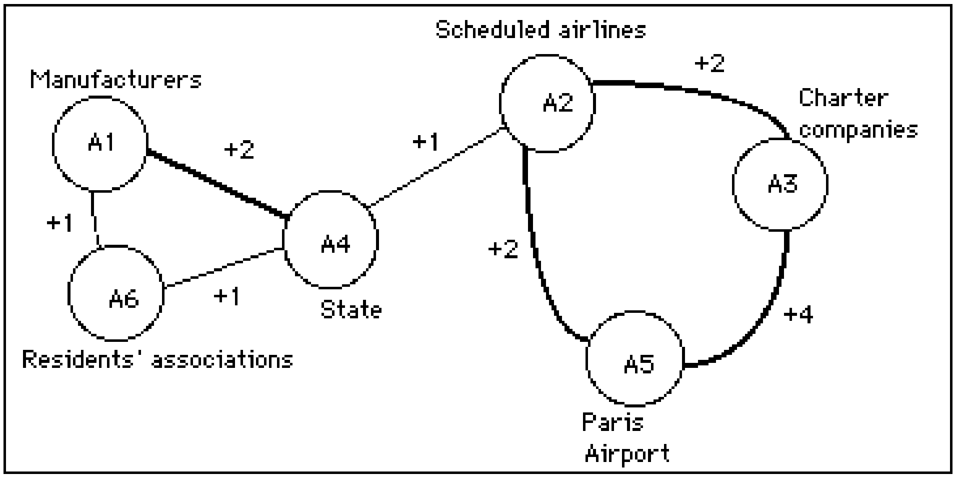
	A1	A2	A3	A4	A5	A6
A1- Manufacturers		0	0	+2,0	0	+1,0
A2- Scheduled airlines	0		+2,0	+1,0	+2,0	0
A3- Charter compagnies	0	+2,0		0	+4,0	0
A4- State	+2,0	+1,0	0		0	+1,0
A5- Paris Airport	0	+2,0	+4,0	0		0
A6- Residents' associations	+1,0	0	0	+1,0	0	
Ci	+3,0	+5,0	+6,0	+4,0	+6,0	+2,0

Table 5: DAA ; matrix of divergences (actor × actor)

	A1	A2	A3	A4	A5	A6
A1- Manufacturers		+2,0	+2,0	0	+2,0	0
A2- Scheduled airlines	+2,0		+2,0	+1,0	+2,0	+1,0
A3- Charter compagnies	+2,0	+2,0		+2,0	0	+1,0
A4- State	0	+1,0	+2,0		+2,0	0
A5- Paris Airport	+2,0	+2,0	0	+2,0		+1,0
A6- Residents' associations	0	+1,0	+1,0	0	+1,0	
Di	+6,0	+8,0	+7,0	+5,0	+7,0	+3,0

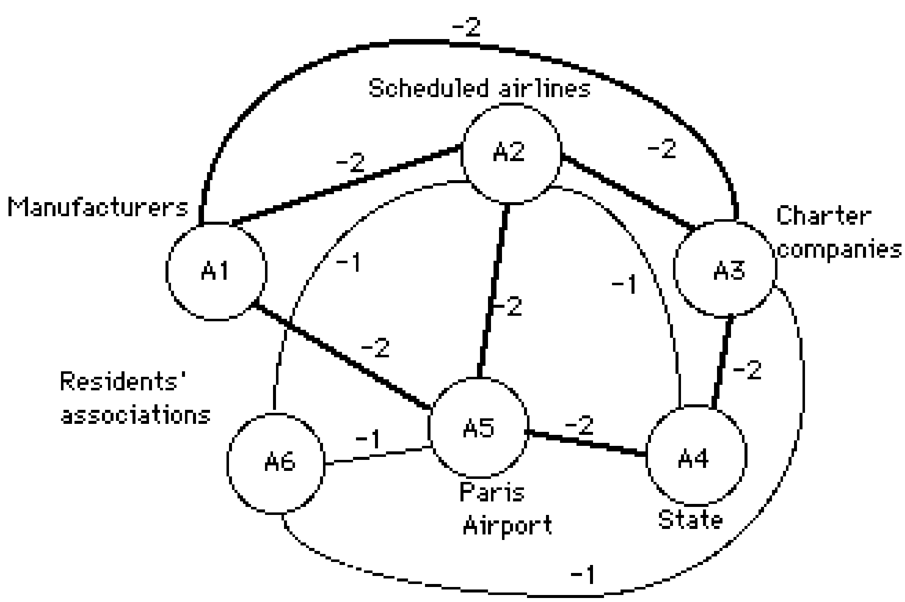
Matrix CAA therefore indicates for each pair of actors the number of objectives on which they are in convergence and the matrix DAA indicates for each pair of actors the number of objectives on which they are in divergence. The two matrices CAA and DAA allow us to obtain two complete diagrams of convergences and divergences. These diagrams are shown below; the thickness of the lines is proportionate to the number of objectives concerned.

Figure 12: First complete diagram of convergences over objectives



The most striking thing is the strong convergence of interest between Paris Airport Authority and the charter companies, and to a lesser extent the scheduled airlines. We also note the lack of common objectives between Paris Airport Authorities (A5) and the state (A4) (at least for the objectives under consideration).

Figure 13: First complete diagram of divergences over objectives



For their part, the aircraft manufacturers, the state and the local residents' associations constitute another group of allies on several objectives.

Complete diagram of divergences

Some actors are in potential conflict with almost all the others over two or three objectives. This is the case for Paris Airport (A5), the scheduled airlines (A2) (the actor most at risk), aircraft manufacturers (A1), and the state (A4).

These first completed diagrams remain rather elementary because they take into account only the number of convergences and divergences over objectives. To bring the model closer to reality, it is advisable to introduce two dimensions that have so far been omitted:

1) the hierarchy of objectives, which varies from actor to actor
2) the relationship of power between actors

These dimensions also affect the interplay of possible convergences and divergences. Before looking at how to integrate the second of these two dimensions, we shall examine the first.

In order to take into account each actor's specific hierarchy of objectives, it is sufficient, for example, to note the positioning of actors in relation to objectives on a scale from -4 to +4, according to whether the level of opposition or agreement is very high, high, medium or low. The more the actor feels concerned with an objective that is important for him, the higher the absolute value recorded.

We thus obtain a second valued position matrix of the MAO type, which we shall call 2MAO.

Table 6: 2MAO ; valued positions matrix (actors × objectives)

	01	02	03	04	05
A1 - Manufacturers	+2	+3	0	0	+1
A2 - Scheduled airlines	-2	0	+3	-1	-3
A3 - Charter compagnies	-1	0	-3	+3	-2
A4 - State	0	+3	+2	0	+1
A5 - Paris Airport	-1	0	-2	+2	-2
A6 - Residents' associations	0	0	0	0	+3
Σ+	+2	+6	+5	+5	+5
Σ-	-4	0	-5	-1	-7

Table 7: 2CAA; Valued matrix of convergences (actors × actors)

	A1	A2	A3	A4	A5	A6
A1- Manufacturers		0	0	+4,0	0	+2,0
A2- Scheduled airlines	0		+4,0	+2,5	+4,0	0
A3- Charter compagnies	0	+4,0		0	+8,0	0
A4- State	+4,0	+2,5	0		0	+2,0
A5- Paris Airport	0	+4,0	+8,0	0		0
A6- Residents' associations	+2,0	0	0	+2,0	0	
Ci	+6,0	+10,5	+12,0	+8,5	+12,0	+4,0

Table 8: 2DAA; Valued matrix of divergences (actors × actors)

	A1	A2	A3	A4	A5	A6
A1- Manufacturers		+4,0	+3,0	0	+3,0	0
A2- Scheduled airlines	+4,0		+5,0	+2,0	+4,0	+3,0
A3- Charter compagnies	+3,0	+5,0		+4,0	0	+2,5
A4- State	0	+2,0	+4,0		+3,5	0
A5- Paris Airport	+3,0	+4,0	0	+3,5		+2,5
A6- Residents' associations	0	+3,0	+2,5	0	+2,5	
Di	+10,0	+18,0	+14,5	+9,5	+13,0	+8,0

The matrices 2CAA and 2DAA are made up of all pairs of valued convergences and divergences. Each element is obtained as the average intensity (in absolute values) of respectively convergences and divergences on objectives.

Example :- Valued convergence between A2 and A3:

$$2CAA_{23} = \frac{|-2| + |-1|}{2} + \frac{|-3| + |-2|}{2} = 4$$

- Valued divergence between A2 and A3:

$$2DAA_{23} = \frac{|+3| + |-3|}{2} + \frac{|-1| + |+3|}{2} = 5$$

We can thus construct a second version of the complete diagrams of possible convergences and divergences, which in this case does not differ noticeably from the first (which is why these second diagrams are not presented here), except on one point. Between the first and second diagram of conflicts we note an increased degree of antagonism between the scheduled airlines and the charter companies. This derives from the total opposition of these two actors over allocation of traffic rights. Of course if we had chosen a different scale for measuring the importance of objectives the results would perhaps have differed more noticeably from one diagram to the other.

The interplay of possible convergences and divergences does not depend solely on each actor’s hierarchy of objectives, but also on the ability of an actor to impose its priorities on others - i.e., on relationships of power.

5. Evaluating the balance of power and formulating strategic recommendations (weighted valued position matrix)

If we place ourselves in the position of an actor, for example Paris Airport, we see that this actor is in potential divergence with almost all the others over a given objective, while at the same time it may form convergences over other objectives. A coherent strategy of objectives will therefore have to impose certain objective priorities. Conversely, defining objective priorities obliges one to formulate convergence policies.

Let us develop the example. Paris Airport has every interest in joining forces with the charter companies (A3) and the scheduled airlines (A2) if it wishes to fight for aircraft specifications which correspond more closely to its constraints (02), and to oppose new standards and regulations on noise pollution and disturbance near airports (05). This being the case, Paris Airport, out of concern for coherence, should place on the back burner those issues in which its own interests diverge from those of the scheduled airlines, i.e., traffic rights allocation (03), and the development of the organized flights market (04). This is particularly important as it is precisely over these two objectives (03) and (04) that the scheduled airlines’ interests are opposed to those of the charter companies. For Paris Airport this tactic can only be put into practice if its potential allies, the airline companies, also pursue the same tactic.

In reality, everything depends on how objectives are ranked, which differs from actor to actor, and we should probably expect open conflict between the scheduled and charter airline companies over traffic rights and the ‘organized’ flights market. These objectives are also very important for Paris Airport, which in principle should first make a bid for convergence with the charter companies.

However, merely being in divergence with an actor is not sufficient for actively opposing it - also required are the direct or indirect means to oppose it. The tactical selection of convergences and divergences is necessarily dependent on these means. Sometimes it is even the existence of a favorable balance of power that sparks off conflict.

It is therefore useful to guide one’s tactical choice by analyzing relationships of power through two matrices - the matrix of direct influence (MID) and the matrix of direct and indirect influence (MIDI). The first matrix, MID, is simply a table (actors × actors) in which the potential influence of one actor over another is recorded on a scale from 0 to 4 (none, weak, average, strong, very strong) - one could use other categories. This first table already reveals apparent relationships of power; simply reading the totals for each row and each column reveals that the state is by far the most influential actor in the system, while at the same time it is one of the most susceptible to the influence of others. In contrast, the charter companies are the least well equipped to achieve their objectives, and are also among those actors most subject to pressure from others.

Table 9: MID; matrix of direct influence (apparent relationship of power)

	A1	A2	A3	A4	A5	A6	Σ
A1 - Manufacturers	0	1	1	3	0	2	7
A2 - Scheduled airlines	2	0	3	2	1	1	9
A3 - Charter compagnies	1	2	0	1	1	0	5
A4 - State	2	3	3	0	3	2	13
A5 - Paris Airport	0	2	3	1	0	2	8
A6 - Residents' associatior	0	1	1	3	2	0	7
Σ	5	9	11	10	7	7	49

But in looking at relationships of power, we cannot restrict ourselves simply to direct influence: an actor can influence another via the intermediary of a third actor. It is therefore useful to examine matrix MIDI obtained simply by taking account of direct and indirect influence (second order):

$(MIDI)_{ij} = (MID)_{ij} + \Sigma_k \text{Min}((MID)_{ik}, (MID)_{kj})$

By doing this, we discover that the local residents' associations are in a stronger position of power than one would have thought a priori (ranked second in terms of total direct and indirect influence over actors' moves). This is thanks to their direct influence on the state, the most powerful actor in the system. The charter companies' position of power seems even less favorable than before (they have very weak influence, and are highly sensitive to pressure, particularly from the state and the scheduled airlines).

As for the Paris Airport Authority, it is in an average position of power in relation to the system as a whole. Its capacity for indirect influence over the local residents' associations is much weaker than its potential for direct influence. On the other hand, Paris Airport has significant leverage for exerting indirect pressure over the state while almost totally lacking means of direct action. We also observe that the airline manufacturers can if necessary exert strong indirect pressure over Paris Airport, probably via the intermediary of the state.

Table 10: MIDI; matrix of direct and indirect influence (real relationships of power)

	A1	A2	A3	A4	A5	A6	Mi
A1 - Manufacturers	4	6	6	7	7	5	31
A2 - Scheduled airlines	5	7	8	7	5	6	31
A3 - Charter compagnies	4	5	5	5	3	4	21
A4 - State	5	9	11	8	7	7	39
A5 - Paris Airport	4	6	7	6	5	4	27
A6 - Residents' associatior	4	7	7	6	7	5	31
Di	22	33	39	31	29	26	180

As we can see, reading the MID and MIDI matrices is a fruitful exercise. Looking at 1978 from the standpoint of 1990, in the final analysis Paris Airport Authority had practically no interest in allying itself too openly with the charter airlines, because these were the weakest link in the overall balance of power. So it should come as no surprise that in 1990, at the height of a euphoric growth in air transportation worldwide, the European charter companies were ‘on their last legs’, to quote Aviation Internationale magazine, N° 996, 15 December 1989. What they should do is to air their common interests with the scheduled airlines, while putting pressure on the state for a degree of liberalization of traffic rights.

Naturally, our example is oversimplified, and it would be unreasonable to expect to make any definitive strategic recommendations based on it. We should also recall that everything depends on how each actor prioritizes its own objectives in terms of the balance of power.

“M_i” is used to evaluate the total direct and indirect influence that an actor A_i exerts on the others.
“D_i” is used to evaluate the total direct and indirect influence that an actor A_i receives from the others.
$M_i = \Sigma_{k \pi i} (MIDI)_{ik}$
$D_i = \Sigma_{k \pi i} (MIDI)_{ki}$

We have seen that it was possible to take account of each actor’s hierarchy of objectives through the valued positions matrix (2MAO). To say that one actor is twice as influential as another in the overall balance of power is implicitly to ascribe twice the power to this actor’s influence over objectives. Its relationships of power between actors are characterized by r_i coefficients, it is then sufficient to weight the lines of the valued position matrix by these coefficients. Thus we pass from matrix 2MAO to matrix 3MAO, the valued position matrix, weighted by relationships of power. The matrices 3CAA and 3DAA are made up of all pairs of valued convergences and divergences, weighted by relationships of power.

How should we define these r_i indicators of relationships of power ? The first idea that comes to mind is to consider the direct and indirect influences less the feedback loops given in the matrix MIDI. The measure of relative direct and indirect influence (M_i - $(MIDI_i)/\Sigma M_i$) gives a good indicator of the power of one actor over the others.

However, with identical relative influence, one actor will be in a better position of power than another if its overall dependence is lower. So we must balance the preceding coefficient (M_i - $MIDI_i)/\Sigma M_i$) with an inverse function of dependence (M_i /M_i+D_i).

$$\boxed{\text{With } r_i = \frac{Mi - MIDIi}{\Sigma Mi} \times \frac{Mi}{Mi + Di}}$$

If D_i dependence is zero, $r_i = (M_i - MIDI_i)/\Sigma M_i$; if D_i dependence is strong in relation to influence, then the r_i relationship of power will be much weaker than the simple relationship (M_i - $MIDI_i)/\Sigma M_i$.

$$\boxed{r_i^* = \frac{ri}{\overline{ri}} = n \times \frac{ri}{\Sigma ri}}$$

Moreover, in order to facilitate understanding and calculation, we suggest considering :
Starting with the matrix of real relationships of power, in our example, we obtain the balance of power coefficient for each actor : r_1^* = 1,26 ; r_2^* = 0,93 ; r_3^* = 0,45 ; r_4^* = 1,38 ; r_5^* = 0,85 ; r_6^* = 1,13

The sum of these coefficients is equal to six. If all the actors had the same relationship of power, all the ri would be equal to one.

We pass from the valued matrix of position 2MAO to the matrix of valued positions balanced by relationships of power 3MAO by multiplying each row of 2MAO by the r_i^* coefficient.

Table 11: 3MAO; valued positions matrix, weighted by relationships of power (actors × objectives)

	01	02	03	04	05
A1 - Manufacturers	+2,5	+3,8	0	0	+1,3
A2 - Scheduled airlines	-1,9	0	+2,8	-0,9	-2,8
A3 - Charter compagnies	-0,4	0	-1,3	+1,3	-0,9
A4 - State	0	+4,1	+2,8	0	+1,4
A5 - Paris Airport	-0,8	0	-1,7	+1,7	-1,7
A6 - Residents' associations	0	0	0	0	+3,4
Σ+	+2,5	+7,9	+5,6	+3,0	+6,0
Σ-	-3,2	0,0	-3,0	-0,9	-5,4

We thus obtain two matrices of convergences and divergences (3CAA and 3DAA) balanced by relations of power.

Table 12: 3CAA; valued matrix of convergences, weighted by relationships of power (actors × actors)

	A1	A2	A3	A4	A5	A6
A1 - Manufacturers		0	0	+5,3	0	+2,3
A2 - Scheduled airlines	0		+3,0	+2,8	+3,6	0
A3 - Charter compagnies	0	+3,0		0	+5,0	0
A4 - State	+5,3	+2,8	0		0	+2,4
A5 - Paris Airport	0	+3,6	+5,0	0		0
A6 - Residents' associations	+2,3	0	0	+2,4	0	
Ci	+7,6	+9,4	+8,0	+10,4	+8,6	+4,7

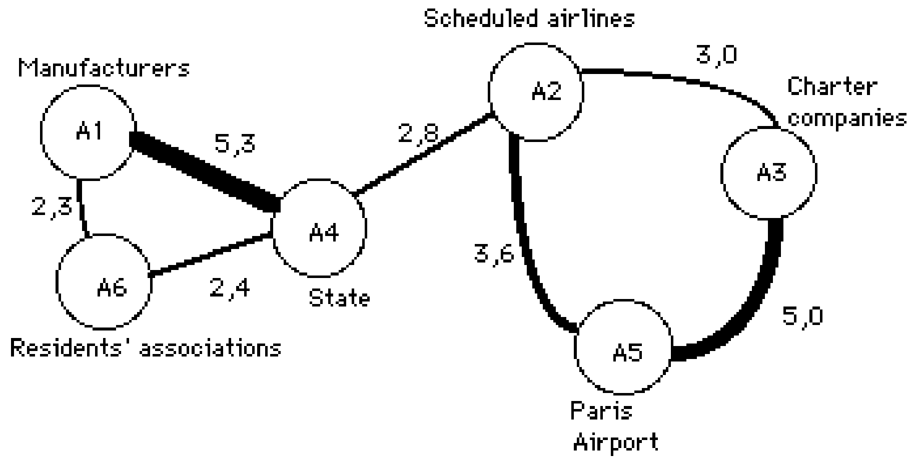
Table 13: 3DAA; valued matrix of divergences, weighted by relationships of power (actors × actors)

	A1	A2	A3	A4	A5	A6
A1 - Manufacturers		+4,2	+2,6	0	+3,2	0
A2 - Scheduled airlines	+4,2		+3,2	+2,1	+3,6	+3,1
A3 - Charter compagnies	+2,6	+3,2		+3,2	0	+2,1
A4 - State	0	+2,1	+3,2		+3,8	0
A5 - Paris Airport	+3,2	+3,6	0	+3,8		+2,5
A6 - Residents' associations	0	+3,1	+2,1	0	+2,5	
Di	+10,0	+16,2	+11,1	+9,0	+13,0	+7,8

Commentary

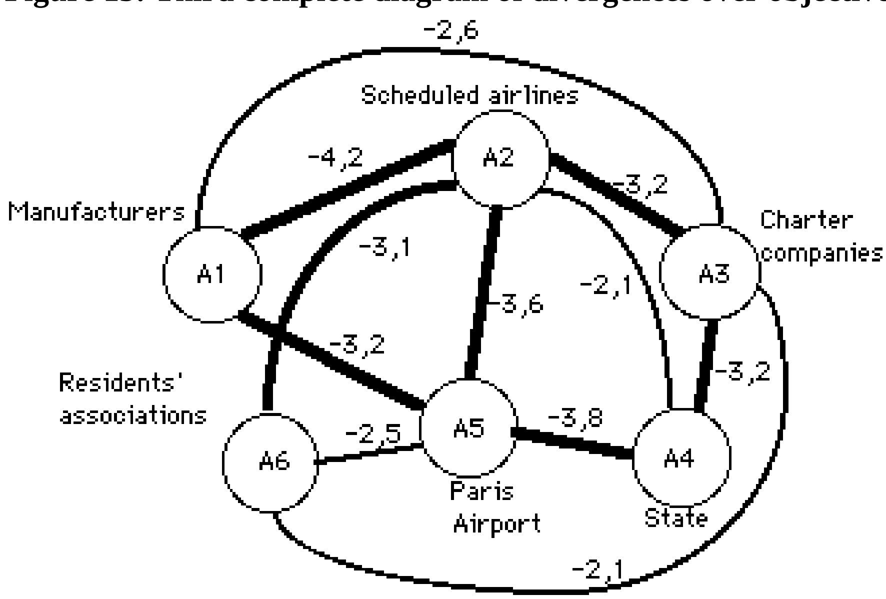
Between the first and the third complete diagrams of convergences, certain developments are worth pointing out.

Figure 14: Third complete diagram of convergences over objectives



The state manufacturers' convergence over objectives becomes noticeably stronger and appears twice as important as the state residents' convergence over objectives, which initially appeared comparable. The convergence over objectives between Paris Airport and the scheduled airlines and charter companies is confirmed as much stronger than the convergence of interests between the companies (scheduled and charter), and is probably a card to be played by Paris Airport.

Figure 15: Third complete diagram of divergences over objectives



Comparison of the diagrams of divergences over objectives allows us to note certain remarkable changes in the actors' strategy when hierarchy of objectives and balance of power are taken into account. Thus, for example, the opposition of interests between the scheduled airlines and the manufacturers seems to be twice as significant as that between the charter companies and the manufacturers or scheduled airlines, which initially appeared comparable. In the same way, the conflicting objectives of the state and Paris Airport become much more critical than the conflict of objectives between the state and the airline companies.

From the above, it is not unreasonable to conclude that the state should support the manufacturers in their struggle for market share, and should strengthen regulations and standards that favor the development of new aircraft. Paris Airport, which is subject to the powerful protection of the state, must above all rely on the scheduled airlines to exert pressure on the state, for the charter companies are in a much less favorable position of power. In doing so, Paris Airport should logically tone down its support for development of charter flights, because the scheduled airlines are opposed to this.

In the example we have considered, taking into account hierarchies of objectives and relationships of power did not cause major upsets to the first analysis. Other scales of notation would probably provide a clearer contrast in results.

We shall not pursue this simplified example any further. For the most complex cases -around 15 actors or 10 strategic issues and about 40 objectives - one certainly has to break down the problem by studying each battlefield separately. This modular use of the MACTOR method implies of course a never-ending task of developing a coherent overall picture with each further addition.

6. Key questions for the future

The evolution of relationships of power between the actors can be presented in the form of hypotheses that may or may not be realized within the time horizon under consideration. These hypotheses are concerned with trends, as much as with events or discontinuities.

The subsequent application of the scenarios method consists of using expert methods to reduce precisely this uncertainty over hypotheses concerning futures hypotheses deriving from the actor strategy analysis.

We believe that MACTOR will disseminate rapidly, as it is a simple and appropriate tool which will lead to a better understanding of the actors' games and power relationships. The air transport example developed here was rather illustrative. We assume that the use of MACTOR by Paris Airport Authority and by the French Electricity Authority to face the new European context proves that MACTOR certainly has a promising future.

IV. NEW FRONTIERS: FROM GROUPWARES TO CHAOS, THE IMPORTANCE OF THE PARTICIPATORY PROCESS

With the development of microcomputers, most of these techniques can nowadays be available on every desk and can be run very quickly. However, the raw data used in these models remain subjective and can thus only be gotten through a participatory process. Therefore, if the use of microcomputers can reduce the time needed for calculating and presenting the results, they have no effect on the main phase of the implementation which consists of setting up an heterogeneous group of experts for discussions, supported by a conceptual and methodological framework, a future-oriented problem.

One could see in new information technologies, such as groupwares, a possibility to improve or to simplify such a participatory process. If participatory modeling tools exist, they have not however been used for such tasks. Actually, even if structural analysis or MACTOR is a well-defined technique, the process still needs an important component of unstructured discussion that can only be reached through meetings. Maybe electronic ones will be organized in a near future but the role of the facilitator in framing the process should not be forgotten. Actually, like operations research, prospective and futures research are more an art than a science. Therefore, if formal techniques and tools are important, the automation of team process is and will always remain primordial.

Concerning the evolution of the techniques themselves and more particularly the concepts used, the ideas of bifurcation, chaos and catastrophes can be, by analogy, useful. Indeed, systems sometimes seem to be chaotic, actors are facing moving strategies, and scenarios often encounter bifurcations. In that way, these tools, used as decision support systems to reduce uncertainty and complexity, could find in these concepts complementary methodological frameworks.

Also fashionable but not new in the prospective and futures research field are the concepts of chaos and bifurcations. Since futures are multiple and undetermined, the door of concepts swings widely open. In fact, if we have first to examine what won't change, the second phase of a prospective approach consists in finding weak signals and breakdown points.

Concluding his first handbook on the prospective approach, Michel Godet emphasized that "the great merit of the work of Prigigine and Thom is in allowing account to be taken of structural instability, and thus to open up a new usefulness for mathematical models, which have to be released from the impasse of continuous mathematics, and from their inability to envisage a plurality of futures and the possibility of ruptures".

Although these mathematics take their sources from the very beginning of the twentieth century (remember French mathematician Raymond Poincaré), they became popular in the late seventies, especially with Prigogine's writings. Regarding breakdown points, the use of the concept of bifurcation is obvious because their critical nature is decisive in determining whether possible futures move towards one branch of evolution or another. In that way, bifurcations give us routes towards *futuribles*, our possible futures. These routes are materialized by the famous diagram that Ilya Prigogine and Isabelle Stengers have drawn in *The new alliance* at the end of the seventies and that has been widely diffused (for example in the WFSF 1993 conference announcement). The usefulness of such models can be found in the short text about “history and bifurcations” that explains this diagram.

Some have also tried to find in René Thom’s catastrophe theory a way to build qualitative forecasting models. Thom’s works gave us in the early seventies a canonical mathematical basis of discontinuous but stable models (the seven elementary catastrophes). These models are based on the concept of catastrophe which is nothing but a leap from a stable state to another, marking a discontinuity. However, the French mathematician has always had a dubious attitude towards the possibility of using them for studying and forecasting real phenomena. Nevertheless, by his systematical implementations, Christopher Zeeman, a British mathematician, opened the way to papers which described, during the seventies, “catastrophic models” applied to economics, politics and sociology. If we consider scenarios as a combination of events and variables, catastrophe theory, with its control factors and behaviour axis, gives us graphic analogies to express the leaps (catastrophes) from an image to another, from a continuous and stable solution to another one.

Whatever the name, bifurcations and catastrophes are, for a prospective use, closely related concepts. The main difference comes from the fact that the second one expresses clearly a mathematical discontinuity in the model. Moreover, while bifurcations are based on quantitative considerations and may be considered as the results from numeric computations (as they were discovered), catastrophes are qualitative and symbolic.

Using the concepts brought up by these theories, some interesting conclusions could be revealed from impact matrices analysis.

When variables are positioned around the bisecting line of the influence-dependence graph of a structural analysis, the system may be considered as chaotic. Therefore, key variables are difficult to find and all could be considered as relays. In that case, it seems that there is no clear organization in the system that may very easily bifurcate from one state to another. In fact, such a system is sometimes moving through a hidden organization that can be discovered by a decomposition into related sub-systems. Beyond direct or indirect relationships between the system components, potential ones are able to change the nature of the system.

The same phenomena can be watched in the influence-dependence graph produced by the MACTOR method. The state of the system is given by a stability indicator. In a chaotic game, many actors may be considered as relays: bifurcations may occur in relation with continuous changes in alliances. In a static but unstable game, changes are more brutal — discontinuous — so that the appropriate analogical name could be “catastrophe” rather than “bifurcation”.

Such an analysis could also be the first path towards a finer study of actors’ strategies with the techniques of game theory. For example, a static but unstable system could suggest a Nash equilibrium. New future developments could thus be the integration of MACTOR with game theory to build a better structured frame of the field of analysis.

Nevertheless, we do not have to wait for that much from bifurcations, chaos and catastrophes even if they seem attractive. One must not forget the principle of contingency that governs the use of the impact matrices techniques presented above. Moreover, their main basis remains judgmental data and simple, but appropriable, models. Therefore such concepts can only be used as analogies and can hardly take the same mathematical form as those developed in physics, biology and even econometrics.

In that way, if chaos, bifurcations and catastrophes give us concepts to name well-known phenomena in scenario writing and may become new guidelines for our thinking, we do not believe they will cause bifurcations in futures research methodology: they do not update the scenario paradigm, nor classic futures techniques. On the contrary they bring a mathematical and symbolic sense to future-oriented formal works such as impact matrices, which become thereby richer in terms of interpretation and communication.

In conclusion, the key factor of success for the implementation of techniques like structural analysis or MACTOR lies in the participatory process for which they give a useful framework. Therefore, all improvements of these techniques have to be assessed by their impacts on this process.

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