INTRODUCTION TO *LA PROSPECTIVE*

Seven key ideas and one scenario method

Michel Godet

This article considers the methodological aspects of *la prospective*. Seven key ideas are described and one scenario method is outlined. A new approach which emphasizes structural analysis and the driver–dependence variables matrix is described and an example of its application given.

Keywords: future studies; French prospective; methodology

THE PRESENT ACUTE CRISIS raging in all industrial countries has only just started. The last illusions created by official forecasts should be swept aside by this outstanding fact.

The current crisis was not only unforeseen (let us remember that in France, for instance, in 1972 decisions on energy were based on forecasts of a continuation in the trend of decreasing oil prices until 1980–1985) but the trend is still continuing and should become even stronger, although all recent official pronouncements still deny this.

This article does not consider the why and the who of what may be a crisis of civilization, rather, it is limited to a consideration of the current crisis in economic forecasting because of its repeated errors. A historical paradox: forecasting developed at a time when it was easier to perform and when it was a less necessary exercise. In practice, econometric models have only been able to show, with the assistance of computers, what everybody could fairly easily find out; everything was more or less directly correlated with the gross national product, which was increasing by 5%/year. In fact, time was the best explanatory variable.

Since 1973, the future has no longer resembled the past; the time horizon of the prospective view, ie distinct disruptions, has been getting closer. Models

Michel Godet is an associate professor of Industrial Prospective at the Conservatoire National des Arts et Métiers, 2, rue Conté, 75003 Paris, France, and a scientific adviser at the CPE (French Ministry of Research and Technology). He is also an active member of the International Association of Futuribles and has written many works on Prospective, such as *Crises are Opportunities*, Gamma Press, Montreal, 1985. This article is a translated and edited version of Michel Godet's new book, *Prospective et Planification Stratégique*, Economica, Paris, 1985. Michel Godet is a member of the advisory editorial board of *Futures*.

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based on past data and relationships cannot forecast these disruptions because they are linked to actors' behaviour which becomes more and more uncertain and conforms less and less to the classical rational scenarios.

La prospective is neither forecasting nor futurology (see Table 1). It is a way of thinking based on action and non-predetermination using specific methods, such as scenarios. Before presenting these methods it is necessary to review certain key ideas which I consider should always be present in prospective work, whatever the actual approach chosen.

La prospective—seven key ideas

We have selected seven key ideas:

- to clarify present actions in the light of the future;
- to explore multiple and uncertain futures;
- to adopt a global and systemic approach;

TABLE 1. DEFINITIONS

The confusion existing between the terms 'projection', 'forecasting', '*la prospective*' and 'planning', is the basic cause of many forecasting errors and misunderstandings. The following simple definitions should therefore be borne in mind.

A projection is the extension into the future of past evolution by using certain extrapolatory hypotheses or variations in tendencies. A projection becomes a forecast only when it is matched up to a probability.

A forecast (to be read fore-cast, ie to shape before-hand) is the appraisal of the way a parameter will evolve at a given time horizon, after adding a certain degree of confidence (probability). Most often, this appraisal is quantified from past data, under certain assumptions.

An exploratory prospective is a range of possible futures (*futuribles*), ie scenarios which are not improbable given the weight of determinism from the past and the confrontation between various actors' projects. Each scenario (set of coherent assumptions) of *la prospective* can be appraised and quantified, and thus become a forecast.

"Planning consists of designing a desirable future as well as the effective means to obtain it." It is therefore a *normative prospective* (R. L. Ackoff, *Methods of Business Planning*, 1973). Too often, a common mistake is the confusion between forecasting and planning; when an error in forecasting is likened to what is only a deviation with respect to goals.

Conjecture Probable hypothesis	***La prospective*** Mainly a Latin concept Vision: global, qualitative, voluntarist, multiple (scenarios)
Projection Extension or variation in the future of past tendencies	**Forecast** An estimate, given a certain degree of confidence Qualitative and deterministic vision
Prediction To announce before-hand (oracle of Delphi)	**Futurology** (Anglo-Saxon concept) All research on the future
Prophecy Prediction by divine inspiration	**Scenarios** Set of coherent assumptions

Planning
"Consists of designing a desirable future and the effective means for obtaining it". Ackoff 1973

- to take into account qualitative factors and the strategies of actors;
- to remember always that information and forecasts are not neutral;
- to opt for a plurality and complementarity of approaches; and
- to question preconceived ideas on forecasts and forecasters.

To clarify present actions in the light of the future

In a world characterized by increasing uncertainties, and by the risk of disruptions in current trends not only in the longer term but also in the medium and short term, the prospective effort, ie construction of the most probable scenarios, is more indispensable than ever for clarifying present action.

Action should not wait for emergencies, crises or catastrophes to occur. The experiences of recent years show that settling the most pressing problems is neither the most economic solution nor the path of least risk.

A preventive approach (anticipating future problems so as to be prepared better for them and to carry out actions to avoid them) is undoubtedly more appropriate to the means available and more effective in solving problems (prevention is generally less expensive than cure).

To explore multiple and uncertain futures

The future should not be viewed as a simple and predetermined line extending from the past: the future is multiple and undetermined. Its plurality and the extent of freedom of human action can be explained together: the future is not written, it remains to be carried out.

The prospective process admits that, at any given moment, the future is multiple and that from the confrontation between the various actors involved will derive one future rather than another. The way the future is constructed can be explained as much by the way relationships between dynamic forces as by the way various determinant factors interact and, naturally, since a variety of futures is possible (alternative evolutionary paths of the Forces involved), *the future* is uncertain.

To adopt a global and systemic approach

The phenomena under study are often complex and interdependent and a global and systemic approach is usually necessary.

Obviously, prospective thinking has to be global: very few problems can be isolated; on the contrary, problems are becoming increasingly interdependent and indeed, increasingly entangled. Hopefully, *global solutions* can be found, even if certain aspects of these solutions are to be applied locally. Furthermore, the complexity of the elements and relationships to be taken into account and the need to locate them within a global perspective, makes analysis especially difficult. It is therefore essential to use methods based on *systems analysis*: this method enables the integration, in respect of the whole complexity of their relationships, all types of processes, conflicts and challenges.

To take into account qualitative factors and the strategies of actors

Frequent errors in forecasting (see Exhibit 1) and, in particular, the inability to forecast crises are proof that forecasting is undergoing a crisis. The impossibility of forecasting the future when only data from the past are used explains the

EXHIBIT 1. THREE EXAMPLES OF FORECASTING ERRORS

1. *Inaccuracy of data and instability of models*
Economics is not subject to the rules which apply to the more exact sciences such as physics: the statistical data are supplied without any estimate of the possible error made when preparing those data. What's the good of using sophisticated calculations which are accurate to within a 100th or thousandth decimal place when the figures before the decimal points are not even certain? According to O. Morgenstern,[a] in the USA even the GNP level is not known within an accuracy better than plus or minus 10% and there is no proof that the bias in this estimated error is systematic. When the scale is not accurate, do not trust the weighting, which means, in effect, that even the variation signs of GNP can be unreliable.

This data inaccuracy seriously jeopardizes the validity of the models when they are not subjected to sensitivity analysis.

The economist should always ask the following question: when input data are infinitesimally modified, is it the same for the variable results?

2. *Absence of an overall and qualitative vision*
The fragmented forecast which only takes some explanatory variables into account (usually economic and qualitative ones), without making allowance for the changing forces involved and the impact of new trends is more deceptive than useful. This lack of foresight is due to the following in particular: the economy is set up as an autonomous sector, the economic forecast is isolated from the social and political forecast and it is fragmented, *inter alia* into technological and demographic forecasts. However, as this change accelerates, interdependency builds up; everything acts on everything else, everything is no longer equal and a global vision is demanded. The quantitative forecast should be replaced by a novel prospective taking into account all parameters, whether qualitative, quantifiable or not, which affect, to greater or lesser degree, the phenomena under study.

3. *Explanation of the future by the past (alone)*
Most forecasting methods are based on trend extrapolation, by the reasoning 'all other things being equal', which is totally illusory in an environment experiencing ever-increasing change, when the phenomena to be taken into account are increasingly complex and interdependent.

Thus, economic models prove unable to forecast structural changes (crises) and their users impute these forecasting errors to the infamous hidden variables.

La prospective is born from the realization that the future belongs to determinism as well as to freedom: what is suffered in the future *results from past actions*; what is *wanted* explains *present actions*. To clarify, it is not only the past which explains the future, but also an image of the future which is imprinted in the present. Thus, for instance, the consumption of an individual person at a given moment depends not only on his previous income (savings) but also on the future income he anticipates (credit) as proved by Milton Friedman in his theory of permanent income.

In short, *it is impossible to forecast the future by only taking into account past data*. The future has to be looked at to illuminate the present, "*the future justifies the present*" (Gaston Berger).[b]

References:

[a] O. Morgenstern, *On the Accuracy of Economic Observations*, Princeton UP, 1963.
[b] G. Berger, *Phénoménologie du temps et prospective*, PUF, Paris, 1964.

inadequacy of standard econometric models, since they do not integrate qualitative and non-quantifiable parameters such as the plans and behaviours of actors—ie sociocultural factors.

Consideration of qualitative factors has to be all the more rigorous since all quantification (which is required for anything that can be quantified) tends to emphasize what is quantifiable at the expense of factors that are unquantifiable.

To remember always that information and forecasts are not neutral

Information about the future, as with the present, is rarely neutral; by omission as much as anything else it usually serves very specific interests.

Information is corrupted because it is power. As has been correctly emphasized by Michel Crozier and E. Friedberg, "Information is a rare commodity and its distribution and exchange are not neutral and free processes. To inform another person, to communicate to someone else pieces of information that they do not have, is to reveal oneself, to renounce trump cards which could have been bargained for; it is also to leave oneself vulnerable to the attempts of someone else to gain an advantage".[1] Let us also add that information is often suppressed by the need to conform to the consensus view—we tend to associate ourselves with prevailing opinions and reject the minority's views.

To opt for a plurality and complementarity of approaches

Available information is often incomplete, there are large amounts of it, and it is unquantifiable, inaccurate and uncertain. Therefore, a plurality and complementarity of approaches should be selected and successive approximations should be preferred to a spurious accuracy. This is the only way in which forecasting can overcome its crisis.

Analytical forecasting and decision methods are, first and foremost, tools to promote rigour, coherence, imagination and dialogue. A method can be considered a good and useful one if it can improve coherence and stimulate imagination; the method matters little provided that the required stimulation can be achieved.

To question preconceived ideas

The first consideration is that a good forecast is not always the one which becomes reality. Indeed, when a forecast gives awareness of a future problem arising, everything should then be done to prevent its occurrence or to minimize its consequences.

Second, an accurate forecast is not necessarily a useful one. By analogy with the theory of statistical tests, three types of errors in forecasting can be identified:

- the first-order risk of keeping a hypothesis about the future which will not become reality;
- the second-order risk of excluding a hypothesis or possible event which in fact will become a reality; and
- the third-order risk of not asking the right questions—ie excluding from prospective thinking hypotheses or events which will play a decisive role in the future.

This third-order risk is frequent in forecasting where errors are more often the result of asking the wrong questions than of giving the right answer. This can be explained by what is called *the streetlight effect*, which refers to a drunk who has lost his door key and looks for it under the street lamp because that is the brightest spot.

In practice, in many areas, and in particular in regard to technology, an expert's judgmental forecast is often the main accessible information tool.

Generally, most experts are conformist (it is easy to side with the majority, since they do not have to do the explaining) and conservative. A good forecast, ie the one which gives accurate foresight, is usually one deriving from a minority among expert views, which tend to be more imaginative. Obviously, then, the hard part is to recognize what are the 'good' minority views.

Finally, the person who presents an accurate view often confronts the problem of getting a hearing—this is a further reason why we should always listen to alternative viewpoints. This would not add credibility to forecasts that are obviously ridiculous but would lead to a questioning of many conjectures and received wisdom. In this sense, then, the first aim of the prospective researcher should be to challenge those who are complacent in and oblivious of their misconceptions.

These seven key ideas form the basis of our prospective approach and the scenario method, which are described below. This scenario method was mainly developed in the department of prospective studies at SEMA between 1974 and 1979. With the benefit of hindsight, it is clear that the development and application of such a prospective approach in various companies and government departments:

- helped to stimulate collective strategic planning and communications within companies;
- helped to improve internal flexibility when confronting environmental uncertainty and to be better prepared for possible disruptions; and
- helped to adapt choice of actions to the future context to which the consequences of actions would relate.

The scenario method: objectives

There are many possible futures (*les futuribles*) and there may be more than one path to any particular future. The description of a possible future and the corresponding path to it make up one scenario.[2]

In France, the OTAM team were the first to use a scenario method in a study of geographical futures undertaken for DATAR.[3] Since then, this method has been adapted to industrial futures, notably in a study of 'chemical–agricultural' futures carried out by C. Kintz and G. Ribeil at SEMA.

The US researchers, Gordon, Helmer, Dalkey, etc have developed several rather more formal methods to construct scenarios. All these methods are based on discussions among experts: Delphi, cross-impact matrixes, etc.[4]

In practice, there is no one scenario method, but rather a variety of methods of constructing scenarios (some being simplistic, others sophisticated). However, a kind of consensus seems to have been reached; the term 'scenario method' only applies to an approach which includes a number of specific steps (systems analysis, retrospective, actors' strategies, elaboration of scenarios) which interrelate logically (see Figure 1).

Increasing uncertainty, growing interdependence, the quickening pace of change in certain areas (political, technological, industrial, etc), and the noticeable lack of action in other (demographic, energy, sociocultural) are all factors which call for a futures approach when considering present actions. Specifically, the following are required:

- *alternative scenarios* for future development, along with identification of the associated problems and opportunities, given the objectives which have been selected;

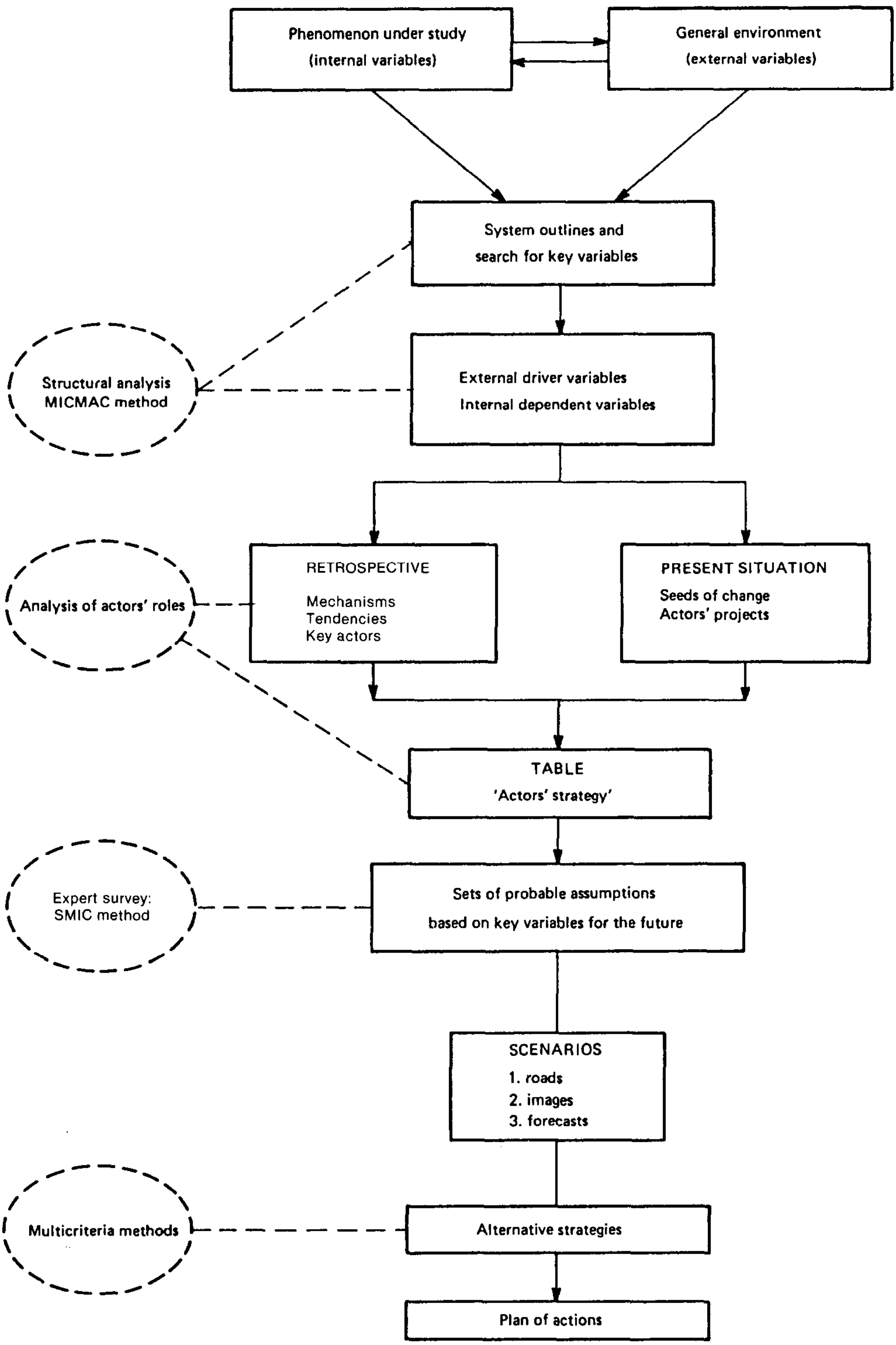


Figure 1. Scenario method.

- *the possible actions* required to remedy such problems or take advantage of such opportunities;
- *the consequences of possible actions* given the scenario envisaged and the objectives selected.

The scenario method specifically tries to conceive all possible futures and to explore the paths leading to them in order to clarify present actions and their possible consequences.

The objectives of the *scenario method* are:

(1) *to detect* the priority issues for study (*key variables*), by identifying the relationships between the variables of the specific system under study through systemic analysis;
(2) *to determine*, especially in relation to key variables, the *main actors* and *their strategies*, and the means at their disposal for bringing their projects to a successful conclusion.
(3) *to describe*, in the form of *scenarios*,[5] the development of the system under study, by taking into account the most probable evolutionary path of the key variables and by using sets of assumptions about the behaviour of the various actors.

Standard forecasting techniques can then be used within the framework defined by the scenario, in order to convert this scenario into quantitative terms. Also, by using the various scenarios, we can assess the consequences of measures already taken, and, by using multicriteria methods, the priority strategic actions to be initiated at once can be identified to take advantage of expected changes and to prepare *an action plan*.

There are two initial stages in the scenarior method—construction of the database and, then, from this base, the elaboration of scenarios which lead to a third, strategic phase.

Identifying the key variables: structural analysis

Origins and objectives of structural analysis

A system consists of a set of interrelated elements. The system structure, ie the network of relationships between these elements, is essential to an understanding of its evolution, because this structure maintains a certain permanence. The aim of structural analysis is to highlight the structure of the relationships between the qualitative variables, whether they are quantifiable or not, which characterize the system under study (eg a company and its strategic environment).

Concretely, structural analysis enables a system to be described by using a matrix which interconnects all the system components. This method enables analysis of these relationships and identification of the main variables.

With regard to the techniques used, as G. Barrand and C. Guigou noted,[6] "structural analysis is based on Leontiev's input–output matrices, on the theory of graphs and the simulation exercises of operational research carried out soon after the last war in the USA, and in particular by the Rand Corporation to fulfil American army requirements." Some systems analysis and technological forecasting methods have their origins in defence research. This was the case in France for the method of 'relevance trees' developed by the Centre de Prospective et d'Evaluation (CPE) (Centre for Prospective and Evaluation) of the French Ministry of Defence.[7] This was not the case with structural analysis, which seems to have been introduced into France by Professor Wanty who worked for the Belgium subsidiary of the METRA International Group and who taught at the University of Paris Dauphine in 1969 and 1970. Since then structural analysis has become more widespread through, in particular, the work of Professors R. Saint-Paul and P. F. Tenière-Buchot, and our own work at SEMA.

Structural analysis has two complementary objectives: first, to obtain, during the initial phase, as thorough a representation as possible of the system under study, in order, second, to reduce systemic complexity to its main variables. In his thesis on structural analysis and its developments J. F. Lefebvre[8] lists several of its applications:

- it can help in thinking about a system in order to build a more elaborate model such as, for instance, systems dynamics;
- it can be used on its own in order, eg, to assess strategic choices;
- it can form part of an overall approach such as the scenario method; and
- it can help group communications and discussions or group adherence to a specific objective.

In practice, structural analysis has been used in two main ways:

- in decision making (research, identification of the variables on which to act to achieve the selected objectives)—the POPOLE model of P. F. Tenière-Buchot[9] is a good example; and
- in forecasting (research on the key variables which bear on the future dimension). This use was developed in the early 1970s and did attract us, in particular the development of the MICMAC method where the importance of a variable is measured less by its direct interrelationships but rather by many indirect interrelationships.[10]

The next section main deals with the latter, use of structural analysis in forecasting. This comprises several stages:

- listing all the variables;
- location of interrelationships within the structural analysis matrix; and
- search for the key variables by the MICMAC method.

Listing all variables

In order to develop as exhaustive a list as possible of the variables which define the system formed by the phenomenon under study and its environment, no research path is *a priori* excluded. All brainstorming and intuitive methods are useful here.

Listing all the variables should be assisted, preferably, by non-directed interviews with the representatives of the actors presumed to be involved in the system under study. The questions should be open, such as "In your opinion, what are the factors which will condition the future evolution of such and such a phenomenon?''

To identify these variables, several different political, economic, technological and social viewpoints should be adopted, in order to build up files and to organize several sessions of collective thinking. Following the accumulation of raw data, the actual listing of all variables is based on aggregating and refining the data so that a homogenous list is obtained. Also, given the nature of the phenomenon under study, it is often advisable to reclassify the variables by distinguishing between internal and external variables; the internal variables characterize the sub-system under study whereas the external variables make up its environment.

Finally, detailed explanations of these variables are essential to identify the various interrelationships. Indeed, such an explanation can provide the detailed analysis of everything implied in the definition of a variable. Without the creation of this common base, the analysis and identification of interrelations could be rendered impossible or meaningless. These files, once completed, are kept open and they are updated as and when required. They thus form an information database which can systematically sort data.

Below, we describe the scale models built, under our supervision, by J. Barrand and C. Guigou[11] as a case study of structural analysis. We concentrate on the determinants of employment and unemployment and the analysis was reduced to the 41 variables shown in Table 2.

Location of relationships within the structural analysis matrix

Within a systematic worldview, a variable can only exist because of its interrelationships; the intuitive recognition of the existence of certain interrelationships did remind us of some variables when preparing the above list.

Structural analysis attempts to interrelate the various variables in a dual input table (see Figure 2).

Before the conclusion can be drawn that there is a relationship between the two variables, the futures group must systematically answer the following three questions:

(1) Does variable i causally affect variable j, or is this relationship the other way round, ie j to i (Figure 3 (a)).
(2) Does i have an impact on j, or does some collinearity exist, ie, the third variable k has an impact on i and j? (Figure 3 (b)).
(3) Is the relationship between i and j direct, or does it operate through another listed variable? (Figure 3 (c)).

Many errors can be avoided by using this procedure, when filling in the matrix.

At present some variables only have a weak influence. However, they could become much more important in a different context in the future; this is the case, for example, with the 'new technologies for industry and agriculture' variables. Therefore, we should take into account *potential* relationships which, depending on the case, are to be added to the reference relationships, ie to those certainly in existence.

TABLE 2. DETERMINANTS OF EMPLOYMENT AND UNEMPLOYMENT

Internal variables			
		1	Unemployment rate
		2	Unemployment rate for women
		3	Unemployment rate for young people
		4	Number of long-term people
		5	Employment in services
		6	Employment in industry
		7	Employment in agriculture
Environmental variables (external)			
Economic and financial			
	Internal	8	Household income
		9	Rate of economic growth
		10	Household consumption
		11	Inflation
		12	Savings
		13	Financial situation of companies
		14	Interest rate (savings)
		15	Rates on the money market
		16	Money supply
		17	Budget deficit
	International	18	Constraints on the external balance of payments
		19	International context
		20	Degree of openness of the economy
		21	European harmonization
		22	Energy prices and raw materials
Technological and industrial variables			
		23	Investment for rationalization
		24	Investment for expansion
		25	Operational productivity per hour
		26	Company competitiveness
		27	Technological and industrial evolution
Socio-demographic variables			
		28	Working population
		29	Employment rate among women
		30	Geographical concentration of unemployment
		31	Immigrant workers
		32	Parallel economy, moonlighting
		33	Social relationships
		34	Uncertainties for the future
		35	Evolution in ways of life
Institutional variables			
		36	Work legislation and regulations
		37	Worksharing and income sharing
		38	Distribution of mandatory wage deductions
		39	Total value of mandatory wage deductions
		40	Training
		41	Work costs (average hourly wage)

Normally, filling in the matrix is a *qualitative* exercise: we only state whether a relationship exists or not, although, the strength of a particular relationship can also be specified. Thus, several direct relationship strengths can be distinguished: very strong (VS), strong (S), average (A), weak (W), very weak (VW) and potential (P). The term 'potential' refers to incipient relationships which still only have a weak influence but which could, in a future context, become very influential (for example the consequences of technical change). Thus, a certain dynamic can enter into the structural analysis, and the sensitivity of some results can be tested against the intensity of the relationships that are being taken into account.

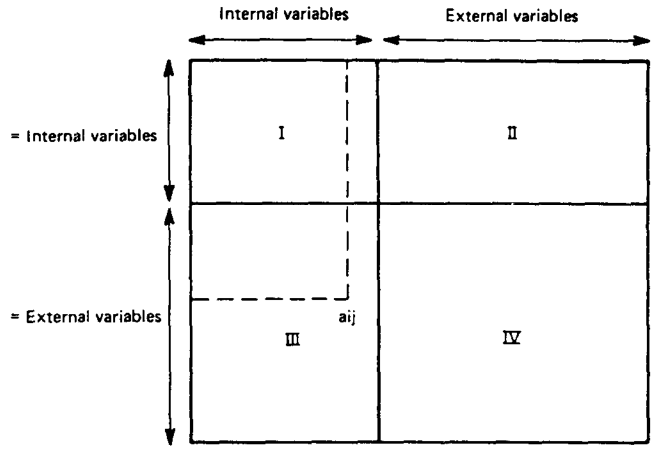


Figure 2. Structural analysis.
I Impact of internal variables on each other
II Impact of internal variables on external variables
III Impact of external variables on internal variables
IV Impact of external variables on each other.
Each element *aij* of this matrix can be explained as follows:

aij = 1 when variable *i* acts directly on variable *j*
0 when the opposite is true

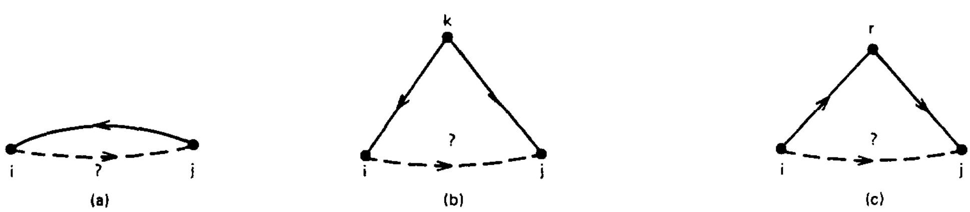


Figure 3. Three possible cases suggesting that *i* has a direct impact on *j*.

One of two methods can be used to fill in the matrix:

- either in rows, by identifying the influence of each variable on all others;
- or in columns, by recording which are the other variables influencing each variable.

Theoretically, it is useful to use both methods and to compare the results by superimposing the two completed matrices in order to identify differences and, consequently, the errors made. However, this practice often proves to be time-consuming and a luxury the researcher can rarely afford. Indeed, most structural analyses completed thus far interrelate several dozens of variables, ie several thousand questions have to be asked, which takes several days of hard work.

Also, structural analysis is a systematic questioning procedure; without the insights offered by the matrix, many of these questions would never be asked. Moreover, new variables are sometimes discovered that nobody had thought of when drawing up the original list of variables.

Filling in the matrix is a good technique for stimulating dialogue. Indeed, it stimulates exchanges of views and discussions to help create a common language within a futures group. As it is, the structural analysis matrix remains qualitative. With greater time available, with a more refined method, and if, especially, we are aiming at a different objective, we could develop a more quantitative matrix:

- *Giving a positive or negative value to direct relationships*, as in the first experiment of J. C. Duperrin and M. Godet.[12] This can be a profitable exercise and reveals positive (amplifying) and negative (regulating) feedback. To perform such an exercise without making an effort disproportionate to its anticipated usefulness, the exercise should deal only with a small number of variables (10 or 15). First, it is not always clear whether an impact is positive or negative; second, the designation of a particular variable could be open to question because, to turn variables into their opposites (eg, increase and decrease) does not automatically alter the value of the row and column relationships. For example, there is the case of consumption as a function of income: as income increases, consumption increases; when income decreases, consumption does not necessarily decrease.
- *Quantifying the strengths of variables*. The coefficients $a\ i\ j$ can for instance be considered as elasticities (the percentage variation in variable j following a relative variation in variable i). In this case, we assume that we can reasonably estimate such elasticities (ranging, *a priori*, somewhere between less than infinity and greater and infinity).

This means that it is impractical or too costly to perform this exercise for a matrix with more than 10 or 15 variables. In any case, it is not very useful arbitrarily to attach a quantitative value between 0 and 10 and then perform calculations which will have little meaning since the accurate value of the starting coefficients is not known.[13]

Although such refinements may be interesting in principle, they are ill suited to the future use of structural analysis. The search for key variables requires an overall vision of the system under study and excludes restricting the analysis at the start to several variables since one is actually trying to identify the main variables from among several dozens of others.

Search for the key variables with the MICMAC method

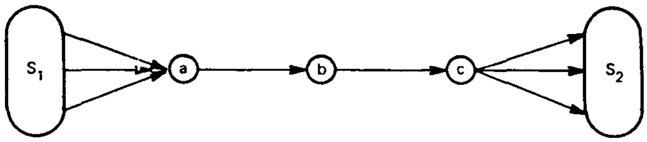
Having developed an exhaustive list of the variables to be taken into account, we now have to reduce the complexity of the system and to identify which key variables should be studied first.

When dealing with an internal sub-system, related to an external environment, there are two kinds of major variables: first, the external variables which are the most influential and the most useful in explanation (the system's main determinants); second, the internal variables which are the most sensitive to this environment. The environmental variables which do not seem to affect the system under study can be discarded.

MICMAC tries to pinpoint the independent and dependent variables (the key variables) by building a typology of these variables in both direct and indirect classifications.

EXHIBIT 2.

1. Let us examine the following example where the system of variables can be broken down into two sub-systems, S_1 and S_2 which are not independent since they are interconnected through variables *a, b, c*.



As regards the direct effects:

- *a* is strongly dependent on sub-system S_1;
- *c* dominates sub-system S_2.

When analysing the direct effects, variable *b* is neglected although it can represent an essential element of the system's structure since it is the relational cross-section point between both sub-systems S_1 and S_2.

Direct and indirect classification (MICMAC)

Straightforward examination of the matrix reveals which variables have the greatest direct impact[14] but is not enough to reveal the hidden variables which sometimes greatly influence the problem under study.

Indeed, in addition to the direct relationships, there are also indirect relationships between variables, through influence chains and reaction loops (feedbacks). A common matrix comprising several dozens of variables can include several million interactions in the form of chains and loops. The human mind cannot conceive and interpret such a network of relationships.

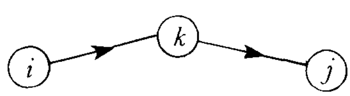
The MICMAC method,[15] a system of multiplication of matrices applied to the structural matrix, is used to study the diffusion of impacts through reaction paths and loops; thus, a hierarchy can be developed for the variables:

- in order of their driver power, by taking into account the number of paths and loops of length 1, 2 . . *n* . . arising from each variable; and
- in order of dependence, by taking into account the number of paths and loops of length 1, 2 . . *n* . . accruing to each variable.

The MICMAC principle: the raising of matrix to the power

The MICMAC principle is a simple one, and is based on the classical properties of Boolean matrices, which are summarized as follows.

If variable *i* directly influences variable *k* and if *k* directly influences variable *j*, we have the following:



In this case, any change affecting variable *i* can have repercussions on variable *j*. There is an indirect connection between *i* and *j*.

Numerous indirect relationships of the $i \to j$ type which exist in the structural analysis matrix cannot be taken into account in a direct classification. When the matrix is squared, second-order relationships are revealed, such as $i \to j$.

Indeed, $A^2 = A \times A = \left\{ a^2_{ij} \right\}$
where $a^2_{ij} = \sum_k a^1_{ik} \cdot a^1_{kj}$

When a^2_{ij} does not equal 0, there is at least one k where $a^1_{ik} \cdot a^1_{kj} = 1$, ie there is at least one intermediate variable k where variable i has an impact on k ($a^1_{ik} = 1$) and where variable k has an impact on variable j ($a^1_{kj} = 1$).

We can say that a second-order path goes from i to j; if $a^2_{ij} = N$, there are N paths of second-order length going from i to j via N intermediate variables. In particular, when $a^2_{ii} = N$, there are N circuits (or influence loops) of second-order length going through variable i.

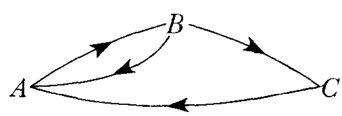
Similarly, by calculating A^3, A^4,............,A^n, the number of influence paths (or influence loops), of the 3rd, 4th, . . . nth order, interconnecting the variables, can be found.

Each time this process is repeated, a new hierarchy of variables can be deduced. Their classification is based on the number of indirect actions (influences) they have on the other variables. When raised to a certain power (usually the power of 7 or 8), *this hierarchy proves to be stable.* This hierarchy is the MICMAC classification.

When the linear sum $_j\; a^n_{ij}$ is raised to a power for variable i (a^n_{ij} being one element of the matrix raised to the power of n), this means that there are a large number of paths of length n rising from variable i, and that variable i subjects the other system (or sub-system, when dealing with a block) variables to a large number of influences).

Hence the MICMAC classification can classify the variables according to the influence that they have (or that they are subjected to), by taking into account the whole network of interrelationships described by the structural analysis matrix.

To make this less abstract, let us take the following example from J. F. Lefebvre's thesis: a system is identified by three variables: A, B, C, which interact on each other in the following way:



The structural analysis matrix can thus be written as follows:

$$M = \begin{array}{c} \\ A \\ B \\ C \\ \\ \end{array} \begin{array}{c} \begin{array}{ccc} A & B & C \end{array} \\ \begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 1 & 0 & 0 \end{pmatrix} \\ \boxed{\begin{array}{ccc} 2 & 1 & 1 \end{array}} \end{array} \quad \boxed{\begin{array}{c} 1 \\ 2 \\ 3 \end{array}}$$

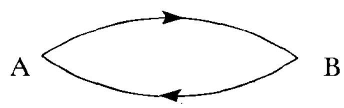
Sum of the elements in each row

Sum of the elements in each column

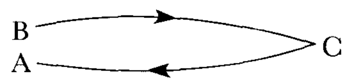
In this first matrix, the diagonal elements are always set at zero: this means that the influence one variable has on itself is not taken into account whereas in the indirect effects (updated by squaring the matrix) this influence is taken into account (these effects always occur through another variable).

$$M^2 = \begin{array}{cc} \begin{pmatrix}1&0&1\\1&1&0\\0&1&0\end{pmatrix} & \boxed{\begin{matrix}2\\2\\1\end{matrix}} \\ \boxed{\begin{matrix}2&2&1\end{matrix}} & \end{array}$$

The digit 1 in the first row, first column, means that there is a circuit of length 2 going from A to A.
Indeed:



The digit 1 in the second row, first column, means that there is a path of length 2 going from B to A.
Indeed:



$$M^3 = \begin{array}{cc} \begin{pmatrix}1&1&0\\1&1&1\\1&0&1\end{pmatrix} & \boxed{\begin{matrix}2\\3\\2\end{matrix}} \\ \boxed{\begin{matrix}3&2&2\end{matrix}} & \end{array}$$

It is clear that all elements of a matrix raised to the power of 3 show that the paths and loops of length 3 go from one variable to the other.

It should be noted, and this has already been underlined, that the row and column classification becomes stable when the elements are raised to a certain power. But, the classifications of this matrix raised to a certain power emphasize clearly the importance of certain variables by the indirect effects (feedback) that they have.

$$M^4 = \begin{array}{cc} \begin{pmatrix}1&1&1\\2&1&1\\1&1&0\end{pmatrix} & \boxed{\begin{matrix}3\\4\\2\end{matrix}} \\ \boxed{\begin{matrix}4&3&2\end{matrix}} & \end{array} \quad M^5 = \begin{array}{cc} \begin{pmatrix}2&1&1\\2&2&1\\1&1&1\end{pmatrix} & \boxed{\begin{matrix}4\\5\\3\end{matrix}} \\ \boxed{\begin{matrix}5&4&3\end{matrix}} & \end{array} \quad M^6 = \begin{array}{cc} \begin{pmatrix}2&2&1\\3&2&2\\2&1&1\end{pmatrix} & \boxed{\begin{matrix}5\\7\\4\end{matrix}} \\ \boxed{\begin{matrix}7&5&4\end{matrix}} & \end{array}$$

Here, the row and column classifications become stable from the power of 4.

Comparison between direct and indirect classifications

This section describes the direct and indirect driver and dependence classifications. They can be overall or partial (external or internal). However, they are always established by considering the paths and loops throughout the whole matrix. For instance, in the external/internal driver classification, the indirect impacts of external variables on internal variables are taken into account through the mediation of other external or internal variables.

When considering the driver power or dependence of a variable, the comparison between the two classifications (direct and indirect) provides much useful information relating to the search for the main determinants of the phenomenon under study and its most sensitive parameters. In particular, by observing the direct and indirect impacts that the variables from the general environment (external variables) have on the internal variables, the following can be obtained:

- a hierarchy for the external variables as a function of their direct and indirect impact on the internal variables;
- a hierarchy for the internal variables as a function of their sensitivity to changes in the general environment.

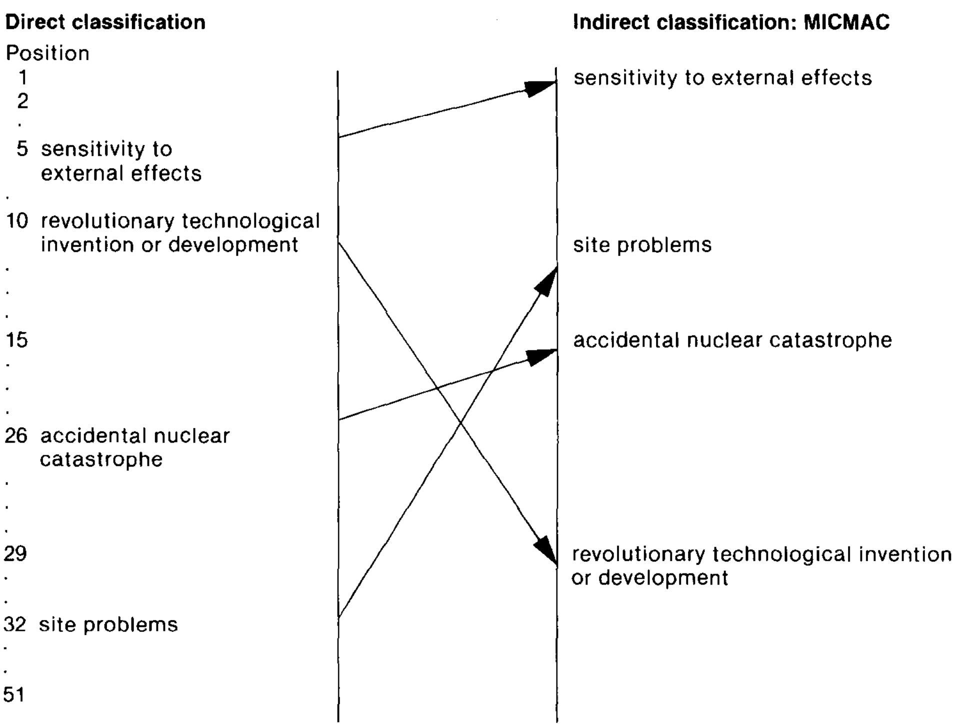
Obviously, the comparison between the classifications (direct and MICMAC) can confirm the importance of certain variables and also reveal other variables which were previously thought to be unimportant but which play a leading role because of indirect actions. It would be wrong to neglect them during the explanatory analysis. The example given here explains how a hidden driver

EXHIBIT 3. EXAMPLE—UNCOVERING HIDDEN VARIABLES

The following example is based on a prospective survey of French nuclear power. This survey was carried out in 1972 by the CEA (French atomic energy commission).

By adopting several viewpoints (political, economic, technological, etc) the think-tank for this survey prepared a list of 51 variables which should be taken into account.

The results obtained are as follows:



The variable 'sensitivity to external effects' moved up from 5th to 1st position. Thus, since 1972 structural analysis has enabled us to foresee how important collective psychology and public opinion reactions would be for the development of nuclear energy.

This evolution is even more striking in the case of the variable '*location problems for the siting of nuclear plants*' which moved up from 32nd position in the first classification to 10th in the second. Thus, *the kind of problems that EDF (French central electricity generating board) had to face at Plogoff had been identified almost ten years before they became reality.*

variable linked to the development of nuclear power in France was revealed (Exhibit 3). Every structural analysis using the MICMAC method did reveal two general points:

- (At least) four-fifths of the results confirmed initial expectations, and for many variables the indirect classification does not differ from the direct classification. Therefore, the highest ranked variables can be selected without too much hesitation, whereas all those which seem in all cases to be secondary can be rejected.
- Between 10% and 20% of the results seem counter-intuitive since, in the different hierarchies, certain variables move quite noticeably up or down the order.

This analysis stimulates discussion within the group of futures researchers and new questions arise. Some of these question preconceived ideas, other questions arise because of the ideas themselves.

We can still remember the 'shock' felt by the management of the French post office in 1978 *à propos* the classification of the positions of these variables with respect to their dependency *vis-à-vis* the general environment. The direct classification seemed the logical one, the mail traffic variables being the most dependent, whereas the workforce policy variables (manpower levels, wages) or the quality of service were considered as internal control variables. The MICMAC classification turned this hierarchy upside down. After long discussions, this *a priori* counter-intuitive result became self-evident: on the one hand mail traffic since 1973 had been recording quasi-autonomous development, almost independent from variations in economic growth to which it had been closely correlated in the 1960s. On the other hand, one had to admit that the workforce policy of a public service has practically nothing to do with what its general management wants but is closely linked to overall government policies for the public sector, the latter also being connected to the political situation. The policy of uplifting the lower salaries and of creating more jobs in the civil service after May 1981 had strong repercussions on the French postal services: over 80% of the workforce belonged to categories C and D of the public sector.

Concretely, the changes in the ranking of all variables can be shown in diagrammatic form (Figure 4), the abscissa showing the ranking of the variable in direct classification, and the ordinate the ranking in indirect classification. Figure 4 is read as follows:

- direct classification: from left to right;
- indirect classification: from bottom to top;
- the main differences are instantly identifiable with respect to the diagonal.

The points on the right of the diagonal are those which moved up in the indirect classification. Those to the left of the diagonal moved down in the same classification. Thus it was easy to identify the parameters which did not move in the two classifications (they are on the diagonal) and those which moved up or down. For instance, in the structural analysis of the determinants of employment and unemployment, the conventional macroeconomic variables drop sharply in the indirect driver power classification whereas other variables

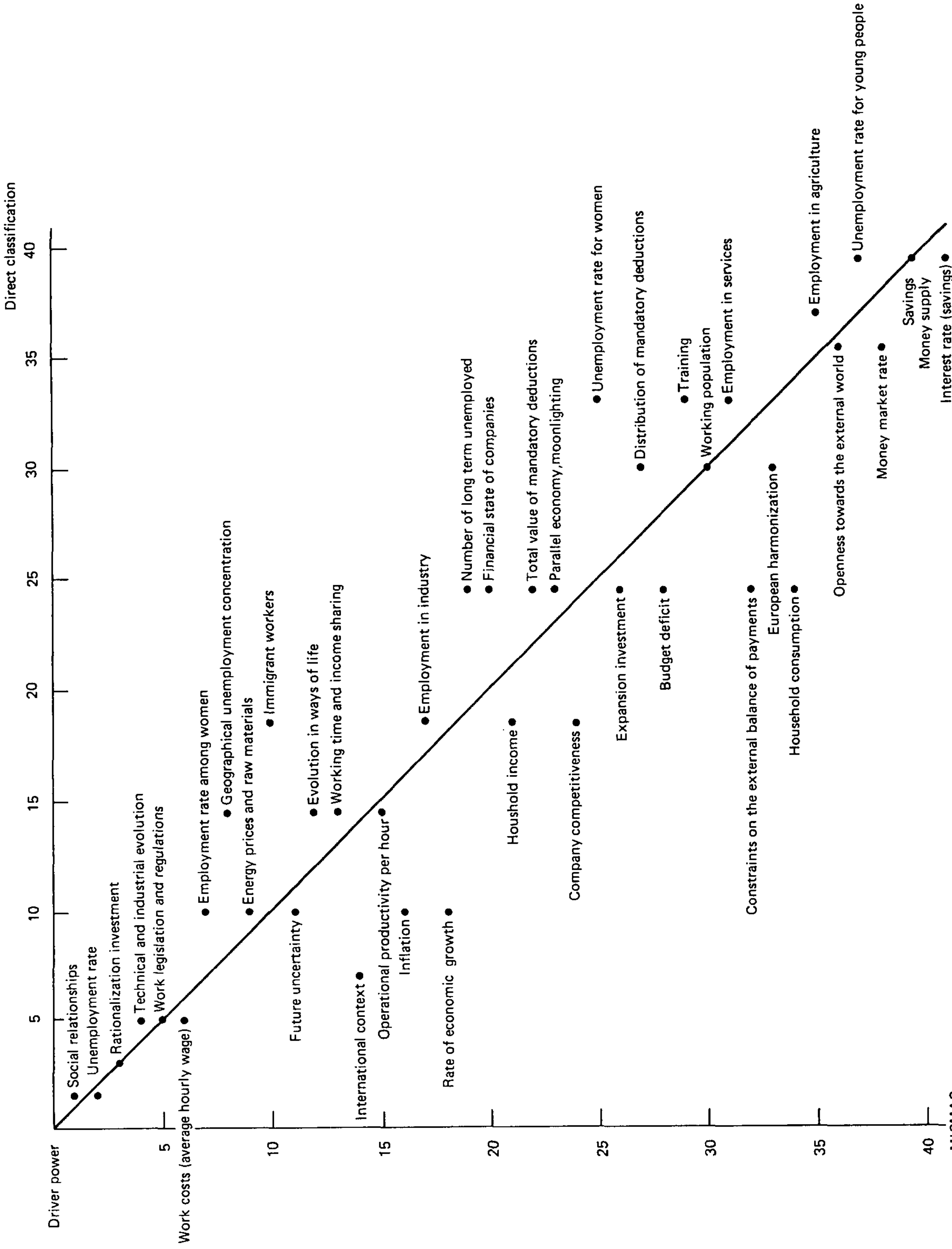


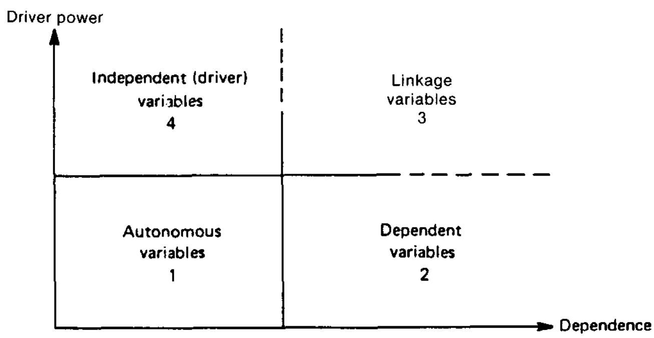
Figure 4. General comparison of driver variables, direct classification and MICMAC classification.

such as 'geographical concentration of unemployment' move up sharply.

Finally, one can test the sensitivity of results as a function of the intensity of relationships. For example, during the first run only a strong and very strong relationship is taken into account. In the following runs, weaker relationships are integrated. In general, the structure of results is not susceptible to the introduction of new relationships, with the exception of some variables recording significant moves up or down in this classification. This differentiated processing is quite useful for determining the impact of potential relationships (eg, following the introduction of a technical or political change into the system).

Driver–dependence matrix

In the MICMAC programme, each variable can be classified as a function of its driver power, and its indirect dependence relative to other variables. This result can be shown in the matrix of driver–dependence.



The driver–dependence matrix can be divided into four sectors:

- sector 1: weak driver and weak dependent variables (points near the origin), a group of so-called 'autonomous' variables.
- sector 2: weak driver and strongly dependent variables.
- sector 3: strong driver and strongly dependent variables.
- sector 4: strong driver and weak dependent variables.

The sector 1 variables are the major tendencies or factors relatively disconnected from the system, with which they only have a few links (however, these links can be very strong); for the system dynamics they show a weak driver power since their relatively self-contained development prevents them from being, at the medium term, control variables in the system under study.

The sector 2 variables are mainly dependent; therefore, they are likely to evolve. They are resultant variables, the evolution of which can be explained by the explanatory variables from sectors 4 and 3.

The sector 4 variables are strong driver and weakly dependent; they condition the rest of the system.

The sector 3 variables are both strong drivers and highly dependent. They should be studied with special care. These linkage variables are naturally unstable. Any action on these variables will have impacts on others and feed-back effect on themselves to amplify or suppress the initial pulse.

The typology of the variables (explanatory, linkage, resultant, autonomous) can help in better understanding a system's structure, and in carrying out new regroupings of these variables by taking into account their position within the driver–dependence matrix.

Thus, J. Barrand and C. Guigou[16] did identify the following groups:

- international variables (nos 18, 19, 20, 21, 22);
- monetary variables (nos 14, 15, 16);
- technico-economic linkage variables (nos 23, 27, 41);
- overall economic variables (nos 9, 11, 17, 24, 38, 39);
- business variables (nos 13, 26, 25); and
- societal and work variables (nos 5, 6, 7, 8, 32, 37, 40).

These regroupings were not evident, *a priori*, since they were mixed as regards their level of dependence and direct driver power. MICMAC was quite useful on this level since it managed to clarify the issues, to reduce the original complexity as shown in Figure 5.

A major benefit of constructing the driver–dependence matrix is the fact that it can check whether what is being explained is related to what is assumed *a priori* to be an explanatory factor and which should normally be considered to be a driver. On this point, the driver–dependence matrix built from indirect impacts often has surprising results. In addition to the scenario exercise, such a structural analysis should be carried out as a preliminary to the construction of any econometric forecasting model.

This analysis could be usefully completed by the method which breaks down the various parameters into carefully related components so as to reveal related (hierarchical) or unrelated sub-systems, and to display the key role played by certain relay variables, as suggested by J. F. Lefebvre.[17]

There is no single, official, scientific interpretation of the MICMAC results. The think tank has to ask the right questions and propose explanations. Thus, for instance, in our example, we might have wondered why the unemployment rate, the parameter which is an important driver and has a high level of dependence, seems likely to be able to explain unemployment through the biasing of social relationships. It might mean that unemployment is not only a resultant (the consequence of rigidities) but also a change factor which, when raised to a certain level affects the social climate and imposes politically motivated measures of flexibility to create jobs and job-sharing schemes.

All these questions have to be answered. This is the aim of the next step for the scenario method. This step essentially deals with the key variables identified by structural analysis, locates which actors are involved with these variables and for whom the past, present and future roles have to be carefully studied. Prior to initiating this analysis on the role of actors, we offer here a (provisional) conclusion on the value and limitations of structural analysis.

Value and limitations of structural analysis

The analytical method described above attempts to identify the key variables (whether hidden or not), to ask the right questions or to analyse counter-intuitive aspects of the system's behaviour. The method should help the decision maker, rather than replace him. It does not try to accurately describe how the

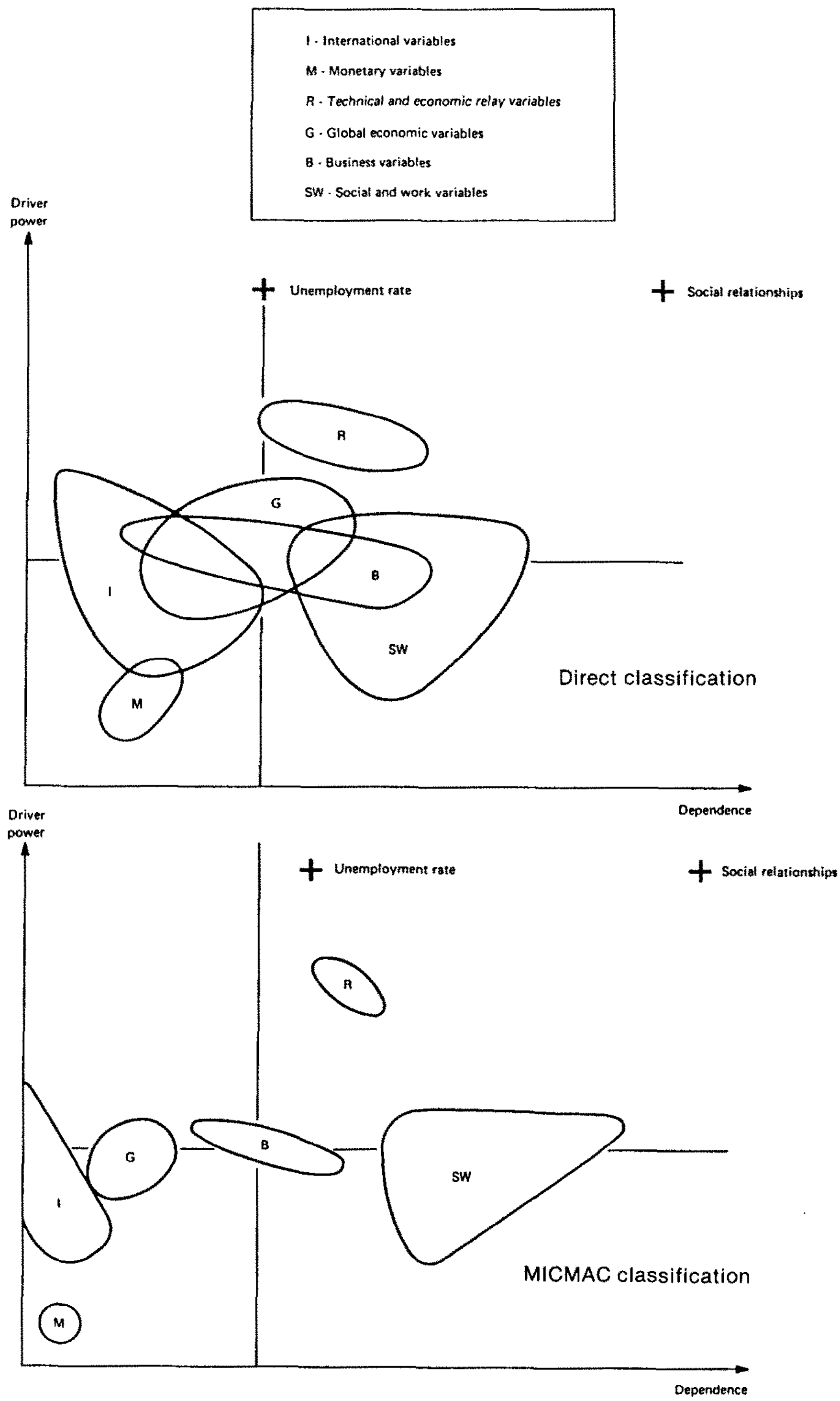


Figure 5. Position of the main groupings of variables.

system works, but rather its aim is to pinpoint the main elements of the system's organization.

The results should be used while bearing in mind the limitations of the analysis:

- The first limitation derives from the subjective character of the list of variables. The precautions taken offer some guarantee of objectivity, but for practical reasons the number of variables should not exceed a few dozen. Therefore, some sub-variables related to one of the problem's dimensions have to be regrouped, more or less arbitrarily. For this method, this is a disadvantage as well as an advantage because any model arbitrarily favouring the quantitative elements to the detriment of the qualitative elements is rejected.
- The choice of a typology of relationships conditions the results. Usually, two types of relationship are taken into account:
  (a) the so-called reference relationship (known relationships which are true today and should remain so in the future); and
  (b) the potential relationships (possible relationships which have not yet appeared, but whose development is incipient).
  On the plus side, this typology is simple. On the minus side it considers as potential, not only what is incipient, but also what is doubtful or disputed. A more extensive study, having more time and means at its disposal, would classify the relationships and their nature (conditional, causal, technical, institutional, psycho-sociological, etc).
- Processing the structural analysis matrix only determines the existence or non-existence of various relationships. However, this matrix includes relationships with widely varying intensity. Its characteristics should be borne in mind when interpreting the results. That is why the intensity of these relationships should be determined, even if only on a qualitative view, in order to carry out sensitivity analyses. However, we should not walk into the following trap, *viz* excessive quantification of the relationship to obtain a semblance of accuracy.

While keeping in mind the above limitations of structural analysis, the results obtained and their essential value should be recalled. This method, first of all, is a tool which should be used to classify ideas and to tackle a problem systematically. Since several thousands of questions have to be asked, certain questions have to be asked to uncover variables which would never have been thought of otherwise. First, the structural analysis matrix acts as a matrix of discovery and helps to create a common language within a think-tank on the prospective exercise.

Second, since a certain number of feedback effects involving each variable have to be taken into account, a hierarchy based on the driver power and the dependence of the variables should be prepared for such variables. Thus, the main determinants of the phenomenon under study can be revealed. The control variables and the resultant variables thus uncovered help better to understand the organization and the structure of the system under study.

One can scoff at the fact that 80% of the results obtained confirm initial intuition and are obvious. It should first be noted that obvious points are easy to prove with hindsight, but it is more difficult to forecast accurately what, in the quagmire of preconceived ideas, is undeniably certain and obvious. Furthermore, 80% of the obvious results show that this approach is logical and common-sensical. This requirement is essential to give some credit to the 20% of 'counter-intuitive' results.

Notes and references

1. M. Crozier and E. Friedberg, *L'acteur et le système*, Le Seuil, Paris, page 107.
2. The word 'scenario' was introduced to futures studies by H. Kahn in his book *The Year 2000*; however, scenarios of a literary genre can be found in, eg Anatole France, *L'Ile des Pingouins*; George Orwell, *1984*; Jules Verne, etc.
3. "Une image de la France en l'an 2000. Scénario de l'inacceptable" ("An image of France in the year 2000. The unacceptable scenario"), French Documentation, Collection TRP No 20, 1971.
4. All these developments are published, at regular intervals, in *Futures* (in the UK) and *Technological Forecasting and Social Change* (in the USA).
5. These scenarios develop: (1) the most probable situation of the phenomenon under study and of its environment for a given horizon, as well as the path leading to it (reference scenario); (2) the extreme situations between which this phenomenon will be located (mixed scenarios, ie pessimistic as well as optimistic).
6. J. Barrand and C. Guigou, "Analyse structurelle, impacts croisés: micmac et smic 10 ans après", Mémoire du DEA 120 économic de la production, INSTN, Paris IX Dauphine CEA, 1984.
7. R. Saint-Paul and P. F. Tenière-Buchot, *Innovation et évaluation technologique*, Entreprise Moderne de l'Edition, Paris, 1974.
8. J. F. Lefebvre, "L'analyse structurelle, méthodes et développements", Doctoral thesis 3rd cycle, University of Paris IX Dauphine, 1982.
9. P. F. Tenière-Buchot, "Modèle 'POPOLE'", *Analyse et Prévision*, Feb–March 1973.
10. J. C. Duperrin and M. Godet, "Méthode de hiérarchisation des éléments d'un système", Rapport Economique du CEA, R-45-41, 1973.
11. Barrand and Guigou, *op cit*, reference 6.
12. Duperrin and Godet, *op cit*, reference 10.
13. H. Lesca, *Structure et système d'information, facteurs de compétitivité de l'entreprise*, Masson, Paris, 1982.
14. The first set of information can be obtained by first analysing the direct impacts: the sum of the first line represents the number of times that variable i has an impact on the system. This number is the *independence* factor of variable i. Similarly, the sum of the j column represents the number of times j was influenced by other variables and represents the *dependence* factor of variable j. Thus, for each variable, an independence factor and a dependence factor can be obtained, to classify variables according to these two criteria.
15. MICMAC: Matrice d'Impacts Croisés—Multiplication Appliquée à un Classement (Cross impact matrix—multiplication applied to classification). This method was developed at the CEA between 1972 and 1974 by J. C. Duperrin and M. Godet; see *op cit*, reference 10.
16. Barrand and Guigou, *op cit*, reference 6.
17. Lefebvre, *op cit*, reference 8.