6

CASE STUDIES IN INDUSTRY AND DEFENCE

The Aluminum Industry

Few cases of structural analysis applied to industrial problems are ever presented publicly. In general, such analyses can not be published because of the confidentiality risks implied. Moreover, by the time the publication embargo has been lifted, the material is usually outdated. Fortunately this is not the case for the Aluminum 2000 futures-thinking exercise, begun in 1985 on behalf of the Péchiney Group. In fact, the specialists rereading the report found that ten years later the analysis had stood the test of time and appeared almost "clairvoyant". [1]

Part of this case study was published in 1989 with Joseph Vialle, then in charge of planning at the Péchiney group. Sections of the aluminum case were presented to Petrobras executives during a conference in Brazil. The conference organizers were kind enough to grant us permission to reproduce the material here.

For Péchiney, structural analysis was only the first step. Scenario building followed from 1986-1987 as a tool to shed further light on participants' strategic choices. Structural analysis proved particularly rich in that it enabled participants to sketch scenarios for the international aluminum industry. As mentioned in the first chapter, a change in corporate leadership interrupted the process, so who knows what might have happened otherwise. Nevertheless, the intellectual investment of the executives who participated was well spent. It always pays to have executives sit down occasionally and reflect upon the long-term. Interestingly enough, the decisions made later, e.g. downstream integration, with the buy-out of American Can, reflected to some extent the conclusions drawn by the Aluminum 2000 group.

A Young Metal with an Uncertain Future

The study aimed at pinpointing the key determining factors in the world aluminum industry with 2000 as a horizon. Structural analysis was the tool of choice. The aluminum system could be characterized by 75 inter-related variables.

The process of teasing out variables and reviewing the mechanisms connecting them was enriched by a series of some twenty interviews, two-thirds of which were conducted with outside experts. After the interviews, a number of the points raised could be considered probable trends or major uncertainties for the future of the aluminum industry.

1. Note that many of these analyses were performed under G.Y. Kerven, then president of the aluminum branch.

The Consequences of Political Uncertainty and the International Economy

Uncertainty awaits on five fronts: geopolitical (mining countries), economic (growth rates in various zones), monetary exchange (currency fluctuations), socio-economic and regulatory. As a corollary, other probable trends put forth for the year 2000, back in 1985, included international monetary instability and fluctuating growth rates. In order to adapt and survive in the face of uncertainty and change, participants saw the need to increase their vigilance and flexibility as well as diversify risks and opportunities.

Technological Explosion in Materials: Threat or Opportunity?

The raw materials sector is experiencing tremendous technological expansion, whether in composites or more traditional materials, e.g. ferrous metals, glass and wood. Why should aluminum be any different? Mixed materials are not deadly competitors and may actually represent potential markets. Everything depends on the will and strategy of the manufacturers involved.

Enlarging the Competitive and Strategic Environment of Aluminum

Manufacturers can find giant competitors along this "multi-material axis", notably international petrochemical conglomerates. One glance at the earnings of these corporations confirms how important this new challenge is to the aluminum sector.

In the eyes of many experts, strengthening the role of the London Metal Exchange (LME) seems inevitable. Nevertheless, the aluminum manufacturers may still be able to guarantee their clients stable prices. In fact, even though the LME might be called upon to play a role in generating fluctuations over the short-term, this should have little impact on the long-term competitive pricing trend in aluminum.

Recycling is a potential advantage for pure materials like aluminum. Why? The separation of composites is difficult. Therefore, the collection and disposal of composite materials may hinder further development of these materials which are at the mercy of a regulatory framework that opposes what has been called "the composite trash civilization".

Choice of Materials by Function and Service

A rapid review of the main uses of aluminum indicates that there will necessarily be a decrease if the main manufacturers limit their role to that of supplier while customers increasingly seek service (a response to a function). Service will no longer be the domain of an isolated material, given the mixes and massive choice of materials available.

Aluminum manufacturers must focus their marketing efforts on supplying a “service package”. Of course this focus would affect R&D, too. Packaging is a perfect example. Here innovative materials go hand-in-hand with tooling innovations and conservation methods, hence closer links to firms downstream.

Approach and Results

In this case, structural analysis was started in May 1985 and ended in October of the same year. Drawing up the list of variables took several collective thinking sessions and involved several Péchiney executives as well as other experts. These meetings were enriched through a series of twenty-odd interviews inside and outside the Péchiney Group. During the listing, variables were divided as internal and external. Internal variables referred to the international aluminum system; external variables, to the geopolitical, social, and economic environments plus technology. By synthesizing ideas, participants succeeded in drawing up a final list of 75 variables.

The structural analysis matrix was filled in by a working committee or group created specifically for the task. Included were Messrs Bercovici, Fevre, Thomas, Vialle (Péchiney) and Messrs Barré, Chapuy and Godet as consultants. They were joined by two materials experts, Mr. Chalmin and Mr. Giraud. The group met over three days during which group members systematically asked about all the eventual interaction between variables. This group asked over 5,000 questions on the direct relationships between the variables and their intensity. The following intensities were established: strong (3), average (2), weak (1) and potential (P). Note that structural analysis also takes into account potential relations although they are practically nonexistent today. The idea is that these relationships may become probable or at least possible in the relatively near future.

Among the variables which seem to have the most influence on the aluminum industry in the world (still horizon 2000), the following eight stand out no matter which classification method is applied. Their determining role appears firmly established.

The most influential variables are as follows:

– competitiveness of materials: this variable is fairly dependent and the most influential across the board. In other words, the future of aluminum depends on a variable with a very uncertain development/evolution;

– financial situation of the aluminum companies: this variable appears second when ranked according to influence. Perhaps surprising, this result indicates that the future of aluminum is shaped by the financial capacity of the firms to implement their strategy and resist the ups and downs of demand and price;

– strategy of the leading clients: The position of this variable, both very influential and quite dependent, confirms the determining yet unstable nature of the main aluminum clients. Yet their choices and behavior will increasingly influence the strategy of major manufacturers;

– price stability: Here the key role of this variable can be confirmed. Its highly influential yet not very dependent nature seems to indicate that manufacturers may suffer price fluctuations;

– Alcoa, Péchiney, Alcan strategies: These three variables are the most unstable within the system. In other words, they are the most influential and the most dependent. The upshot is that the strategies of the main manufacturers are interdependent. It is worth noting that the variable "competition/cooperation among manufacturers" is ranked third in terms of potential influence whereas it ranks 41st in direct classification;

– transformers' strategies: This variable plays a vital role in the aluminum system. It is comparable to the variable "leading client strategies".

If we examine the more or less dependent nature of the variables in the aluminum system, we see that the most dependent variables are often the most influential. In fact, of the nine most dependent variables, six belong to the ten most influential. These are the actors' strategies variables already mentioned.

It is not at all surprising that strategic-technological foresight which depends on actors' strategies is also highly dependent. Among the dependent variables, we also found corporate research policy, innovation in aluminum products, recycling, competitiveness, and political corporate image. These are all closely linked.

Priority Variables Classified as Direct, Indirect or Potential

The Most Influential Variables (to be mastered)	Competitiveness of Materials Financial Situation among Aluminum Companies Leading Client Strategies Price Stability Alcoa, Péchiney, Alcan Strategies Transformer/Processor Strategies Price of Non-standard Products Management Criteria (quality, productivity, profitability
The Most Dependent Variables (to be monitored)	Strategic and Technological Foresight (*veille* in French) Corporate Research Policy Recycling Relative Competitiveness of the Companies Political Image of the Companies Strategies of the Second-Rung Companies

Some results raise more questions than answers. It actually seems that the relative competitivity of the companies involved is far more influential and less dependent in terms of indirect and potential effects than in terms of direct effects. Should we conclude then that in the future the competitive gap between the various companies will become more determinant and less "variable"?

In any event, the results concerning the demand variables are remarkable. The direct classification introduces a dichotomy between the rather dependent variables, e.g. consumption markets (packaging, construction) and demand variables that are almost independent of the system considered part of the professional markets (aeronautics, energy). In other words, part of the demand for aluminum is independent.

What surprises us should not confuse us, though. Instead some of these realizations urge us to think in a more in-depth and imaginative manner. In general, most of the results from the structural analysis confirm an initial intuition. Yet we remain on guard against the temptation of concluding that this type of analysis is unnecessary. In fact, it is always easier *ex post* to say that something was obvious than it is to reject *a priori* certain pieces of "evidence" rather than others.

Overall, what surprised us was the fact that the demand variables are not very dependent. This is intriguing in that they normally should have appeared as result variables. Moreover, the variables characteristic of professional markets and mass consumption have increasingly more influence when we integrate the indirect and potential effects. This result could mean that manufacturers have less mastery of the marketplace than expected. If demand from leading clients drove the market, then the competitiveness of the materials would tip the balance.

Another interesting result drawn from structural analysis: the relatively influential character of the macroeconomic variables (monetary fluctuations, industrial production) and social variables (lifestyle and consumer habits). Most of these variables lose their relative influence on the system when the indirect and potential effects are taken into consideration.

Emerging Variables Ranked Indirect and/or Potential

Emerging Variables (Influence)	Demand Variables New Markets for Aluminum Innovation in Product and Market New Competitors in End Markets Strategy of Manufacturing States Competition-Cooperation among Manufacturers Rate of Use of Capacities (electrolysis, semi-products)
Emerging Variables (Dependence)	Free Market for Standard Products Dowstream Integration for Industrial Clients Upstream Integration for Mass Market Linkage, Networks, Partnerships

Should we conclude that the future of the international aluminum industry depends less on political, economic and social uncertainty than the strategies of the main actors within the industry and their capacity to innovate both technologically and commercially? We lean towards that general view.

Elements for Building Scenarios

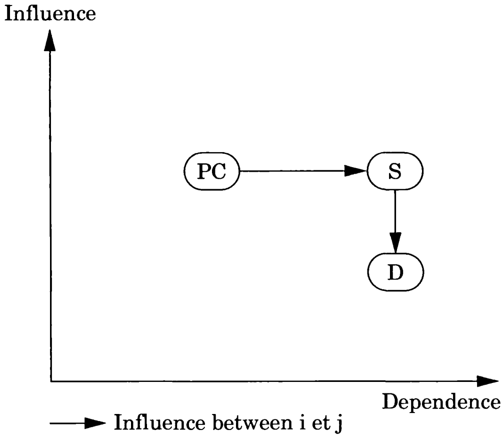
Positioning variables along the influence/dependence axes and monitoring their development provides vital information that guides our thinking to possible scenarios for the future of the aluminum industry for the year 2000. (Note that although this horizon has now been reached, the material presented herein has not been changed and reveals the pertinence of the exercise.)

The structural analysis with a horizon of 2000 provided the raw data needed to analyze how the industry would develop and to highlight the relationships between groups of variables.

Yesterday, an Ideal?

The past situation is described in the following diagram which picks up the part of variable positions on the direct axis. This is an "ideal" (perhaps yesterday?) or a stable situation in which demand is dominated by the strategy of the large companies and the production context (variables 23 to 29).

The Past Situation in the Industry



PC: Production Context: Exit and entry barriers, Manufacturing flexibility, Innovation in processing, Rate of use of capacities, Recycling.

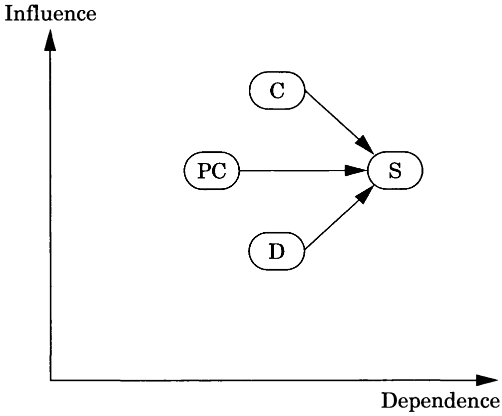
S: Strategies: Leaders' Strategies, Transformers' Strategies.

D: Demand: Professional Markets, Greater Public Markets.

Today's Ambiguous Situation

Demand is becoming independent in terms of the leaders' strategies. These strategies are less dependent on the production context than on the influence of the control variables.

The Current Situation in the Industry



C: Control Variables: Competitiveness among Materials, Financial Situation of the Companies, Price Stability, Leading Clients' Strategies

Tomorrow's Industry: The Risk of a Separation between Manufacturing and the Market(s)?

The aluminum system is evolving in such a way that the potential indirect relations lead to the risk of a split of manufacturing and markets.

The fact that the demand is becoming independent points toward a potentially difficult situation in which the control and demand variables are influential on the strategies, thus playing more on themselves than on the production context.

Two Contrasted Strategies

The "split up" scenario envisions the manufacturers' strategy as one under the influence of both demand for the product and the control variables. The production context is no longer the determining one. In fact it has shifted into one of dependence on the system.

Strategy 1: Aluminum in either a defensive or an introverted position

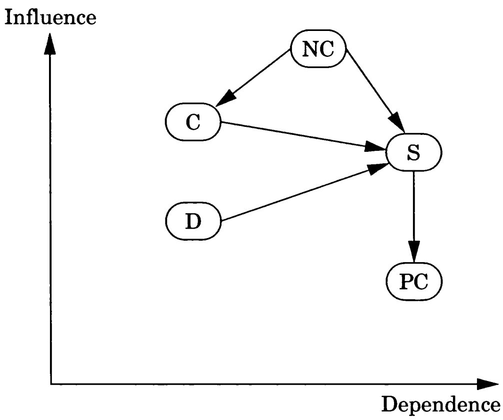
Given the inertia in the aluminum industry, manufacturers adopt a stance somewhere between defensive and introverted or inward-looking. The nuance depends on whether or not they react to the influence of the old control variables (C) and the new control variables (NC). Two new actors in particular might acquire a pivotal position and encourage this type of development, namely:

– new competitors on the end market;
– producer/source states.

Faced with this enlarged strategic environment, major aluminum manufacturers appear weak and threatened as they are divided by the strategies or actions of their traditional competition. Is this divide and conquer?

The results of strategic analysis in terms of indirect and potential relationships reveal that the system under study would tend to develop towards this strategy; i.e., between defense and introversion. Why? The demand is losing in terms of dependence and gaining in terms of influence. Domination by manufacturers thus becomes only a vague memory. Moreover, the strong increase in indirect and potential influence of new control variables confirms the above. In this strategy, manufacturers managed to cooperate and make objective alliances, a common front of sorts to face the threat of new competitors and competitive materials.

Strategy 1: Aluminum: From Defensive to Introverted Position



NC: New Control Variables:
– New Competitors on the end markets
– Role of manufacturer/source states
– Competition-cooperation among manufacturers

Strategy 2: Aluminum, from Innovation to Offensive

A second strategy foresees aluminum manufacturers moving into an offensive mode through product innovation. Manufacturers thus open up new markets and take control of a portion of the demand (D2). In fact, they readily adapt the production context to the development of another part of the demand (D1). The success of this market segmentation strategy depends on a fairly substantial mastery of the control variables (C + NC).

This strategy is far from being excluded by the structural analysis since the "innovation" and "cooperation among manufacturers" variables are potentially highly influential on the overall aluminum system.

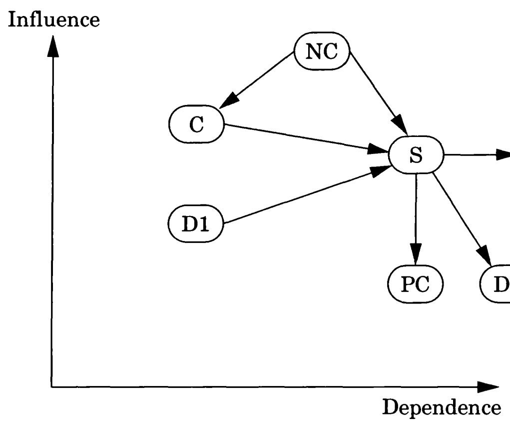
In conclusion, the great disparities in material use from one country to the next can not be explained by the intrinsic performance of the materials but rather by the strategy and behaviour of the main actors operating in a particular country. As a result, the aluminum industry's future depends on the manufacturers' capacity to be:

– flexible, even when facing political, economic and financial uncertainty on an international level;

– innovative, both technologically and commercially, in order to offer a broader range of mixed materials, which include aluminum, and thus meet the needs of functions and systems. Increasingly, the client will demand that the supplier be a multi-material provider. Obviously marketing will play a pivotal role in this area.

In sum, structural analysis enabled the participants to create a hierarchy of key variables for the future of the aluminum industry by weighting the role of certain economic and financial restrictions which, after all, are the same for the competition. The ability to innovate, meet the needs of the market and create other needs will enable one aluminum manufacturer to succeed rather than another. The conflictual or cooperative nature of the actors' strategies and behavior will also play a determining role.

Strategy 2: Aluminium: From Innovation to Offensive



IN: Innovation:
– Production innovation
– Commercial innovation

EDF: The Utility of Futures-Thinking

This chapter section was prepared by Assaad-Émile Saab, in charge of the "Mission Prospective" at Electricité de France, in order to provide a brief history of how futures-studies exercises and strategic scenario building have evolved in a major European corporation. Rarely do we have the opportunity to reflect on how a corporation or an institution thinks about the future. The EDF case reveals just how far we have come in terms of tools, concepts and breadth of thought.

A Forecasting and Planning Tradition

Although named differently at different times, *la prospective,* foresight, or a futures-thinking process has existed at Électricité de France (EDF) since the utility's inception. This process has always been considered an integral part of forecasting and planning. Naturally accurate forecasts of future demand were essential to a company mandated to ensure the production, delivery and distribution of electricity. Beyond these basic functions, there was the need to set rates that were both fair and economically feasible. Interestingly enough, this type of forecasting at EDF also led to the development of exemplary econometric tools. Of course, in the past, the production of electricity was tremendously important for a country rebuilding and then experiencing rapid development. In fact, the magnitude of the investments required made electricity part of the national plan.

Always necessary, always present at EDF, futures-thinking has nevertheless gone through several stages.

During the 1950s and 60s, growth in electricity production remained fairly regular at 7% to 8% annually. In terms of consumption, figures doubled in one decade – a famous statistic. In those days, futures-thinking exercises were not called such and relied essentially on extrapolation. The general idea was to outline demand for electricity over the long-term, e.g. 10 to 20 years. The institutional environment was considered stable and only the economic parameters of growth were needed to generate a forecast.

Suddenly the 1970s and the oil shock hit. Futures studies or any future-thinking endeavor needed to integrate discontinuities or breaks in economic growth and consequently became more exploratory. After this watershed event, it became necessary to develop different scenarios using various hypotheses on how energy prices would develop while taking into account the growing number of uncertainties.

During the 1980s, EDF was obliged to ask new questions. At this point, after the previous decades in which scenarios were based on either energy or economics, EDF had to consider the institutional and political context in which it would continue developing. Changes in this context, or environment, stemmed from the new Europe and the decentralization of the French state. Simultaneously, technology was developing at a supersonic pace while competition among different forms of energy (electricity, gas, fossil fuels) grew fiercer.

Lastly, in the 1990s, new themes became obvious priorities:

– first, the development of the institutional framework within a new European context;

– second, adoption of a European Community directive within the national electricity market;

– third, the "green wave" with sustainable development included as not only an economic but also as a social stake in terms of intranational solidarity and social justice;

– fourth, new borders of national and international development considered as specific opportunities to draw upon the competitiveness and productivity made possible through growth in multiservices and international business.

The Necessity of Futures Thinking

An exploratory procedure applied to just one company's future appears inadequate, given the need to reflect broadly on the corporate environment and to question the uncertainty affecting the institutional, economic and technological dimensions. In short, EDF needed to define its stakes in the institutional, economic and technological fields. The question was how to do it. Management wondered if the traditional forecasting and planning approach would be adequate. Jean Bergougnoux, manager of the economic research department, sought the help of Jacques Lesourne in laying down the groundwork of a futures-thinking approach. A team within the economic research department was created to work with Lesourne and to assess the results of futures-thinking exercises.

The first step involved identifying through a systemic and structural analysis the important parameters, major trends and the actors within EDF's internal and external environments. This step enables management or other participants to determine EDF's means and its margin of maneuver. The scenarios envisioned were not to focus solely on energy and economics anymore. Instead they would include social, political, technological and institutional aspects. EDF could no longer simply cross a few hypotheses and actors' strategies to define the most probable scenario. Contrasted scenarios had to be multiplied in order to see a multiple and uncertain future, as well as estimate the company's capacity to develop and adapt to that future. In response to EDF's needs, the following scenario-planning method was developed from 1986 to 1987.

A New Organization: Prospective and Strategy

In 1988, the chief executive officer of EDF introduced a strategic directive in which futures thinking required a strategic aim and did not need to shed light on possible futures. This strategic management process followed four stages:

1) exploration of both environment and future;
2) definition of strategic axes;
3) decisionmaking in accordance with strategic orientations;
4) evaluation of the results and appropriateness of the implementation of these orientations and strategies given the initial objectives.

At this point in EDF's history, futures studies, scenario planning, or *la prospective* had to be clearly linked to strategy, hence the new term prospective stratégique or strategic futures thinking. Given the need to introduce change into the company itself, a "strategic economic futures research" section (DEPS in EDF's corporate organizational chart) was created. In tandem, a futures committee headed by Christian Stoffaës was set up. The "futures mission" within the DEPS was mandated to ensure that the studies produced by the various working groups would be implemented and monitored.

An Effective Program

Several studies were carried out simultaneously every year, so that some forty reports were finalized from 1988 to 1998. At the outset, Jacques Lesourne had suggested as an objective that at least half the studies started by the committee and monitored by the mission should be delivered to the strategic management committee; in other words, with the executive organ that meets with the president and CEO as well as the key managers or officers at EDF. Within the first three years, 80% of the studies were indeed sent to this decisionmaking level. This percentage serves as an indicator of the quality of these studies and the activity of the project leaders.

The futures approach also serves to initiate a collective thinking process within the various units and departments themselves during the preparation of strategic plans. Already in 1989, futures-thinking committees were struck in operations departments in order to shed more light on the decisions for which they were responsible. As a pedagogical exercise, futures thinking was thus extended to an increasingly broader circle. Futures-thinking seminars were initiated at departments in EDF-GDF (Gaz de France) for managers. In fact these seminars became part of the training program for new unit managers.

A Joint Futures-Thinking Exercise

By 1990, other French firms were expressing interest in EDF's methods. The CEO decided to launch a club called Prospective et Entreprises (Futures and Firms) whose members still include large public corporations like Gaz de France, France Télécom, the French railroad (SNCF), the French Post Office, and ELF (now privatized), but also other members, like L'Oréal, the Ministry of Defense and more recently, the Parisian Public Transit System (RATP).

The purpose of the club was to provide a forum where people could meet, share experiences, debate issues, and possibly undertake joint studies on the major stakes and developments affecting the member-corporations within their respective environments.

The club has carried out several timely studies over the past few years. In fact the studies have often foreseen topics of national interest. From the top of the list:

- future of contracts between the state and public corporations;
- French public corporations and EU law;
- future of public utilities in Europe;
- future of social relations within statutory companies in Europe;
- future of retirement plans in France and Europe;
- future of intermediary agencies;
- future of capitalism in France.

The Futures-Thinking Philosophy at EDF

Anticipate in order to Decide

Traditional forecasting and planning methods suited an economic context of regular growth within a stable institutional framework. However, over the past three decades, companies and organizations have recognized the limits of such methods in the form of demand, global competition, industrial restructuring, geopolitical and institutional changes. In today's world, extrapolating from the past to forecast the future is no longer enough.

On the other hand, strategic decisionmaking does not only consider investment choices, the traditional domain of planning and economics. All the major choices involving the future are strategic, e.g. relationships with major partners, alliances, organizational management, investment in human resources.

In the face of uncertainty, the futures-thinking method serves to imagine hypotheses clustered around scenarios, to suggest reactions or strategic options, and to evaluate the alternatives; i.e., compare possible choices.

The First Link in the Managerial Chain

Futures-thinking activities are the first stage of integrated strategic management, as Jean Bergougnoux defined it in 1988. One should ensure that the future has been thoroughly explored before making any decisions. In this respect, a futures-thinking exercise is not a purely intellectual exercise of gathering data, and providing academic conjectures or drafting forecasts. The purpose of the futures-thinking enterprise is to provide those in charge and those making decisions with what they need to know in order to make sound decisions.

The Principles of Corporate Strategic Prospective

The systematic monitoring of developments includes detecting trends and important signals through what is traditionally called scanning in English (veille in French) and observation of the environment. Equally important are a follow-up of strategy and the actions of the company's major institutional, technological, and commercial partners.

The use of experts in future studies enables researchers or managers to base their work on specific analyses carried out by specialized professionals handpicked from either inside or outside the company. Besides expertise, imagination must be mobilized to shake off traditional ways of thinking and to get off the beaten track.

Reactivity and flexibility in terms of adaptation are needed because no single strategic option may be considered valid in as much as the circumstances have not changed. In other words, managers, executives, experts, and all other participants must think and reconsider the situation. Given potential threats and opportunities, futures thinking and scenario building help to imagine the possibilities and propose alarm systems.

The connection between futures thinking and strategy must be respected. They actually form a duo that is complementary yet contrary. Thinking about the future is a functional activity; in other words, an advising activity designed for decisionmakers. It must be clearly distinguished from strategic decisionmaking and its implementation, which depends upon the corporate hierarchy. Futures-thinking activities suggest open action, with a freewheeling, imaginative yet analytical spirit. Once the line between futures thinking and strategy has been drawn; however, strategy must be stable and shared by all in order to be implemented effectively.

Organizing Futures Thinking

Organizational Principles and Structures:

Between 1988 and 1998, futures-thinking activities enjoyed a more structured framework than in the past, and dovetailed with EDF's three-level decisionmaking system, as follows:

1) The futures-thinking committee is responsible for leading and coordinating studies. It comprises the six main mangers or officers of the company (HR, economics, futures thinking and strategy, finance, legal, research, development, marketing) as well as experts from the central administration, and the individuals responsible for futures thinking within the operational departments. The futures-thinking

committee sought not to do everything alone but rather to assist EDF's experts and decisionmakers in their reflection by asking questions and providing techniques or analytical tools.

2) The strategic management committee (CGS), presided by the CEO, brings together members of the administration and the officers. As the main entity mandated to define EDF's strategic orientations, this committee receives various studies from the futures- thinking committee, as well as reports from different committees within the administration. It occasionally receives studies from the operational departments themselves.

3) The economics and futures-thinking department (DEPS) unites the departments in charge of investment planning and rates, among other functions.

This organizational structure ensures the link between futures thinking and strategy by distinguishing the role of experts from that of operational decisionmakers and that of other instances within the company. It also differentiates between the futures-thinking activities of general management and that of the separate operational units.

Managers for production and transportation, for EDF-GDF services, and for equipment are called upon to develop futures studies in their own area. In general, each operational unit in the company is asked to develop its own futures-thinking and strategic methods as they relate to a decisionmaking area considered its own within the preparation of its strategic plan.

Recent restructuring at EDF will probably lead to a revised version of the existing structure but will not likely challenge the overall spirit.

Some Methodological Tools

Most of the tools available ranging from the Delphi to the Mactor method were applied at EDF. Mentioned below are structural analysis, actor analysis, scenario building, and multicriteria analysis.

Structural analysis enables managers or any other participants to draft relevant questions as it provides a systematic panorama of the interactions and mutual dependencies of the parameters that influence the future of a company. This type of analysis also helps identify key variables according to their role as a driver or lever and their impact on the company.

Analysis of actors' strategies, that is the choice of coalitions and their contents, constitute the basic elements of strategic options. In fact, the developments are largely a function of the strategies and movements of major corporate partners.

The combination of multiple hypotheses that can be formulated for the future soon becomes a quagmire. By building coherent scenarios, as well as paths that link these scenarios, we can make contrasted futures understandable and then judge the probability of these scenarios occurring.

Strategic options constitute the choices available to a company in decisionmaking. The consequences of these alternative strategic options are assessed in light of a specific scenario being carried out. Multicriteria analysis evaluates the consequences according to the grid of objectives set by the company including the corporate mission and the company's basic interests.

Open evaluation is an essential rule in this process. A futures-thinking exercise sets its own ethics, primarily to never conclude in a definitive manner. A futures study should simply provide decision-makers with a grid for evaluation purposes plus the instruments needed to make informed strategic decisions.

Permanent Foresight at a Strategic Company

A strategic company must constantly pay attention to what is going on both inside and outside its walls. The futures-thinking committee is responsible for:

– distributing studies which may be made available to the public at large;

– holding training seminars as well as lectures/debates suitable for all those responsible for futures endeavors;

– analyzing and evaluating the current observational and monitoring structures (or creating them) in the departments within all those areas affected by corporate strategy (be it institutional, industrial, technological, commercial or social).

The above structures primarily observe the environment of the company, detect any indicators of change, alert decisionmakers to sensitive changes, and encourage strategic reactivity at the top administrative level.

A Group Learning Experience

Futures thinking at EDF was also designed as a collective pedagogical process that would prepare people to face greater uncertainty and accept the major changes ahead. For when there is a shared future vision, strategic choices virtually impose themselves.

EDF did not opt for a specialized, centralized department but rather a structure that relies upon work carried out by several multidisciplinary teams, dialogue among various managers or directors and the breaking down of traditional barriers. The overarching goal is a permanent exchange of information and ideas as well as the creation of new ways of thinking about the future.

At EDF, studies on the future have always relied on internal expertise first. Outside opinions from universities or consulting firms are nevertheless systematically encouraged through a budget provided to project leaders.

Major Topics

Before the futures thinking committee was created, EDF had undertaken two major futures studies, "EDF and the Future" and "The Future of the Electronuclear Industry". The procedures and methods used therein contributed to the strategic themes and orientations of the initial studies carried out by the futures-thinking committee.

Since 1988, numerous subjects have been explored, thus providing background material for fifty-odd studies under the auspices of the futures-studies committee. As a result, dozens of experts and various departments within EDF worked together. These studies generated a flood of environmental scenarios, some of which did not take into account neighboring notions expressed, albeit in different terms, in other research papers. This multitude, although creative, lead to a certain opaqueness which was lifted only by ensuring that the procedures were set out and linked better. This is the price to be paid in the decentralized exploration of a multiple or pluralistic future. By summarizing the various efforts, a document called "Environmental Scenarios" was produced. It suggested five possible scenarios for the institutional development of EDF. This document provided a base for the studies that the new futures-thinking groups would produce. On the basis of that document, we could outline the following five centers of interest and five transversal themes:

Centers of Interest

The centers or poles of interest create clusters of different studies around a few major interests.

– International pole: brings together the studies related to the future in the EU electricity sector, ranging from the British to the East-European and including internationalization of electricity, the EDF's potential role as a European actor in North Africa (the Maghreb).

– The technological/economic pole directly related to electricity: includes studies on thermal decentralized production, on the partnership between EDF and basic industries, on fuel price developments, means of production, nuclear energy (irradiated fuel, technological foresight in the electronuclear sector, possible nuclear surprises). The study on global warming is also closely linked to technology, whether it focuses on the role of CO_2 or reflects upon how to avoid CO_2 emissions by using electricity produced from nuclear power plants. Lastly the effects of technology on distribution have been explored in future studies on EDF's clientele and client-computer-EDF interfaces. This is the case of the so-called "smart meters".

– The general technological pole affects EDF's situation as an actor in telecommunications or the role of EDF with regard to computerization. It also includes the future of the nuclear industry.

– The institutional pole structures EDF relationships with its various partners, e.g. public authorities, local groups, rural spaces, water legislation, and management of hydraulic resources, industries involved in changing electrical equipment and, in a slightly different register, the situation of EDF as a commercial actor and the future of the EDF-GDF mix. This pole also accounts for corporate research studies on ideological developments and changes related to electricity.

– The internal managerial and social pole covers the social future and role of managerial control as well as the future of human resources with 2010 as a horizon.

Major Transversal Themes

Five major themes stand out in almost all the futures studies:
- the powers of local groups;
- the relationships between the state and company;
- the nature and degree of European integration;
- the deregulation of the electrical system (which enters into the more general deregulation framework);
- the technological changes in electricity production and distribution.

Other key themes:
- the environment, given that EDF strategies must take into account the public's awareness and demands concerning ecology, especially water management;
- the future of irradiated fuels;
- electrical networks;
- industrial safety;
- climatic changes.

Challenges for the Years 2010-2025

EDF in the World to Come

At the dawn of the new millennium, changes appear to be occurring faster than ever before. Fifty years after its inception, EDF is now crossing the threshold into a new world in which international development, management methods, the European electricity market, restructuring of electro-technological and nuclear industries inform the corporate environment. Even if historical movements are progressive, historians like to use dates and events as hooks. After the "after-directive" context (company directive delivered June 20, 1996), the future ceased to be written in the singular. Instead scenarios became plural; the strategic options, very open.

At this point, the president of the EDF requested a futures studies along the lines of "what could EDF look like like in 2010 or 2025?"; "what are the stakes (medium-term 2010) and (long-term 2025)"; "what is involved in terms of preparing EDF and the next decisions to be made?"

Three major themes stand out as priorities in the medium-term: development of the institutional framework in terms of European Union dynamics; renovation of the social; and new frontiers in development. The technological theme should be envisaged as long-term, given the uncertainties surrounding the horizon of technological ruptures (breakdowns or breakthroughs) and the relative weight of the demand for energy and the environmental pressure on technology. The future of the nuclear energy industry is a special case to be considered when reflecting on the future of technology. The absence of CO_2 emissions tips the scales in favor of nuclear energy or balances out the implied waste disposal problem.

Institutional Framework and the European Union

The European community directive on electricity has already changed certain aspects of the EDF's institutional structure, legally established in 1946. Yet still other changes may be expected, especially at the executive level and in the roles played by the respective regulatory agencies at the local, national and European levels.

It will also be necessary to work on the notion of "industrial and financial group" since the EDF group's development should be considered in terms of "maintaining the status of an EPIC" (Public Company of an Industrial and Commercial Nature). Also at stake here is the principle of specialization which becomes an issue of limiting our sphere of activities to our core competencies and developing some room to maneuver with Europe.

Equally important in terms of the institutional framework will be:

– monitoring the process of restructuring in the electricity industry in Europe and the world;

– keeping a clear vision of the legal and economic stakes for the EDF group at a national and European level;

– promoting active strategies that mobilize staff and encourage initiative in terms of dealing with current or potential competitors.

Social Renewal

Beyond problems in changing working relationships, the fundamental question is: What should be done now to keep the social component integrated in EDF's desirable futures? EDF feels that it has time but not much and should act soon!

Without further delay, EDF must outline its paradigm for the company's development in order to guide the various actors involved.

Otherwise, there is a real yet underestimated risk that changes and decisions will be postponed and the potential or opportunities afforded by changes in EDF's environment will be jeopardized.

In order to flesh out the key long-term questions on national and international development, the following elements of a long-term policy should be considered:

– the international sector offers tremendous opportunities. EDF should seize well targeted opportunities in order to benefit from its sources both in terms of the competitivity and productivity inherent in international growth;

– downstream development is not an end in itself but rather a means of reinforcing EDF's positions and of preparing for the competition's attack;

– EDF's durability lies in lasting alliances with local groups. This solid foundation should be consolidated and supported in both qualitative and quantitative terms.

Technological Challenges and Sustainable Development

Visibility right up to the horizon 2025 remains high. Although during this period the world demand for energy should double, the primary source of energy and the conversion methods are ostensibly the same. The foundation of electricity production will remain fossil fuels, existing nuclear energy, increased hydroelectric equipment, and the development of renewable energy, where possible. The main uncertainties will come from environmentalist pressures. Here the overarching question is whether sustainable development is possible in both the developed and developing worlds.

Will we see harmonious use of the earth's resources in the upcoming thirty years? Will regional imbalances grow? Will we rise to the challenge of paying the ecological price of growth?

Strategy and Futures

Perhaps more than in other large companies, EDF's futures-thinking and scenario-building procedures are organically and institutionally tied to strategic decisionmaking. It is not enough to supply decisionmakers with a backdrop for global scenarios or to draw their attention to one particular eventuality. The idea is to define, evaluate and provide probability rates for a limited number of strategic options. From this perspective, penetration of the futures-thinking process throughout the organization is essential even beyond the pedagogical goal of making people aware of the future. Assessing a posteriori the results of futures- thinking studies when confronted with both reality and the strategic options that those studies inspired thus becomes extremely important.

Futures thinking, strategy and operational decisionmaking must interact while remaining distinct. In this way, the strategic company can succeed in acting not only on the current "front" but also on uncertain futures which yield both threats and opportunities.

ICW 2010: Looking for a New Individual Combat Weapon

This case study, part of a project code-named ICW 2010, includes information from research carried out on behalf of the French Ministry of Defense, Armed Forces (DGA), in 1989. In fact, we thank Mr. Michel de Lagarde of the DGA for his kind permission to publish this remarkable example.

The ICW 2010 exercise was supported methodologically by Michel Godet, who was assisted by Pierre Chapuy and Isabelle Menant of the Groupe d'Etudes Ressources Prospective Aménagement (Gerpa). With the help of complementary studies, the ICW exercise led to the design of a prototype "multi-arm-multi-projectile" weapon, abbreviated as PAPOP in French. It is an individual combat weapon (ICW) with indirect aiming that enables an infantry soldier to fire upon stationary, armored or moving targets with specific projectiles.

The ICW 2010 remains remarkable as one of the rare published cases in which a futures-thinking exercise led to concrete action. What makes this case all the more fascinating in terms of futures-thinking endeavors is the rediscovery of morphological analysis. Somehow morphological analysis had been ignored since the late 1970s. Since then, however, scenario building "by method" has become almost systematic, be it for partial or full scenarios. Perhaps the inventor of morphological analysis, Fritz Zwicky, did indeed succeed in making invention a routine!

Actually this case also reminds us why morphological analysis was forgotten. The method quickly leads to a morphological space rich in scenarios and technologically possible solutions. So the quandary becomes choosing only a handful. The famous, out-of-print book by Eric Jantsch (1967) on the topic developed the selection process at length; however, microcomputing, notably the Morphol software package, has helped in navigating through morphological spaces. In this instance, computers also enabled us to develop Multipol, a simple and appropriable multicriteria selection method for uncertain futures.

How to Define a New ICW?

The mandate from Armed Forces Headquarters was for a "brain trust", or expert panel, including representatives from the Infantry Center for Tactical Studies and Experimentation, the army's technology department and the DGA. The objective was to carry out a study that would define and design a future weapon system for infantry. Participants included Lt. Col. Fluhr, Lt. Col. Navec, ICETA (chief engineer) Durand, Messrs Dupuy, de Lagarde, Rouger, and Senior Medical Officer Gorzerino.

The initial idea was a study on what this weapon could be in terms of tactical use of the infantry, the potential of various types of technology, as well as the ICW's technological and industrial limitations (horizon 2010). The objective was to highlight the most promising techniques and technologies which could then be acquired or developed to meet the specifications determined for this new weapon.

This pre-feasibility study was designed to define a weapon corresponding to NATO's specifications for an individual combat weapon (ICW). These included the following:

– incapacitation of targets that are heavily protected and invisible behind a mask or in a shelter;

– increase in the area of engagement and efficiency of the grenadier-infantry soldier;

– incapacitate moving targets from a specific distance.

If the last two can be achieved by improving classic weapons firing small caliber ammunition with kinetic energy, the first specification would impose a radically new design.

Approach Adopted

With a view to organizing their reflection, participants (the brain trust) decided to use structural analysis to highlight key variables likely to affect this future weapon. Why structural analysis? The simple answer is that the method was very frequently used at that time and was found in the first chapters of my book.

Yet three years down the road, the group had not reached any satisfactory conclusions. Some of the difficulties encountered stemmed from the French army's rotation system at headquarters. For example, the futures-thinking group included officers from across the country, named to posts in different places and at different times. Over three years, the constant turnover had affected the quality of the exercise. Another problem was the seemingly innocent shortcut that the participants discovered. They used to fill out the structural analysis matrix individually rather than collectively in a workshop. At the risk of being redundant, we emphasize here that this type of activity must be a structured group effort.

As a result of the problems outlined above, the DGA contacted us to help pick up the pace. We can not really say whether or not the tool already chosen was the most appropriate; however, it was most important for the group's self-confidence and faith in futures-thinking tools to demonstrate how to carry out a successful structural analysis.

We advised the group to employ the following futures tools:

– strategic futures workshops, anticipate missions, capacities and equipment with a horizon 2010;

– structural analysis and Micmac to pinpoint key variables in the strategic environment, ICW military effects, limitations and specifications;

– morphological analysis to scan the field of possibilities and find practical solutions in order to profile the ICW;

– Multipol method for multicriteria analysis in an uncertain future to select the most interesting solutions.

The work really consisted in drawing up a list based partially on workshop results. This voluntarily limited list would, nevertheless, represent the system variables for the future ICW and enable us to construct a structural analysis matrix. Filling out and processing this matrix allowed participants to position these variables on planes, along axes, according to their influence and relative dependence. Analysis of the variables led to a graph and the selection of key variables used in the study of four technical components and six essential selection criteria. On the basis of these elements, the futures-thinking group carried out a morphological analysis. Using the Multipol method, participants could trace the most compelling configurations of the ICW in terms of strategy, technology and economics with the horizon 2010.

Structural Analysis and Key Variables

The futures-thinking circle was reinvigorated through workshops and opened slightly to include new participants. Members of the working committee led a collective session on the following:

– the future environment, in order to identify the stakes and threats. Each group member was asked as an individual (silently) and then collectively to list strategic, technological, economic, and socio-organizational changes, as well as determine desirable, feared, and anticipated consequences. They also were asked to identify the actors involved and the stakes;

– the armed forces' missions, capabilities and equipment adapted to this environment. This dimension would allow participants to see which capacities needed to be adapted. Again individual and collective reflection focused on the characteristics required according to capability and equipment.

Also on the agenda, a hunt for clichés, organized by the armed forces, again with a 2010 horizon. Here each participant was asked to list individually then collectively the clichés or conventional wisdom "out there" on the army, its missions, capabilities, equipment, and relations with NATO partners, in 1989 and from then to 2010. Lastly, the group proved or disproved each of the main clichés presented.

The List of 57 Variables

The structural analysis method seeks to highlight key variables, hidden or not, in order to ask the right questions and encourage participants to think about counter-intuitive aspects or behavior within the system. In this instance, structural analysis was enriched by the use of the Micmac approach. (Note: Micmac is the French acronym for Matrix of Crossed Impact Multiplications Applied to a Classification.)

What is surprising does not have to be confusing but should elicit serious thinking and trigger extra imagination. For example, structural analysis aims to assist futures-thinking groups, but it does not replace them. The method does not detail systemic operations but rather highlights the main characteristics of the system's organization.

This particular structural analysis ran for three months. The working group drew up a list of variables following the workshops. These 57 varieties were then classified in different groups: environmental variables (Friend/Enemy, Combat, Technico-political); effect variables (Negative for Enemy (ENI) and positive for Friend); restriction and quality variables (ICW use).

Using variable "index cards", each variable on the list was defined completely by the members of the working group, and then validated collectively. Participants took an initial census, per variable studied, of the relations of influence and dependence with the other elements on the list and then ferreted out the technological elements, with possible configurations, as seen below.

Structural Analysis and Key Variables

The direct influence of each variable on the set of other variables are illustrated in matrix form. Each element of the matrix represents an influence (0 = no direct relationship of influence on the two variables considered; 1 = a direct relationship of influence). We also took into account the level of influence between two variables. The following convention was used: 1 = low relationship; 2 = average; 3 = strong; P = potential relationship. Note that P may indicate what is now a nonexistent or almost nonexistent relationship, but the system may make it probable or at least possible in a relatively distant future. P levels were also given 0-3 ratings.

The working group filled in the matrix during a three-day meeting. Participants systematically considered all the eventual relations between variables.

Some 3,249 relationships; i.e., 57 × 57, were considered direct influence given priority status. For example, direct influence i on j or direct influence j on i, by excluding the indirect influences, those which pass by an intermediary variable. Obviously it is important to distinguish the direct influence relationships from those that are not! In our experience, a good matrix rating would reveal 15% to 25% direct influences, according to the dimensions of the matrix. The rate reached here (23%) thus seems correct.

List of Variables (A): Environment

Variable Category	N°	Variables Retained
Friend	1	Characteristics inherent to soldier bearing ICW
	2	State of soldier bearing ICW in combat
	3	Individual equipment of basic unit
	4	Group equipment of basic unit (Friend)
	5	Organic arms of basic unit (Friend)
	6	Firing support possessed by basic unit (Friend)
	7	Basic unit's actions (Friend)
	8	Operational capability of the basic unit (Friend)
Enemy	9	Characteristics inherent to eneny soldier
	10	State of enemy soldier in combat
	11	Individual weapons and equipment of enemy soldier
	12	Group equipment of the basic unit (Enemy)
	13	Organic arms of the basic unit (Enemy)
	14	Firing support that the basic unit possesses (Enemy)
	15	Concept of enemy force use (Enemy unit action)
	16	Characteristics of enemy's modes of action in combat
	17	Operational capability of the basic unit (Enemy)
Combat	18	Priority enemy targets for the ICW (Enemy soldier on foot)
	19	Secondary enemy targets for the ICW
	20	Numeric balance of power
	21	Theater of war
	22	Conditions of operations
Technical-Economic Aspects	23	Technical changes affecting the IWC 2010
	24	Interoperability/Functionality of ICW
	25	Political image of a French ICW
	26	Army's budgetary limits
	27	French industrial policy
	28	Industrial policies of Frace's partners

List of Variables (B): Effects to Be Produced

Variable Category	N°	Variables Retained
Negative Effects on Enemy	29	Pinpoint antipersonnel effect sought
	30	Area antipersonnel effect sought
	31	Antivehicle and anti-light-armored vehicle effet
	32	Antitank effect sought (degradation, firing function, mobility function
	33	Antihelicopter effect sought (dissusion)
	34	Antimine effect sought (detection, forward release)
	35	Degradation of the enemy's means of firing assistance
Positive Effects on Friend	36	Detection acquisition and localization of enemy
	37	Continuous all-weather combat
	38	Symbolic nature of ICW

List of Variables (C): Restrictions & Qualities

Variable Category	N°	Variables Retained
Concept	39	Concept of dependability of the arms system
	40	Functional organization of the arms system
	41	Power source
	42	Mass of arms system with initial issue
Technical	43	Nature of projectile
	44	Aiming
	45	External ballistics
	46	Terminal ballistics
	47	Fire power
Use	48	Ease of use in peace time
	49	Ease of use of ICW in approach-march combat situation
	50	Minimal amount of prepartion time to fire ICW
	51	Ease of use of ICW in firing
	52	Discretion and invulnerability of ICW
	53	Overall tactical efficiency of antipersonnel (Friend)
	54	Appropriateness of ICW to threat
$	55	Cost of ICW possession over 25 years
	56	Competitiveness
	57	Distribution of ICW

ICW Variable Card n° 29

VARIABLE CATEGORY	Type B Negative effects to be produced on ENI (Enemy).
TITLE	Effect sought: timely anti-personnel at a set distance (imperative).
DEFINITION	✓ Incapacitate an enemy solider, in the open at a set distance. ✓ Once hit, the enemy soldier must not be able to return fire and must be incapacitated for at least 7 days. ✓ Being incapacitated means: – definitive destruction (death); – long-term suppression (7 days). Lethality must be preferred over suppression.
KEY POINTS	✓ Incapacitate an enemy solider at specific distance? ✓ Immediate or temporary incapacitation? ✓ Immediate of temporary suppression?
INFLUENTIAL VARIABLES	18, 30 à 36, 54, 55.
INFLUENCED VARIABLES	2, 5, 7, 10, 11, 23, 30 à 33, 35, 38 à 40, 42 à 47, 53 à 56.

Participants should always keep in mind the limits of structural analysis. The first limit stems from the subjective nature of the list of variables. Caution has, of course, been exercised in that information has been gathered and condensed in the "variable cards". Moreover, given the logistics involved, the number of variables can not exceed a few dozen. An arbitrary regrouping of the subvariables is the next necessary step. This is both the advantage and disadvantage of the method.

The second limitation stems from the subjective nature of filling in a matrix. A matrix is never reality. It is a means of looking at reality, like a snapshot. To use the photograph analogy, structural analysis reveals things that translate part of reality, as well as the talent of the photographer and quality of the photographic equipment. In fact, examples from a French governmental commission (Commission Boissonnat) on labor have shown that structural analysis may actually reveal group subjectivity, lead participants to hold their reactions in check to encourage consistency in the group or challenge certain clichés.

With the limits of structural analysis in mind, we can review the results obtained and their essential contribution. The method serves to structure ideas around a problem systematically. The obligation to ask thousands of questions prompts participants to discover relationships that would never have been considered otherwise. Overall, the structural analysis matrix serves as a probe and provides the futures group with a shared language.

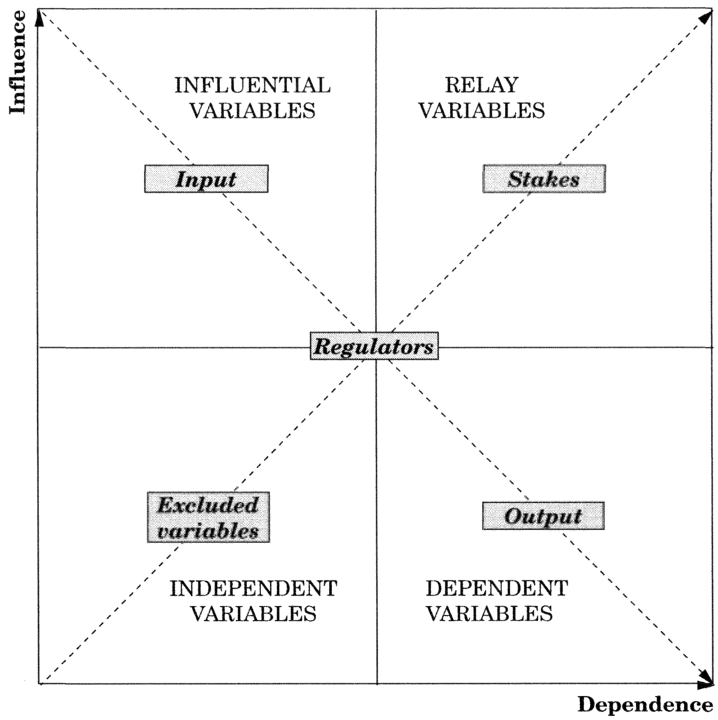
The more a variable has an effect on other variables, the more influential it is. The same applies if that variable is influenced by others more than it depends on them. In the end, each variable is matched with an influence indicator (within one basis point of the total influences normed for the system) and a direct dependence indicator for the entire system.

By reading the matrix, we can classify the variables by their

– level of direct influence: importance of influence of a variable on the whole system, obtained through the total of links created per line;

– level of direct dependence: degree of dependence of a variable, obtained by the total of links created per column.

Plan Influence/dependence



The full set of variables may thus be positioned one basis point within the plane of influence (ordinate) and the plane of dependence (coordinate) since the values of influence and dependence are normed.

Secondly, if we take into account the feedback effect in which each variable is involved, we can hierarchize the variables according to

ICW 20100 Structural Analysis Matrix

	N°	Variables Retained	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
VARIABLES A		**ENVIRONMENT**																	
FRIEND	1	Characteristics inherent to soldier bearing ICW	0	3															
	2	State of soldier bearing ICW in combat		0					2	2									
	3	Individual equipment of basic unit(Friend)		2	0					1									
	4	Group equipment of basic unit		2	1	0				2									
	5	Organic arms of basic unit (Friend)		1		1	0		2	2									
	6	Firing support possessed by basic unit (Friend)		1					0	2		1							1
	7	Basic unit's actions (Friend)		1	1			1	0			1							
	8	Operational capability of the basic unit (Friend)		2					3	0									
ENEMY	9	Characteristics inherent to enemy soldier									0	3							
	10	State of enemy soldier in combat										0							3
	11	Individual weapons and equipmentof enemy soldier		1	2							2	0						1
	12	Group equipement of basic unit (Enemy)										2	1	0					2
	13	Organic arms of basic unit (Friend)			1							1		1	0		2		2
	14	Firing support that the basic unit possesses (Enemy)		2								1				0			
	15	Concept of enemy force use (Enemy unit action)		2	1	1	1	1	3	1		1	3	3	3	3	0	2	2
	16	Characteristics of enemy's mode of action in combat		3					1							1		0	
	17	Operational capability of the basic unit (Enemy)										2						3	0
COMBAT	18	Priority enemy targets for the ICW (Enemy soldier on foot)			2	1	3	1	2										
	19	Secondary enemy targets for the ICW			1	2	2	P	1										
	20	Numeric balance of power		3			3	3	3			2							
	21	Theater of war		2	3	3	2	2	3	2	2	2	2	3	2	2		3	
	22	Conditions of operations		3	2	2		3	3	1		3	1	2		3	3	2	1
TECHNICAL-ECONOMIC ASPECTS	23	Technical changes affecting the ICW 2010			2	2	2	1					2	2	2	1			
	24	Interoperability/Functionality of ICW																	
	25	Political image of a French ICW		1															
	26	Army's budgetary limits			1	1	1												
	27	French industrial policy																	
	28	Industrial policies of France's partners																	
VARIABLES B		**EFFECTS EXPECTED**																	
NEGATIVE EFFECTS ON ENEMY	29	Pinpoint antipersonnel effect sought		1			1		1			3	P						
	30	Area antipersonnel effect sought		1			2		1			3	P						
	31	Antivehicle and anti-light-armored vehicle effect		1			1					1							
	32	Antitank effect sought (degradation, firing function, mobility funtion)		1			1					1							
	33	Antihelicopter effect sought (dissuasion)		1			1					1							
	34	Antimine effect sought (detection, forward release)		1						1									
	35	Degradation of the enemy's means of firing assistance		1			1		1			1							
POSITIVE EFFECTS ON FRIEND	36	Detection acquisition and localization of enemy		1		1	1			1									
	37	Continuous all-weather combat		1					2	2		1							
	38	Symbolic nature of IWC		3						1									
VARIABLES C		**RESTRICTIONS & QUALITIES**																	
CONCEPT	39	Concept of dependability of the arms system		1															
	40	Functional organization of the arms system																	
	41	Power source																	
	42	Mass of arms system with initial issue		2	1														
TECHNICAL	43	Nature of projectile			2							1	2						
	44	Aiming		1															
	45	External ballistics																	
	46	Terminal ballistics			P							2	2						
	47	Fire power		2			1		1										
USE	48	Ease of use in peace time		1						1									
	49	Ease of use of ICW in approach-march combat situation		1					1										
	50	Minimal amount of prepartion time to fire ICW																	
	51	Ease of use of ICW in firing		1															
	52	Discretion and invulnerability of ICW				P													
	53	Overall tactical efficiency of antipersonnel (Friend)					1		1										
	54	Appropriateness of ICW to threat		1			1		1										
ECONOMIC	55	Cost of ICW possession over 25 years																	
	56	Competitiveness																	
	57	Distribution of ICW	1										P						

18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
																		1	1		3			1		2					1	2	2		3	1	1		
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	0												3	1	1	1	2	2												1		1	1			2			2
1	1	0																		1																3			
1	1	2	0	3														1	2												2								
				0														2	3								2				1	1	2	1	2	2	1		
2	2				0	P		1	2	2								2	3	2	3	2	3	2	3	2			3					1			3	2	1
						0	1	1	1	1									1	1	3	1	3		3	1					1						2	2	
					1	1	0	1	2	1										1																			1
		1			2	1	2	0	3	2																											2	1	1
					3	2	2	1	0	1											1	1														P	2	2	1
					3	2	1		1	0																										P	2	2	1
					1						0	2	1	1	1		1			2	2	2		1	3	3	2	3	2						3	3	2	1	
					1						2	0	1		1	1	1			2	2	2		1	3	3	2	3	2						3	3	2	1	
					1						P	P	0		2		2			2	2	2		1	2	2	1	2	2	1	1		1		2	2	3	2	1
					1						P	P	2	0	2		2			2	2	2		1	2	2	1	2	2	1	1		1		2	2	3	2	1
					1						P	P	1		0		2			2	2	2		1	2	2	1	2	2	1	1		1		2	2	3	2	1
					1						P	P				0		1		1	1	1		1	1	1		1			1				1	2	3	2	1
					1						P	P	1	1	1		0			1	2	1		1	1	1	1	1							1	1	2	1	1
					2						2	2	1	1	1	1	1	0	2	2	2	1	1	1		3				1	1	2	3	1	2	2	2	2	1
					2													2	0	1	2		1	1	1	3	3			1	1	1	1	P	2	3	3	2	1
							3	1												0	2									1								1	
					1													1		1	0	2	1	1	1	2			2	3	3	3	3	2	2	2	2	2	3
					1	1														1	2	0	2	2	3	2	2	2	2	2	2	3	3	1	3	3	2	1	
					1	1												1	1	1	2	1	0	2	2	1	2	1	2	1	2	2	2	2			2	1	
					1															1				0		1	1		3	2	2	1	2		2	2		1	
					1	2														1	1	2	2	2	0	2	2	2	2	2	2	1	1	2	2	2	2	2	1
					1													3			2		1	2		0	2			2		2	3	1	3	3	2	2	
					1	1																2	2		1	2	0			2		1	2	1	2	3			
					1															2		1	1		1			0	1	2					3	3	1	2	
					1															1	1								0						2	2		1	
																				2	1		1		1					0	1				1		1	1	2
																			1	1	1	1	1	1					1		0	1	1				1	1	1
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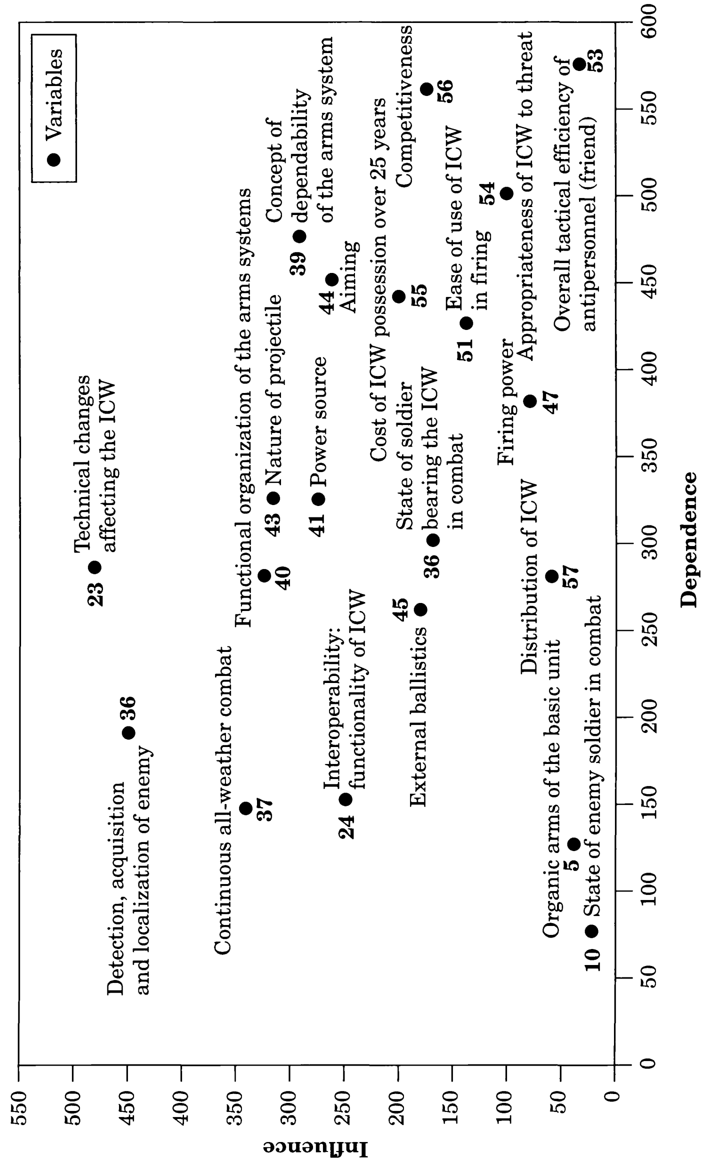


Plan Influence × Dependence : Micmac

influence and dependence. In effect, the Micmac method does allow participants to see the influence that one variable exercises on another through a third, a fourth, even a fifth. The direct and indirect influences of the variable represent the system the most realistically. Highlighted are the determining factors (main determinants) of the situation under investigation. The input variables and result or output variables help participants understand the organization and structuring of the system under the microscope.

The Micmac grid or plane follows in a simplified form; i.e., it does not retain the ICW external variables, which are essentially input variables, and the excluded variables. According to the working committee, the so-called key variables which have an above-average influence are also essentially relay variables. The variables with above-average dependence are output variables

What to Do with the Key Variables?

True confessions from an expert consulting team: after structural analysis, we felt a bit sheepish. How could we use these results to look for new technological solutions for the ICW? This question seemed unanswerable, an intellectual roadblock of sorts, until the umpteenth rereading of the variables reminded us of morphological analysis, as invented by Fritz Zwicky in the 1940s for American military applications.

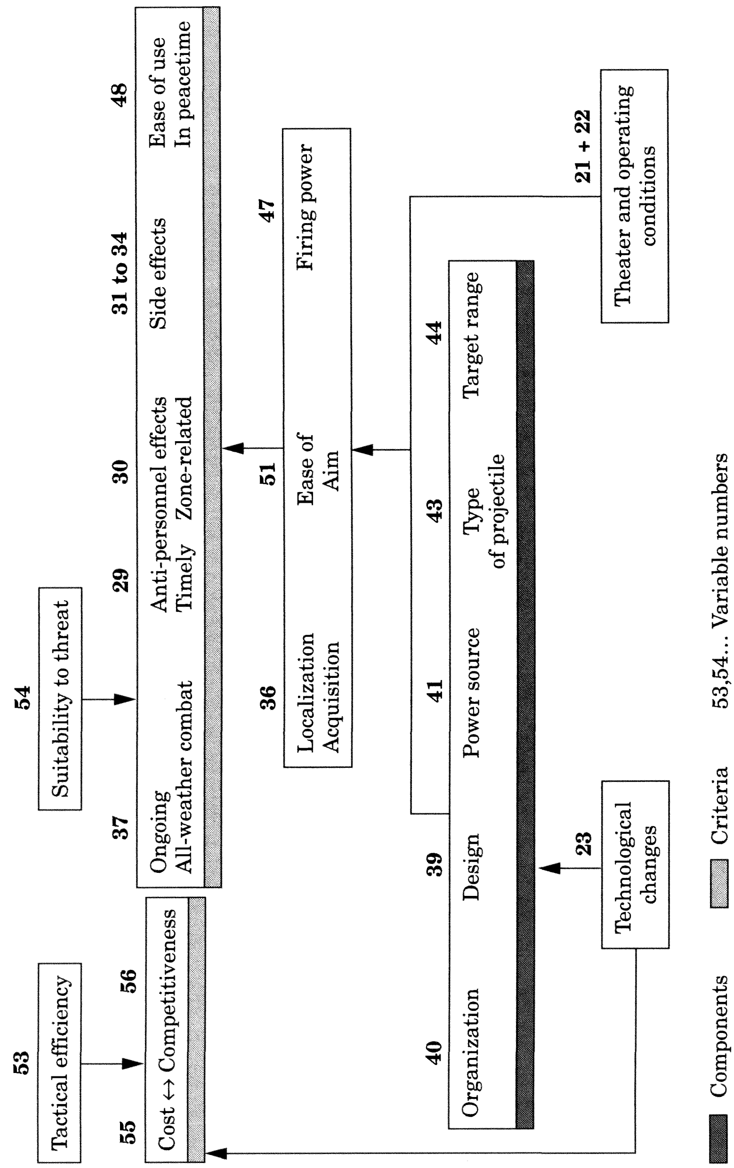
In concrete terms, we simply needed to recognize that nine of the key variables were technological components of the ICW and that six were evaluation criteria, e.g. continuous all-weather combat, pinpoint antipersonnel effects, side effects, possession costs, competitiveness, ease of use in peace time. The last criteria were put aside initially.

These nine technological components of the ICW (functional organization of the weapon and projectile, energy sources, type of projectile, aiming, materials, etc.) may lead to several configurations, possible technical answers, which may have already been at least partially listed through the "variable cards". Although the numbers may still boggle some, the next steps are simpler, so to speak. There were thousands of possible technological solutions so that the question was where to start and how to decide on a limited number of new solutions that meet the objectives set out.

The ICW's Morphological Space or 1001 Solutions

The ICW was considered a nine-component system in which each component can take a specific number of configurations. In the example given here, the source of energy may take the following configurations: solid, liquid, gaseous or electric. Here are a few other configurations as defined during this exercise:

Key Variables ICW 2010



– Monoarm, or one type of launcher (e.g. FAMAS);

– Polyarm, or several type of launchers (e.g. M16);

– Single (mono) projectile, or the firing of one projectile of one type only, at a time;

– Polyprojectile, or the simultaneous firing of several projectiles identical (or not) or the successive firing of different types of projectiles.

The array of technological solutions identified through this decomposition is called "morphological space". Each solution corresponds to a path in the morphological space. This path links the configurations of each component at a rate of one configuration per component. The ICW morphological space represents 15,552 combinations, or nine components with respectively 2,3,6,3,6,3,2,2, and 2 configurations.

Using this method raises several issues related to the limits and the illusion of massive mathematics. First, the selection of components is delicate and requires serious, in-depth thinking like that also carried out in this study using structural analysis. Actually the number of components and configurations multiplies quickly so that the system soon becomes unwieldy. On the other hand, an overly limited number of components would impoverish the system, so there is a need to find a compromise like the one adopted in the AIF case. The compromise always implies retaining those components which are the most determinant. It is important to pay attention to the independence of the components, also called dimensions, and not confuse them with configurations, also called hypotheses.

This scan of possible solutions within today's imagined field may appear exhaustive because of the exponential mathematics. Yet the field has not been definitively surveyed because it evolves over time. By omitting one component or simply one configuration essential to the future, we run the risk of ignoring a facet of the field of possible futures.

To prove our point, let us switch to a hypothetical past case, if this method had been applied to the function "knowing what time it is" in the early 1950s or 1960s participants would have imagined everything except the quartz watch!

Lastly, the user or participant can end up drowning in numbers. The very stating of solutions becomes difficult once up in the hundreds. For a system with four components and four configurations, we start with 256 possible combinations already. How can we outline the useful morphological subspace, or subset of useful solutions, under these conditions?

A Vast Morphological Space: Fifty Solutions Selected

Reducing the morphological space is not only desirable but also necessary because the human brain can not explore one by one the possible paths generated and it is futile to identify combinations which will be

ICW Morphological Space

Compnent		N°	Configurations					
Functions	ARM	40	mono-arm 1			poly-arm 2		
Organization	PROJECTILE		none 1		monoprojectile 2		polyprojectile 3	
Type of projectile		43	kinetic 1	explosive 2	incendiary 3	chemical 4 biological	rays 5	multiple-effects 6
Aiming		44	direct visual 1 (market, optical, line of fire no target device)		indirect visual 2 (sreeen)		non-visual 3 (radar IR, laser)	
Power source		41	solid 1	liquid 2	gas 3	electricity 4	nuclear 5	mechanical 6
WEAPON DESIGN		39						
Maintenance			modular 1		non-modular 2		consumable 3	
Functions			functional chain 1			fonctional bloc 2		
Internal kinetic of ICW			moving parts 1		non-moving parts 2			
Materials			classic materials 1			non-classic materials 2		

rejected once the selection criteria (technical, economic, etc.) are taken into account. Some choices have to be made in order to identify the fundamental components with regard to the criteria. In the case of ICW, we opted to follow a four-part procedure.

Selection Criteria and Policies

Here participants had to identify the economic, technological and tactical selection criteria that would enable them to evaluate and pick out the best paths (technological solutions) from the array of possible paths (morphological space) prior to morphological analysis. The following criteria were retained from the structural analysis: continuous all-weather combat, pinpoint antipersonnel effects, side effects, possession costs, competitiveness, ease of use in peace time.

Different weighting systems for the criteria defined the various policies. In this respect, two policies were defined: economic and military in accordance with the principle that participants had to retain solutions corresponding to all the military objectives and economic restrictions. The economic policy successfully integrates the cost of owning the weapon over a 25-year period and competitivity but also covers the continuous combat or side effects; whereas the military policy favors something suitable to the threat, e.g. continuous combat, antipersonnnel effects and side effects, but also considers competitiveness.

Weighting Criteria for Each Policy

Criteria	Policies	
	"Economic"	"Military"
❶ Cost	6	1
❷ Competitiveness	4	3
❸ Continuous, all-weather combat	3	5
❹ Anti-personnel effects	1	5
❺ Side effects	2	3
❻ Ease of use in peace time	2	1

Pinpointing the Main Components and Technological Incompatibilities

Prior to assessing the solutions, we believed some pruning was needed. It was decided that an initial reduction of the morphological space would mean keeping only those components, among the nine key variables identified, which seemed to be the most determinant given the criteria already mentioned and the policies defined using these criteria. For this to work, the components were classified according to the criteria. To determine the main components, each one was graded on a scale of 0 to 5 in terms of impact on the criteria, e.g., none, very weak, average, strong, very strong.

After working individually, group members reached a strong consensus that enabled them to retain the following four components:

– organization of the weapon;
– organization of the projectile;
– nature of the projectile;
– aiming.

The result applied to both policies considered, the economic and military, after a weighting of the coefficients per policy.

This procedure enabled us to examine, as a priority, four main components out of the nine initially considered. The original morphological space of 15,552 possibilities was thus reduced to a useful subspace of some one-hundred solutions. In other words, the group was able to reduce the space by a factor of 150.

A review of technical incompatibilities then enabled participants to eliminate a healthy 50% of the solutions.

From Evaluating Solutions to Choosing the PAPOP

We then evaluated the various remaining solutions according to each economic and military policy; in other words, for each weighting of the criteria. Our assessment enabled us to set up a classification of these fifty-odd solutions. (The Multipol software classifies this type of data quickly.) To do so, we graded each solution according to the six criteria retained. By applying the corresponding weight to each policy, we got two grades for each solution. Two classification systems were thus created, as the following diagram shows. When compared, we could discern the hard core 22 solutions which included:

– best solutions for the overall set of criteria and the policies (in top ten classification);

– average ranking solutions or those with one grade in one classification system and rising in the other classification system (from tenth to twentieth position);

– excellent solutions in terms of certain criteria only and maintained by a particular member of the working committee.

According to the chart, the combination 2363 is classified first, according to military policy and fifteenth according to economic policy.

The twenty-two solutions were found in the deep core of the useful morphological space and then regrouped by family. In other words, they appeared according to their similarity or identical solutions to one of two configurations.

Each of these families and the twenty-two solutions was analyzed and evaluated in detail with special attention paid to the configurations linked to the five secondary components.

ICW Morphological Space with Four Key Components

Component		N°	Configurations					
Function Organization	ARM	40	mono-arm 1			poly-arm 2		
	PROJECTILE		none 1		monoprojectile 2		polyprojectile 3	
Type of projectile		43	kinetic 1	explosive 2	incendiary 3	chemical biological 4	rays 5	multiple-effects 6
Aiming		44	direct visual 1		indirect visual 2		non-visual 3	

TECHNICAL SOLUTIONS	FR.F2 or PM (1,2,1,1)	FAMAS (1,3,6,1)	PAPOP (2,3,6,2)

Wrap-up and Comparison of Economic and Military Rankings (Extracts)

Solutions				Military Policy Ranking	Economic Policy Ranking
OA	OP	P	V		
2	3	6	3	1	15
1	3	6	3	2	4
2	3	6	2	3	9
2	1	5	3	4	18
1	2	6	3	5	5
1	3	2	3	6	13
1	2	2	3	7	8
2	3	2	3	8	35
2	3	6	1	9	13
1	3	6	2	10	6
1	3	6	1	11	1
2	3	1	3	11	34
1	2	6	2	13	3
1	3	1	3	14	22
2	1	5	2	15	20
1	1	5	3	16	23
2	3	2	2	17	33
1	2	6	1	18	2
1	3	2	2	19	20
1	2	1	3	20	12
2	3	2	1	21	27

Abbreviations: OA: Organization Arm; OP: Organization Projectile; P: Profile of projectile; V: Aiming.

This last phase enabled the group to advance the following conclusions:

– analysis and reflection on the different components of the arms system, so that the nature of the projectile plays a determining role in defining the ICW;

– given the horizon, use of a radioactive arms system was excluded for considerations related essentially to the battlefield environment. (Note that the concept of a biochemical warfare system was also excluded);

– the four remaining concepts could be classified in two categories: innovative concepts with multi-effect, explosive or incendiary projectiles, a classic concept using kinetic projectiles which would be an improvement on existing systems.

The study also revealed a certain number of conclusions considered transversal:

– interest in a single-arm weapon for mass use;

– ease of use and cost;

– key role of fire-control in continuous all-weather combat;

– advantage of a single projectile weapon being multi-effect and the innovation of a "polyarm multiprojectile" weapon of less complexity yet high performance overall in terms of the evaluation criteria.

After these additional studies, the PAPOP was designed. The "infantryman's weapon for the 21st century", it is original as a multi-arm-multiprojectile weapon that uses an explosive ammunition launcher and a kinetic ammunition launcher. The PAPOP met the needs expressed in terms of the following essential criteria:

– explosive ammunitions set-off by a triggering device programmed to follow a path to achieve a high probability of hitting camouflaged targets;

– high caliber, which, combined with strong initial strength, leads to a strong, specific impulsion. The idea being to obtain a high probability that the target will be incapacitated with its NATO protection;

– effective fire-control, assistance in programming for the soldier firing and indirect aiming will allow the soldier to fire from a sheltered spot.

At this juncture, two lessons in morphological analysis should be reviewed. First, morphological analysis imposes a structured form of thinking about the components and configurations to be considered and allows for a systematic scanning of the field of possible futures. Although perhaps initially overwhelming, the mathematical formulae must not paralyze the thinking process in some form of "analsis paralysis". The useful morphological subspace can be reduced to one- tenth or one one-hundredth of its original size. To do so, selection criteria are introduced. For example, the multicriteria method Multipol, plus the restrictions of exclusion or preference. The Smic-Prob-Expert method allows for the probabilization of the combinations of configurations.

Lastly, after this exercise, the group declared that the use of the various methods had been a productive "detour" in structuring and organizing its thoughts, especially on the definition of ICW key variables using structural analysis to unearth the technological components and selection criteria as well as to analyze and evaluate the concepts of weapons systems using morphological analysis and multicriteria evaluation. The participants also emphasized how much more useful these methods were when the user remains aware of the inherent limits and respects certain conditions for their application.