A B S T R A C T

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The Development and Use of System Dynamics within an industrial context

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System Dynamics was introduced in ELF, a major French Oil Company, in 1974, and has developed from a one-man effort to a permanent team of some eight engineers ans scientists.

Applications have delt, among others, with :

1) macro-economics : world commodity and oil markets
2) the economics of long term oil exploration and production
3) social applications : working relations between workers, engineers and management in an oil refinery
4) the dynamics of information generation and use at various levels of the Company

In addition, some effort has been applied towards a more efficient and systematic use of scientific tools in System Dynamics : classical and modern control theory, catastrophy and bifurcation theory, fuzzy sets,

This paper will describe briefly some of the above mentioned applications, with a few of the corresponding results.
The use of System Dynamics in increasing both in ELF and more generally in France, but we will also describe some of the difficulties and failures we have encountered in developing this tool for decision making.

Our paper starts with a revision of Burns'ideas (1) followed by a new proposal for rigorous automatic conversion, with the following steps :

- Conversion, illustrated by a simple example including rate to rate interactions
- Minimization of the number of levels
- A minimum set of loop-variables is automatically built while the set of information variables (auxiliaries) is hierarchised
- Our reduced representation occurs.
  It allows easy multiple and diversified applications of mathematical and numerical methods for analysing building and controling Large Scale System Dynamics Models.

Moreover, this last point will be illustrated by industrial applications of our method within ELF-AQUITAINE (3)

Other algorithmic developments will become the subject of further papers in the near future.

An example of our reduced representation is shown in the drawings attached.

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The DEVELOPMENT and USE of SYSTEM DYNAMICS WITHIN an INDUSTRIAL CONTEXT

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I - INTRODUCTION

This paper is destined not so much for those who are present at this conference than for the members of the business community whose absence constitutes one of the main problem facing System Dynamics.

Indeed, since its inception more than 20 years ago, quite a few Industrial or System Dynamics publications have dealt with industry or government related applications. However, very few of those have been effectively developed within and presented by business or government representatives.

What is the reason for this situation ?

Is it due to a lack of interest on their part ? Hopefully not, or else what are we doing here ?

Is there interest, but insufficient know-how for these organisations to hire and use their own System Dynamics specialists, thus always requiring sub-contracting to universities or private consulting organisations ?

Or, as is sometimes rumored, are there System Dynamics studies being really developed within business and government, with models as well as results being kept highly secret ?

We believe that both lack of know-how and secretiveness are highly detrimental to the development of System Dynamics. Hence the purpose of this paper, namely to describe without divulging any secrets, the general activities of the System Dynamics group of Elf Aquitaine, thus ascertaining that within a business organisation, such a group can develop, gain a valid and useful know-how and yet have frequent exchanges with the outside world.

Hopefully this will help other groups similar to ours, to come into the open and describe some of their work. We believe this to be a requisite for a successful development of System Dynamics in future years.

II - THE SYSTEM DYNAMICS GROUP of ELF AQUITAINE

The use of System Dynamics within our company started seven years ago with a one-man effort and developed gradually to its present state of nine concurrent projects. Our team numbers 4 permanent members and an average of 4 graduate students. Everyone's background is scientific with majors in control theory, computer science, numerical analysis, etc... but always with some knowledge in economy.

The Graduate students are working on a thesis within the French University or Scientific Institute System ("Grandes Ecoles") with which we have developed close cooperation : the thesis is done within our group and the student works practically full time with us, while his thesis supervisor is a member of the University of a "Grande Ecole". This has proven to be very beneficial to System Dynamics since it has led several of our students to give lectures or courses in their Alma Mater, thus spreading their practical know-how and generating further interest among students and faculty.

Most theses develop a practical application of System Dynamics - essentially the conception and development of a new model, exclusive of its use which becomes the task of our permanent members - but at least one thesis (cf.bibliography) has dealt with theoretical developments concerning the use of System Dynamics and control theory. In this respect, we are fully aware that the development of new conceptual tools must parallel the use of System Dynamics in practical applications.

Our models originate either through a demand ("we have a problem ... can you help us ?") from various sectors of the company, or from our own feeling as to the future usefulness of certain studies. The latter case corresponds in general to more esoteric and far-fetched models, such as for example the general analysis of the structure of information within Elf.

Our experience has shown that very few System Dynamics studies can be performed in a short time, i.e. less than a year, if they are to be of real use*.

* This is due to the fact that seldom can simple models bring more information than what a good manager can get from his insight. To go beyond, the model must represent the complexity of reality, thus becoming, unfortunately, complex itself.

This is in fact a serious handicap to the development of System Dynamics, since, when people ask for help, they need help quickly. On the other hand, we have found that most of our models, whether used or not, remain valid and usable - with minor changes - for very long. This perennial characteristic of our models is an important facet of our work... but requires patience !

III - A SHORT DESCRIPTION of SOME of OUR MODELS

Our work can be classified in three domains :

- Macroeconomics
- Social and personnel type problems
- Business and Management

1 - Macroeconomics

Several models have been or are being developed in two main areas :

- commodity markets at the National or the World level

The main work - a model of the World Protein Market - originated form Elf's one time interest in the development of single cell proteins (developed from oil or gas) and more generally in the whole commodity market. Developed in cooperation with INRA, the French National Agricultural Research Institute (cf.bibliography), this model incorporates the soybean-corn competition, both at the producer and at the consumer level, and a meat sector, the final user of both corn and soybean.

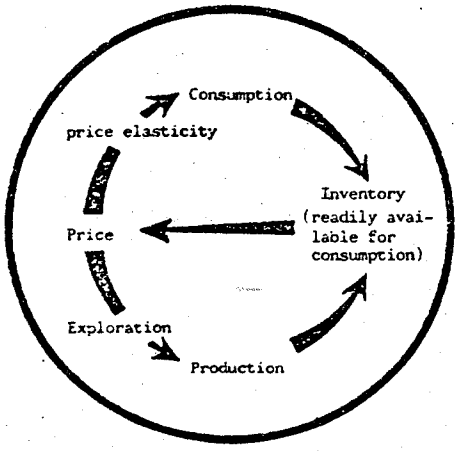
Since obviously our company is in no position to act on these markets at the world level, the main use of our models in this area is to try to ascertain the cycle length (for example the effect of meat cycle on both corn and soybean) and the sensitivity of the commodities to various possible changes in the market. This helps ascertaining the risks involved and defining the optimum time for possible policy changes (namely getting in or out of the market).

- Oil Market

Our main effort at present in this area relates to the world crude oil market. The model which we have developed, and which is now operationnal, is simplistic in some aspects but quite sophisticated in others. Simplistic it is in that it considers, for the time being, only one product - an average crude oil - one world producer and one world consumer. But its central variable, price (spot), is determined through quite a complex - and we think realistic - price formation mechanism.

We consider the oil market mechanism as being an assembly of three sub-structures, each corresponding to a different reality :

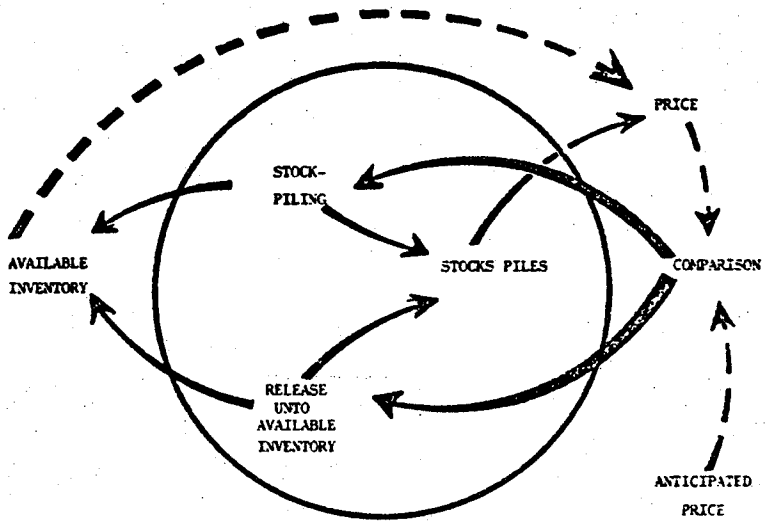
- a classical offer and demand structure whose main variables are production capacity, consumption, inventory and price.
This sector contains the long time constant links such as those relating price to consumption (non linear and time-delayed elasticity) and price to production capacity development.



Oil Model : General Diagram

But in the short term, the classical offer-demand approach is insufficient since it cannot represent the very brusk price changes which have been experienced lately.
Hence we have introduced a :

- Stock-piling sector which represents rapid stock-piling transactions or in the contrary releases of available stocks back onto the market.

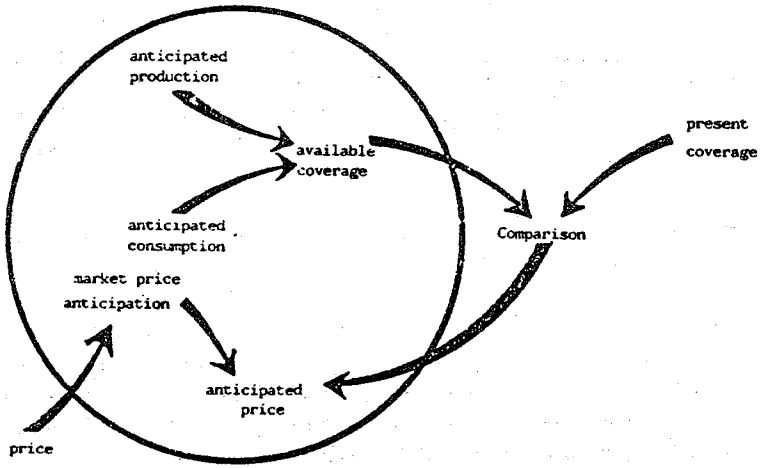


These transactions - which can and are being done by states, major oil companies, small operators or even a large conglomerate of individuals - result from an evaluation of market tendencies and a comparison with present realities.

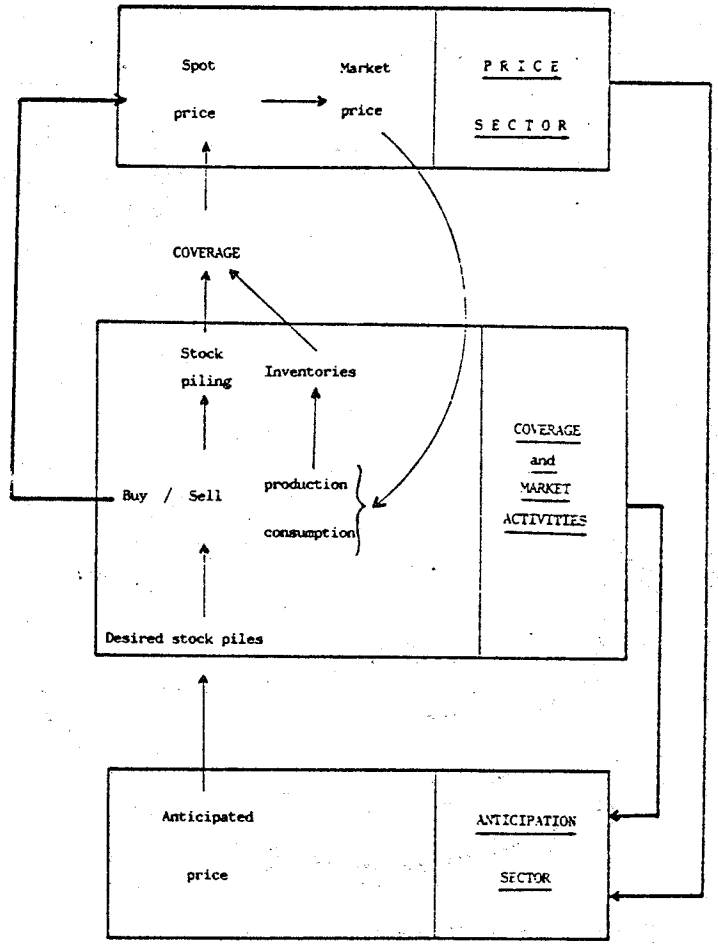
Hence the third sector represents :

. the anticipated oil market situation

It is similar to the first sub-structure in that it contains all the main variables of the real world, but anticipated for a near future. In addition, these anticipations are instantaneous, so that this sector gives rise to very short time-constants.



The complete model is thus an assembly of these three sub-structures and can be representated by the following very simplified diagram, which shows how price - the central variable of interest in our model - is determined and simulated through market activities, adding the anticipated world as a cause for action on the market.



As may be noticed, we have incorporated both rapid and slow dynamics in our model of the oil market. This is important since, because of non-linearities, long-term response is often strongly influenced by short-term reactions. Thus we can use the model to analyse either short-term or long term evolutions, or both.

Here again, the user of this model is in no position to alter reality, hence is not interested in testing the effects of structural changes in the model. Rather, the latter is used to determine market sensitivities (and their evolution in time) and possible responses to various political or economical changes.

2 - Social and personnel development models

One of our main work in this area was presented at the 1980 IEEE Convention on Cybernetics and Society (Boston, October 1980) hence I shall not describe it here except to say that three successive studies were performed, concerning working conditions in refineries and relations with shiftworkers. These studies went from the very general, with no computer model but a set of causal diagrams which proved very helpful as an analysis tool, to the very specific-how to improve the role and usefulness of six shift-worker supervisors -, leading to a broad computer-based model of work relations between various hierarchical levels of employees and employers.

The latter model is not limited to the specifics of shift-work in refineries. However its broadness does constitute a handicap in that quite some effort is required - both from modeler and decision maker - to transform results from the model unto specific proposals for change in work relations or conditions in various sectors of the company.

In fact, we feel that such a handicap occurs rather frequently in S.D. studies and is very detrimental to the development of System Dynamics. Few S.D. practitioners are willing or are readily available to change roles from model designer and developer to model user. Once models have been developed, the interface with potential users (the decision makers) is often lacking.

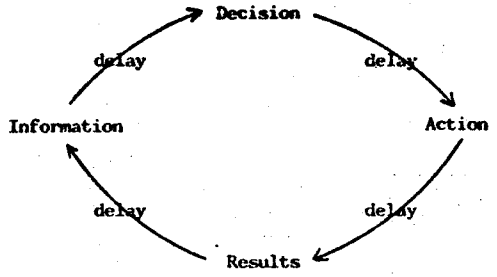
And without such an interface, models cannot be regularly, systematically and competently used, and they quite often, though injustly fall into oblivion.

3 - Management type models

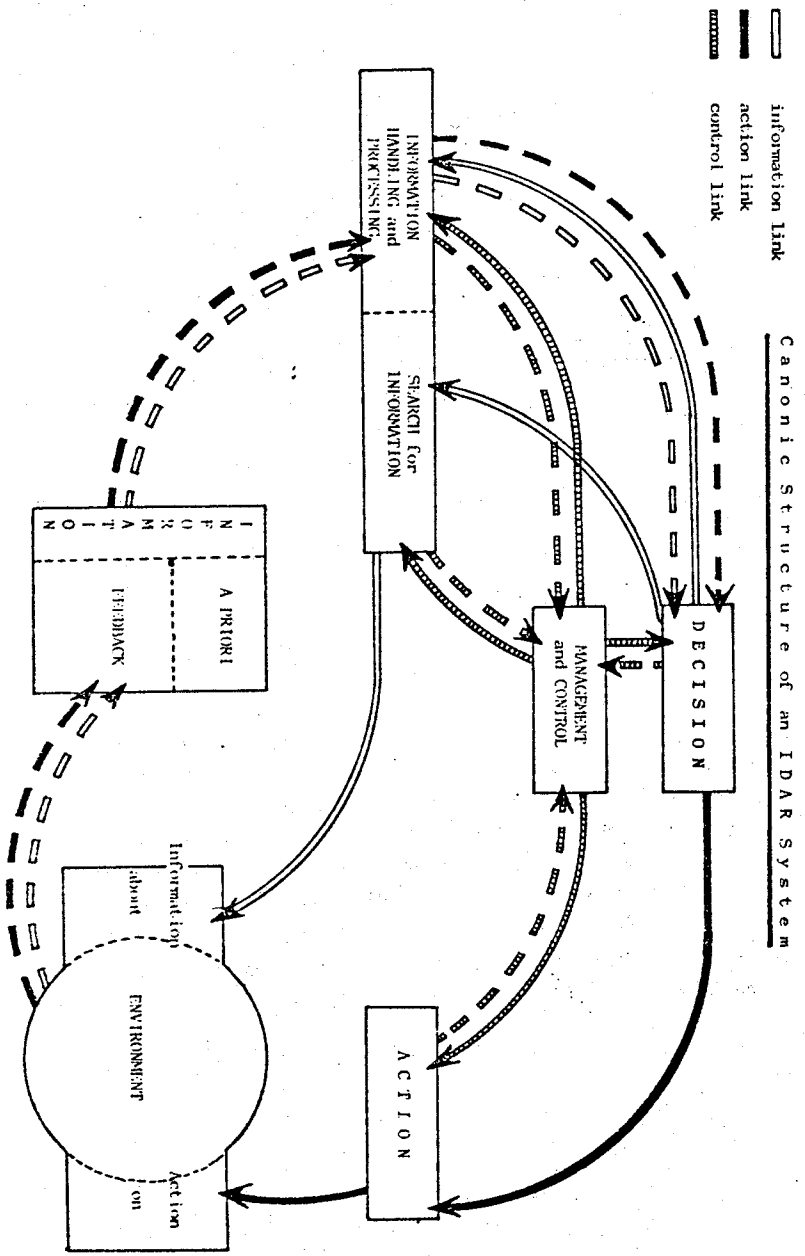
This category includes all our work using the Project Management Modeling System developed by Pugh-Roberts, a model of gasoline characteristics versus consumption, and, naturally, several Oil Production and Exploration models.

Of the latter, two are now operationnal and can be used either for the analysis of long term consequences of erroneous evaluations in oil reserves, or to determine the influence of feedbacks between exploration and production, taking into account the spatial (and financial) competition between simultaneous oil field developments.

Another such model, now reaching an operationnal stage, concerns the needs, transmission and use of information in the oil exploration domain. The well-known general loop (which we call the I.D.A.R. loop)

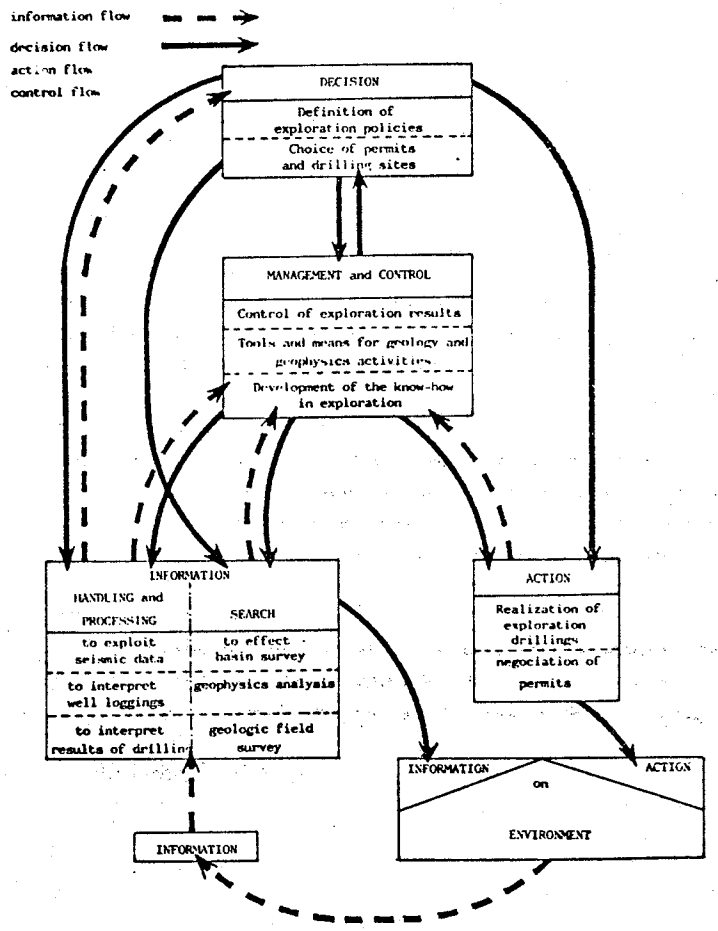


has been transformed into the following still simplified general structure diagram, introducing control activities, information gathering activities, etc...



At present, the corresponding model is used to study the dynamics of the information system existing within the Exploration Structure of the Company, with the above general structure diagram filled in as follows. We are able, with this model, to assess the influence of various information errors (distorsions, lags, etc...) on the results of our exploration activities.

The IDAR diagram as applied to the Oil exploration structure



But the same type of analysis can be applied to other areas - for example restricting it to the activity of well drilling, which also requires and puts into effect an I.D.A.R. structure - or even to other domains, such as the information structure of various departments, factories or labs, etc...

Needless to say, one often faces a strong reluctance and even opposition when initiating and performing such a study. Even more opposition is to be expected at the final stage of the work, if changes in the existing information structure are proposed.

IV - SUCCESSES and FAILURES

It is often difficult to evaluate the degree of success of a model. Should it be used often, or rather at decisive decision making steps ? Is it considered a success when it merely helps decision makers to perceive problems and the rational reason for a possible solution ? Should it aim at top managers or rather at middle level management, potentially more available and dedicated to frequent uses of the model ?

The answer to theses questions really depends on the topic, the people concerned and the complexity of the model.

Let us only mention a few characteristics of most of our models and / or results

- none of our models are simple, short and rapidly developed. In our environment, simple models teach nothing and lead to either evident or erroneous results. Hence most models require at least one man-year of work.

- because of this complexity, proposals for simple and at the same time, radical policy changes are unfrequent.

- counterintuitive results are not infrequent, but corresponding policies are difficult to implement because of the high risks involved (as an example, a proposal which would lead to some improvement, but after an initial worsening of the situation, is unlikely to be implemented).

As for failures, we have already mentionned what we feel is one of the main cause of difficulty : namely a certain lack of interface with decision makers when it comes to detailed uses of the model, hence difficulties in the follow-up of our studies, i.e. the regular, frequent and often boring use and update of our models. We suggest that, for System Dynamics in general, this may be one ot he essential causes of its slow development in the business community.

V - CONCLUSION

System Dynamics is slowly but steadily developing within Elf Aquitaine. But this is no self congratulatory note. Let us repeat that this paper was written mainly for the purpose of inciting other individuals or groups working within industry or government to let themselves be known through similar publications.

This, we believe, would give a new boost to System Dynamics at all levels - applications, research, teaching, publications -, all of which are needed for a harmonious development of this science.

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