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A. F.

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CHAPTER I

INTRODUCTION

Paolo Bisogno and Augusto Forti

Taking an interest in the future is among the most instinctive of human activities. Conscious of the existence of time as well as space, man has always tried to guess what the future holds. Until recently scholars have left the field of speculation to the pseudo-sciences of astrology and palmistry or to the ambiguities of the oracles. Imaginative writers have made some brilliant contributions, but the development of mathematical modelling and other predictive techniques are relatively recent arrivals.

The new techniques have come at just the right moment. Today the study of the future has a much sharper relevance than ever before, because people have begun to realise that the future can be controlled - or even that it must be controlled if there is to be a future at all; man should take charge and choose his own future from a wide range of possibilities. Unless he does so, the pressures of the present will impose their own logic and produce a future from a flawed mould - a future in which the contradictions of wealth, privilege and power are monstrously exaggerated by the magnifier of economic growth.

Society today faces a multiple series of crises: "a crisis of crises" in the words of John Platt. Each one may seem soluble on its own, but interactions between them may produce 'super-crises' which temporarily stretch ingenuity beyond the breaking-point. Because of the massive scale of man's activities - militarily, ecologically, and industrially - a failure to deal with even one of these 'super-crises' could have fatal results.

The last century has seen enormous scientific progress and an accellerating rate of technical change (although in historical terms we should be wary of assuming that there is anything unique about that). Science applied in the haphazard ways of the past has produced both technical and social progress, but it has also heightened social disequilibrium. That the benefits of science do not automatically go where they are needed can be seen in the widening gap between the developed countries and the Third World, and in the economic disparities between different regions in the same country. It has been humiliating for scientists and economists to watch the partial failure of the ambitious plans of technical and economic development with which the first Development Decade began. All these failures have left us with increased social tensions both nationally and internationally, and pose a special new responsibility for science.

The gaps between social progress and technical progress were quickly noted by the general public, more slowly by scientists themselves. Today it is possible to detect a general public bewilderment at the activities of science and scientists. Research workers themselves were perhaps slow to see it, but they too have now caught something of the same confusion: the old certainties are lost.

It is perhaps unneccessary to rehearse the list of crises which face the world today. Many, like war, poverty and political manipulation, are as old as society itself, but their impact has been sharpened by the contribution of science. Others, like overpopulation, are relatively new on a global scale, although they may have occurred as local phenomena before. Yet others, like possible ecological catastrophes, derive both from the scale and temper of human activity. In some cases, practices acceptable for generations, like dumping rubbish in the oceans, have become intolerable on the grounds of scale alone. In others, totally new problems have been created by the rapid growth of new technologies like the motor car or the chemical industry.

Today's crises are the crises of exponential growth. Yet long before we have devised any way of solving them, we are moving towards another set of crises, associated with the inevitable change from a 'growth' to a 'stable' economy. While this change, if it occurs, may help solve some of today's problems, it is bound to create more at the same time. Who will bear the costs of such a change? Will the rich countries be willing to share their riches with the developing and poor countries? Mankind will have to learn to adapt to a new revolution before he has even adapted to the last.

Despite the evident crisis, there still exists a tendency to argue in terms of scientific and technological 'rationality' - a tendency which is built into the social system itself. To a trained scientists, this 'rationality' tends often to become an end in itself, even when it is clearly no longer in step with social reality.

It is becoming obvious, however, that the final aims of science and technology are much more than just the achievement of its 'technical' objectives. Science should also aim to perfect the cultural integration of the individual into society. In the past, its effects have usually been the opposite, producing alienation which increases as science becomes more successful. Industrial production and science have become intimately linked, but man has been the loser. Man is also omitted from consideration whenever technical, economic or 'prestige' problems become preeminent - how else can one explain the close involvement of science with military and space research, where the benefits are merely accidental?

Futures research emphasises that the future is not a single inevitable whole, but a series of choices. In setting out and balancing the different possibilities so that a decision can be made between them, mathematical modelling can act as a social laboratory in which the consequences of different actions can be worked out before political commitments are made. Experimenting with the world in this way will not prevent mistakes being made, but may help to avoid the most damaging of them.

This ambition, however, still lies in the future. Even the most confident modellers at the Venice meeting took pains to emphasise the crudity of their models and were anxious that conclusions should not be drawn before more refined models had been built. A model is no better (and frequently rather worse) than the information from which it is constructed.

This raises one of the most interesting questions to come out of the meeting. Should social modelling be regarded simply as an academic exercise until the models are perfected? Or should the models, fallible as they are, be used as one element in policy-making? Dennis Meadows argues that decisions are already being made today on the basis of implicit social models, the models which inhabit the minds of policy-makers and politicians. If a mathematical model could incorporate all the same inputs, he says, its results should compare favourably with the mixture of information, folklore and prejudice which makes up the social 'models' already being used. In addition, they would have the advantage of making explicit the assumptions which are merely implicit in the 'models' presently in use. However crude, Meadows argues, they could be no worse than what we have already.

Others might disagree, particularly when the inadequate inputs of present day models are considered (see the present discussion about the Club of Rome model) but nobody at the seminar could deny that, although imperfect, models are becoming more and more widely applied to many aspects of our life.

In the long term, it will clearly be necessary to involve all the social sciences in model-building. The experimental method applied to modelling is a powerful tool, but its limitation is that it omits the areas of knowledge which are by nature inexact, and which at this stage cannot easily be formalized. The future will undoubtedly see attempts to bring together biology, anthropology and sociology to produce a unitarian science of man, able to predict the dynamics of social development.

One of the most serious limitations of social modelling, as participants at the seminar agreed, is the partial and incomplete nature of the information available to the model-builder. The system is 'econocentric', in Alvin Toffler's phrase, providing masses of economic information but very little else. Even the economic information may prove inadequate if society is passing through a revolutionary change, as Toffler suspects. So far, economic analyses of the future have been based on the expectation of continued economic growth; if such expectations are not realised, the models so far built are likely to fail. Unfortunately, methods of incorporating 'soft' information into mathematical models are still inadequate. Thus it is often the most important information which has to be left out when models are constructed.

In mathematical modelling, this poses a most important question; whether it will in fact ever be possible to harness a technique based in the 'hard' sector of our culture to problems related directly to the 'soft' sector. For modelling today does not concern itself with the world of values, but the world of facts. Making this transition will be one of the most intriguing problems to face future researchers in the next decade.

The problems which science faces today are changing rapidly. Science has moved from being a pure 'divertissement', an academic pursuit, through a phase in which it was strongly coupled with the productive process, into a third phase. A decade ago, people talked of a 'policy for science' and tried to devise ways of encouraging science and keeping scientists happy - generally by increasing the annual science budget by a respectable percentage. Today the question is not 'what can I do for science?' but 'what can science do for me?'. The change is from a 'policy <u>for</u> science' to a 'policy <u>through</u> science'.

The very success of science and technology in the second phase - that of improving the efficiency of the productive process - has produced a growing alienation based on the imbalance between technical and social goals. What public opinion is trying to say is that it is now the task of science to try to re-establish a connection between its own goals and those of society - or at least to ensure that the two are not working in entirely different directions. This is certainly one of the motives behind Technology Assessment, a technique which attempts to assess the social and environmental consequences of a new technology before it is adopted on a wide scale.

What this may mean is that social goals will come to have a greater priority than economic ones. The question we shall ask is not 'how much growth?' but 'growth for what?'. The pre-eminence of economic issues is almost over.

It is one thing to make this declaration, quite another to put it into practice. For economics possesses what social systems lack - a unified theory which brings them into the realm of science and out of the realm of mere speculation. Economics is still far from an exact science, but the work of Keynes and others has at least built up a framework on which models can be based. Social science is still lost in a welter of undigested statistics from which no patterns have yet emerged.

Social modelling can perhaps do something to fill the void. There is probably no advantage in a heroic computer model which attempts to simulate the whole of society - indeed, the idea contains a kind of scientific arrogance. Rather what is needed is a series of modest steps which lead us forward by a process of exploration, gradually refining and extending the models and improving their accuracy.

The humility implied by such a process ought to be an important element in all social modelling. Nobody believes that utopia is to be found in the memory of a big computer. The task of social modelling is not to define what <u>ought to be</u>, but to present a series of possibilities of what <u>might be</u> and leave the choice to others. The modellers' responsibility ends with the description of alternative possible futures: at this point he becomes a private citizen whose opinion is worth no more and no less than anybody else's.

But the earlier stages in the process <u>will</u> be the function of the scientists. The first stage is to identify reality and to define ways of formalizing it mathematically, so that a simulation can be built and programmed into the computer. The second is to validate that model as far as possible, and finally in the third stage, to use it to simulate a variety of alternative futures based on different assumptions and policies.

The final stage will be explicitly political: to make a choice between the various possible futures presented by the model. This phase is the most important of all, because it may require politicians to take decisions which are extremely radical and, worse, appear illogical at the time they are made. Jay Forrester has argued that the world has now entered a situation which he describes as 'counter-intuitive', in which all the obvious, conventional decisions succeed in doing is making the situation worse. "If we follow intuition" he has written, "the trends of the past will continue into deepening difficulty".

This claim is not universally accepted, so the point can be made differently. If social models are to make a new contribution, they must occasionally suggest courses of action different from those which would have been taken anyway. If they do not, their contribution will merely be to strengthen the _status quo_. Sooner or later the time will come when the conventional wisdom suggests one course of action while the social model suggests another. Then the attitude of the politician will be of profound importance.

A decision-maker under these circumstances is faced with a mass of difficulties. In addition to the irrational and conservative nature of mankind, he is working in a society based on certain assumptions, foremost among them the assumption of continued exponential growth. While some of the advanced countries are moving towards an acceptance of the idea that economic growth should slow down and possibly ultimately stop, the developing countries are understandably reluctant to see this happen at least until they have achieved parity. And even within the advanced countries, there is still a lack of sensitivity to ecological issues and a marked tendency - which again is understandable - by the less privileged to argue for more economic growth rather than less. Ideological and religious objections form another barrier.

These difficulties, serious as they are, are not reasons for abandoning the target. They merely emphasise that the need for rational ways of planning the future is growing more urgent every day. After centuries of confident expansion, man is coming up hard against the limits of his world, recognising that nothing can go on expanding for ever. The next frontier will be the development of an understanding of social systems. It will not be easy, no easier, according to Jay Forrester, than the development of science and technology. But no project could be more fascinating and important.

In introducing this seminar, in which different and sometimes antagonistic points of view were expressed, we hope to make a contribution towards a better understanding of the problems and difficulties which face those involved in mathematical modelling for social problems. We also hope that the contributions presented here will provoke thought, not only among specialists but also among those involved in policy-making. This is why a special effort has been made to publish the material of the seminar in as simple a way as possible so as to be easily accessible to non-specialists.

CHAPTER II

THE STATE OF FUTURES RESEARCH

THE ROLE OF FUTURES RESEARCH IN SOCIETAL MODELLING

Olaf Helmer

It is a pleasure and an honour to be here, on behalf of the Institute for the Future, to participate in the planning and preparations for this conference. I do so because I feel that a futurist approach to the problems of our society will be helpful. A futurist approach is characterised by what you might call a highly pragmatic attitude, which manifests itself in a number of ways. First of all, we all know that the pace of change in our own environment - physical, technological and social - has accelerated greatly and it is becoming more important than ever that we address ourselves to solving tomorrow's problems today. If we address ourselves merely to today's or even to yesterday's problems, by the time we find solutions, the solutions will tend to be obsolete.

For example, if you were to address yourself to the problem of educational reforms, it is not sufficient to think simply about what was wrong when you yourself went through the educational system, or even what is wrong about the present system. What you have to ask yourself is what will be the requirements of education say five or ten years from now, and what will the world be like ten, 20 or even 50 years from now, for which we want to educate our youngsters. So I repeat that it is important that we address ourselves _today_ to solving tomorrow's problems.

The second reason for calling the futurist approach highly pragmatic is that it insists on expressing its solutions to societal problems in operationally meaningful terms. That is to say, in terms which are very directly related to the decisions that have to be made today. Third, because of the urgency of the many problems of our society, we feel it important to try to make some progress even in areas where at present no polished theory is available, be it economic, political or social. We try to do the best we can by constructing _ad hoc_ models where necessary, and applying the attitudes and the procedures of what is generally referred to as operations analysis.

Of course it is not enough simply to have the good intention of bringing a pragmatic attitude to bear on the problems of our society, it is essential also that we have the methods to carry out these intentions. I think I can say that a number of rather promising new methods are at least being developed. None of them are perfected as yet, but several are promising. Among the so-called methods of futures analysis I would like to mention three. One is the Delphi Method, another is the Cross-Impact Method, and the third is simulation. Let me say a few words about each of these three methods.

I think I need to say least of all about the Delphi Technique because it has been used so many times and I am sure most of you are familiar with the basic principle. It is simply a technique for eliciting and combining the intuitive judgments of experts in whatever fields are relevant to the problems under investigation. In dealing with the future, it is particularly important, since you do not usually have a complete theory available, to rely on these intuitive judgments, the insights of specialists in the particular field with which you are dealing, and so a method such as Delphi for collecting and combining the opinions of experts has an important place. Dr.Dalkey, later in this conference, will have an opportunity of telling you about the results of some of his many experiments. Let me just mention two directions in which I think future work in this field might go. One is to make the Delphi Method more flexible by combining it with simulation techniques. Experimentation in this field is badly needed and I hope that such experimentation will take place in the very near future, so that we can hope to develop a tool for collecting and collating expert opinions that is more effective than the two methods now available.

Another direction in which I think future work in this field will go is that of automation. There is already talk of setting up a computer network in which the usual interrogation of experts through questionnaires can be replaced by a system in which the experts are placed at a computer terminal and interrogated directly on-line and where the follow-on questionnaire can be automatically produced by computer so that no time is lost.

Let me also say a few words about the Cross-Impact method. The usual procedure, in, for instance, a Delphi approach is to ask particular questions, such as when will such-and-such a development take place: when will we have a cure for cancer, when will we have controlled thermonuclear energy, and so on. It is clear that potential events that might take place in the future are not unrelated to one another. The occurrence of any one such event inevitably has effects on the occurrence of others. With this in mind, Tate Graden and myself developed some years ago a technique which is called the Cross-Impact technique and which proceeds as follows.

If you are interested in a number of possible future developments, let me call them, say D1, D2, D3 and so on, we construct a matrix, with the possible events arranged horizontally and vertically. In each cell of the matrix, for instance at the D1, D3 cell, we enter information about the effect that the occurrence of D1 would have on the probability of occurrence of D3. We would start by making estimates of the probability that each of these developments would occur. Let me call them P1, P2, P3. We could say that the probability of which had been P3 will be changed in a certain way as a result of the occurrence of D1, and it will become, let us say, P3. Of course in some cases the cells will remain empty, because there will be no effect. But in others the probability will either go up or down. If it does nothing else, the scheme at least gives you a systematic way of looking at interactions.

But it is more than that. For one thing, you can check such a tabulation for consistency. After all, the probabilities P1, P2, P3, will at best only be estimates provided by experts in the field. Experts can be wrong. The estimates may not be compatible with one another. There is a way of checking the consistency of such a matrix, which is as follows. You select one of the developments at random, let us say D2. We then decide whether or not the development D2 is or is not taking place by a random mechanism. Suppose we decide it does take place: then we make the appropriate adjustments in the probabilities of the other developments so they will be changed from the original values to P1', P3', and so on. Having done that, we select another development at random, let us say D4. We go through the same procedure, and re-adjust the probabilities once again. We continue the procedure until all developments have been resolved, in the sense that we now know which of them have taken place and which have not. We keep a record of the number of times each of the developments has taken place, and by repeating the experiment a large number of times, say a thousand times (which we can do very easily on a computer) we then find out with what relative frequency each of the developments in fact occurred.

Now if our original estimate P2, say, was 30%, then you would expect by going through this procedure a large number of times that in 30% of the cases D2 will in fact turn out to have been the case in 70% of the cases not. If that is not so, then the original estimates we made are not self-consistent, and adjustments have to be made. You then begin to look for the points where perhaps the original estimate had been in error.

There are some conceptual objections to this very simple scheme I have described, and there are some difficulties in carrying out the balancing. However, I don't want to get into these now; we are aware of them, and the technique is undergoing some refinements at the moment. But it is a promising tool for the following reason. You can use this Cross-Impact matrix to carry out what you might call sensitivity analysis. For example, you can ask how much the outcome is affected if the probability of D2 were not P2, but some other value.

This opens the door to an application which is very important in what you might call simulated planning. You can include among the developments potential actions which you might want to take, perhaps forming components of a policy you are contemplating. You can ask yourself: suppose D2 were part of such a policy, what would happen if in fact I took that action, if I made D2 happen? That would mean that you would give P2 the value one, you would simply take the action, and make it come about. We can then trace through the consequences of that action, both the direct and indirect consequences and see what effect it has on the probabilities of occurrence of all the other developments.

For example, suppose you were contemplating the expenditure of a large amount of money on cancer research and let us say that D3 is the event "a cancer cure has been found". You could simulate that in this model by raising the probability of a cancer cure coming about, P3, by a certain value, making the reasonable assumption that the expenditure of money will raise the probability of a cure being found. So you have a ready means of simulating the effects of research and development, and the scheme can also be applied in the operation of a firm. A planner might be considering the possibility of building a new plant, let us say, or doing research and development towards a new production process. The method clearly applies to planning in the public sector, the planning of the future of a city, the planning of a nation. I don't want to overstate its utility, because I would like to emphasize that this is a technique which is still very much under development but I do think that it shows promise enough and that we may hope one day that it will indeed become a very powerful instrument.

As we all know, progress in the social sciences has not been as fast as progress in the physical sciences, and it has been said very often that many of the world's problems result precisely from the lag in progress in dealing with human affairs compared to the progress that has been made in the natural sciences. I don't think that here we have a theory, but we at least may have a substitute for a theory, a means of looking at the interactions that might take place between potential future developments that affect our society.

I have already briefly talked about simulation and I think that will suffice for the moment. When you use simulation as a tool in the planning process, the basic information that is required almost invariably has to come from specialists and so you also need something like a Delphi technique, a Delphi approach, to get the basic information you need. So the three techniques I mentioned, Delphi, Cross-Impact and simulation, are very closely tied together.

THE PRESENT STATE OF FUTURES RESEARCH IN THE SOVIET UNION

N. Moiseev

It is very important to understand the main trends and directions in the development of simulation models. So far these developments have taken place independently within various countries, producing not only a difference in terminology but a definite difference in understanding and in the selection of the main directions of research. Therefore the exchange of opinions which is occurring today is extremely important.

I propose to tell you about the approach we have taken in my country, the Soviet Union, and perhaps I could also run briefly over the other possible directions. You must remember that in my country simulation models are problems which are dealt with by mathematicians and physicists. For example, in our group here today, two are professional mathematicians and the other two are professional physicists. Now the fact that we are physicists influences our selection of problems for modelling, and has a definite effect on our views. For example, until now, we have been unable to understand fully what is meant by "systems analysis", although we use this term, because to us it means something directly concerned with physics.

I should like to start my report by explaining the difference between a simulation model and a mathematical model, to show just how we see this difference. For a long time the concept of a mathematical model has existed. We call mathematical models "a description of events the study of which allows us to solve one or a series of mathematical problems". In this respect, the problems of physics are all mathematical models, and the problems of planning are mathematical models (when the criteria are explicity defined) but not all problems by far can be reduced to mathematical modelling.

Parallel to the development of mathematical models we have witnessed the development of 'expertise' methods in different countries. Frequently these methods are called Delphi methods, in memory of the Delphic Oracle and its fruitful activity. In other countries different terms are used but that does not change the substance of the matter. Using these techniques, man has the ability to take decisions