

INDIAN STATISTICAL INSTITUTE

TWENTYFOURTH CONVOCATION ADDRESS

**Taming of Uncertainty**

**Dr. C. R. Rao, F.R.S.**

*National Professor, India*

*and*

*Eberly Professor of Statistics  
Pennsylvania State University, USA*



**29th December 1989**

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Mr. Chairman, Director, Graduating Students, Guests and Colleagues :

IT IS CUSTOMARY for the convocation speaker to congratulate the recipients of degrees and diplomas, tender some advice and wish them a bright future. What should the speaker say when he himself is the recipient of a degree ? Perhaps, I have to convince myself that because of my advanced age, I have to advise myself as others may not like to, wish myself a bright future as others may not see any, and congratulate myself for the special honour not ordinarily bestowed. Any how, I feel proud, and I would like you also to feel proud, because the degrees of the ISI, the famous acronym for the Indian Statistical Institute, are not ordinary degrees. They are something special. The ISI stamp on the certificate, we may wish it to be on the forehead, is an assurance of the quality of the product. Statistical expertise is aptly described as a national resource, and as such you are in great demand and you have a privileged role to play in using this resource to improve the quality of life of individuals in our country.

The award of an honorary D.Sc. by the ISI which has been my alma mater as well as my place of work for over forty years gives me a feeling of nostalgia. I remember the productive daily hours of work spent with my colleagues and in discussing with Professor P. C. Mahalanobis, addressed always with reverence as the Professor. I remember the impact made on the research scholars of the Institute by the visiting luminaries like R. A. Fisher, A. N. Kolmogorov, Norbert Wiener, J. B. S. Haldane, John Galbraith and P. M. S. Blackett. I remember one professor asking another in the faculty tea room : What new theorem have you proved today ? I remember the Institute as a meeting place of scholars from all over the world and a melting pot of diverse ideas. I remember the bright young research scholars involved in lively discussions both in the Institute while at work and in the residential area while walking round the pond, which we used to call *pondering*. I was extremely happy working in the Institute under such invigorating environment. I would like to thank the ISI for the honour they have done me, an honour which will sustain me in further continuing my academic pursuits. I would also like to take this opportunity to thank my numerous colleagues who worked with me and who helped me in building up the Institute as a unique center of research, training and consultation in statistics.

Earlier in my speech I have referred to statistical expertise as a national resource. Perhaps I should elaborate on this theme to emphasize the need to explore and exploit this resource for the benefit of mankind.

We live in a world of uncertainty. In our daily life, we take decisions under uncertainty, whether it is crossing a road in chaotic traffic, choosing a career, marrying, investing money or dealing with other individuals. At a different level of uncertainty, the government takes policy decisions to meet the short and long range needs of the society and political decisions to safeguard country's interests against internal dissensions and external aggression. The natural scientist builds theories to explain observed phenomena and predict future events recognizing the haphazard behaviour of the fundamental particles of nature. The social scientist tries to formulate empirical laws frustrated by the uncertainty of human behaviour, the most uncertain of all uncertainties.

Uncertainty has been the greatest challenge to mankind from times immemorial. Can we avoid things which we will not do if we knew precisely what is going to happen? Since the future is unpredictable however much information we have, there may not be any system of correct decision making. An analysis by psychologists of human behaviour in decision making has shown that we know more than what we do and a greater degree of uncertainty is believed than we actually possess. We often wonder after knowing the consequences of a particular decision made as to why we did not choose other alternatives which could have led to a better success.

Can we choose between alternative decisions in an objective way? To the human mind tuned to deductive logic of arguing from given premises to correct propositions, the problem of inferring from incomplete premises to uncertain conclusions appeared to have no rational solution. Uncertain situations, and possibly wrong decisions have led mankind to depend on pseudosciences like astrology for answers, seek the advice of sooth sayers or become victims of superstition or witchcraft. A new logical approach was needed to deal with uncertainty.

The breakthrough came only in the beginning of the present century with the new concept of quantifying uncertainty based on information, which provided a practical solution to decision making. If we have to take decisions under uncertainty about the state of a system we are dealing with, mistakes cannot be avoided. If mistakes can not be avoided, we may be able to find out, using the available information, how often and what kind of mistakes

we make by adopting a certain decision making process. Such knowledge would enable us to evaluate alternative decision making processes in terms of benefits or loss and choose an optimum procedure, i.e., the one which gives the least loss. Thus the key to the problem lay in quantification or modelling of uncertainty in a pragmatic way ; how often do we succeed by following a specified rule under different states of a system.

How do we model uncertainty ? Uncertainty arises due to lack of information and intuitively speaking, the more information we have, the less is uncertainty. These ideas have been used to express uncertainty as a function of information, which constitutes the subject matter of statistics as a science different from statistics as just information or data. Although there are some controversies about the exact form in which uncertainty can be expressed as a numerical function of information, its use as a tool for decision making has ushered in the era of *information* as the key ingredient for progress. Now-a-days, much emphasis is given to the development of technology for gathering, storing, retrieval and transmission of information on a massive scale.

New questions arise. What information should we collect and how should we process the data to yield the parameters for decision making in a given situation ? What is the cost of information to reduce uncertainty to a desired level ? These are the questions which need statistical expertise to answer. This is where you, the graduates of the ISI, come in.

Information is, indeed, a commodity which has a price. With more information we have less uncertainty, so the cost of reducing uncertainty depends on the information we can buy. We may never be able to reduce uncertainty to the zero level by increasing information and the law of diminishing returns may set a limit to the amount of information we can acquire.

The advanced countries are advancing faster than the less advanced because of heavy investment they are able to make in acquiring information. This is bound to increase the disparities in wealth between countries. It is said that in the USA, about 40 to 50 per cent of the employees in public and private sectors are really engaged in information gathering and information analysing activities. This suggests that in an economy, particularly in an advanced economy, information gathering is recognised to be a major part of the economic activities of the country.

I do not know what part of our economic activity is devoted to acquisition of information. Perhaps it is negligible. It is not enough to use the existing or available information in an optimum way. I hope we are at least doing this. But this is not an optimal solution. We need to consider information itself as a commodity to be produced, the utilization of which in turn would lead to a maximum rate of return on investment.

The prosperity of mankind depended in the past on agricultural and later on industrial revolution. But these have not taken us far enough. Our inability to foresee the future and account for uncertainties in decision making stood in the way of progress. With the quantification of uncertainty we have developed forecasting techniques helpful in formulating socio-economic developmental plans. Thus the greatest resource which can bring prosperity to a country is not so much, "capital and raw material" but the "technology of using information for right guessing". We may call this the "Futurological Revolution".

In conclusion, I would like to leave the following thoughts with you.

Quantification or modelling of uncertainty based on available information is one of the triumphs of the present century. It was realized that although the knowledge created by generalizing from the particular is of an uncertain nature, it becomes certain knowledge if we can quantify the amount of uncertainty in it. The new paradigm is the logical equation :

$$\boxed{\text{Uncertain knowledge}} + \boxed{\text{Amount of uncertainty in it}} = \boxed{\text{Certain knowledge}}$$

This is not philosophy. This is a new way of thinking symbolising the practical wisdom in utilizing uncertain knowledge. It has helped the scientist in summarising the results of an experiment in a logical way of presenting the alternatives hypotheses with their probabilities and in suggesting promising lines of new investigations. It has led to optimum decision making at individual and institutional levels ensuring maximum possible benefit to society.

The more information we have, the less is uncertainty and consequently the less is the loss in decision making. Information has a cost, but any investment on it will yield rich dividends.

Decision making under uncertainty is the subject matter of statistics. The technical problems involved in this process are not always simple, and new methodology has to be constantly developed to refine earlier methods and to meet the demands of new situations. The need for statistical expertise is bound to grow, and so will be the need for statisticians.

Statistics touches every one and in all walks of life. Public understanding of statistics is far more important than any other area of knowledge. It is important to the government in making policy decisions, to the businessman in maximising the rate of return on investments, to the professionals in medicine, economics and many other areas of science in taking wise decisions in routine work as well as in research and finally to the layman in his or her day-to-day activities at home and at work. The benefits to the society if each individual develops the ability to read and write are well known. The benefits are far greater if each individual is statistically numerate, i.e., has some understanding of the uncertainties of nature and human behaviour and acquires the skill in using information for decision making. Every citizen must know, through statistical knowledge, how to protect himself and his family against infection, guard himself against propaganda by politicians, and unscrupulous advertisements by businessmen, shed superstition which is worse than disease, take advantage of weather forecasts, understand disasters like the Bhopal gas leak and scores of other things affecting his life on which he has no control. H. G. Wells had foreseen this when he said :

“Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write.”

My advice to any benevolent government interested in the welfare of the people would be :

Give them not subsidized bread. Give them information so that they can earn all their wants of life.

In his book on *Social Functions of Science*, Bernal wrote in 1939, “The work of the scientists has revolutionalised the modern world, but this happened not because but rather in spite of the character of the scientists themselves”. The message of Bernal’s statement is that the scientists must improve their contact with the public and learn how to communicate science to the non-scientists. The Indian Statistical Institute, with its diversified interests and activities bound by the common thread of statistics is in an ideal position to propagate statistical thinking among the public, the government and the

scientists in other disciplines. There is also a need to introduce statistics as a subject of study in high schools, so that the students become familiar with the concepts of variability, risk and probabilities of events. Our educational system seems to be more geared to cautioning students against risk symbolized by statements like "Do not count the chickens before they are hatched" rather than preparing them to live in an uncertain world and face situations on the cutting edge of modern life.

In the past, the economy of a country depended on how well it was preparing for war. We are witnessing today a transformation from threats and confrontation to conciliation and negotiation. A country's biggest problem of the coming decades is not the challenge of war but of peace. The battle ground of the future is going to be economic and social welfare where we have to fight hunger and deprivation afflicting the society. We do not seem to be fully prepared for the attack. Our success will depend on acquiring and processing the information needed for optimum decision making by which the available resources, both in men and material, are put to maximum use for improving the quality of life of individuals. This has to be done in such a way that the progress is equitable and sustainable, with particular care to see that no irreversable damage is done to the biosphere. In achieving this revolution, statistics would be the key technology, a technology for shaping a new world through peace.

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