

INDIAN STATISTICAL INSTITUTE

FIFTYNINTH ANNUAL REPORT

April 1990—March 1991



203 BARRACKPORE TRUNK ROAD
CALCUTTA-700 035

INDIAN STATISTICAL INSTITUTE

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0. INTRODUCTION

Research in the theory and applications of the new discipline of statistics began in India in the twenties at the pioneering initiative of the late Professor P. C. Mahalanobis. During this period a small group of young scientists collected around him, which later came to be known as the Statistical Laboratory. This group developed into the Indian Statistical Institute in 1933 in the form of a learned society registered under the Societies Registration Act.

As the Institute expanded its teaching, research and project activities and earned national and international recognition, in 1959 the Parliament of India enacted the Indian Statistical Institute Act, declaring the Institute to be an Institution of National Importance and empowering it to award degrees and diplomas. The already existing teaching programmes were now consolidated and expanded, and courses for the degrees of Bachelor of Statistics (B.Stat. Hons.), Master of Statistics (M.Stat.) and for diplomas in several applied fields of statistics were initiated. The award of the Ph.D. degree was undertaken and courses and guidance for this purpose developed. At a later stage, M.Tech. programmes were started in Computer Science and in Quality, Reliability and Operations Research.

The recognition by Parliament gave greater encouragement to research activities not only in statistics and mathematics, but also in various areas of the natural and social sciences without whose live contact, it was believed, the methodology of statistics could not grow. One of the primary objectives of the Institute is to emphasise the importance of statistics in relation to other disciplines. The research activities of the Institute are, therefore, of multi-disciplinary nature. The Institute therefore does not only maintain research groups in statistics and mathematics, but also in the social, biological, physical and earth sciences.

The Institute has its headquarters at Calcutta and two other centres at Delhi and Bangalore. It also has a network of service units in Statistical Quality control covering many major cities of India.

The Institute has, over the years, had the distinction of having on its rolls and as collaborators of Professor Mahalanobis, very eminent scientists, among whom may be mentioned the late Professor J.B.S. Haldane, F.R.S., the late Professor S. N. Roy, the late Professor R. C. Bose and Professor C. R. Rao F.R.S.

During the year under review the Institute organized several national and international conferences, workshops and summer and winter schools in a variety of subjects. Special mention may be made of a Workshop on Linear Models and Design of Experiments (at Calcutta), a Winter School on Algorithms and Computational Complexity (at Calcutta), an International Workshop in Quantum Probability and Applications (at Delhi, jointly with NBHM), a Conference on Recent Developments in Probability and Statistics in memory of Professor C. G. Khatri (at Delhi, jointly with Dept. of Statistics, Delhi University), an International Conference on Game Theory and Economic Applications (at Delhi), an Instructional Conference on Operator

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Algebra (at Bangalore, supported by NBHM), a Seminar on Problems of Large Scale Sample Surveys in India (at Calcutta), an International Workshop on Applications of Statistical Methods in Theoretical Physics and Fluid Mechanics (at Calcutta), a Symposium on Central and Genetic Diversity in Indian Population (at Bangalore, jointly with IISc, Bangalore), and the Second Summer Course in Quantitative Economics (at Bangalore). In addition to the above, the different Units of the SQC & OR Division and DRTC, Bangalore Centre, organized a number of workshops, Symposia etc. during the year.

The Institute also organized a UGC-sponsored training course in statistics for university and college teachers.

Many faculty members from the Division of Theoretical Statistics and Mathematics and Applied Statistics, Surveys and Computing participated in the Statistics Section of the Indian Science Congress in which Professor J. K. Ghosh was the President and Professor B. K. Sinha was the Recorder. Dr. Debashish Sengupta of ISI won an Young Scientist Award at the Science Congress. Also, Professor K. R. Parthasarathy was elected President of the Statistics Section for the next year.

The two-year M.Tech. programme in Quality, Reliability and Operations Research, started during 1989-90 at Calcutta, made satisfactory progress. The SQC & OR Division won another laurel when Shri N.T.V. Ranga Rao of the SQC & OR Unit at Hyderabad got an international award and a cash prize from Japan for his essay on "Improving quality of work life through productivity in small industry".

The Institute's regular courses went on well. For the academic session 1990-91, a total of 8,844 candidates applied for admission to the various degree and diploma courses, and they were called for written selection tests which were conducted at 21 centres distributed all over the country. A total of 5,172 candidates appeared for these written tests, and subsequently, a total of 640 candidates were called for interview. Finally, 315 candidates were offered admission to various courses like B.Stat. (Honours), M.Stat. (S-stream and M-stream), M.Tech. (Computer Science) and M.Tech. (Quality, Reliability and OR), besides Ph.D. programmes in different fields.

The Institute operates the International Statistical Education Centre (ISEC), which was established in 1950, jointly with the International Statistical Institute, under the auspices of the UNESCO and the Govt. of India. During the year 1990-91, this Centre conducted the 10-month Regular Course of the 44th Term with 26 participants from 17 countries in South and South-East Asia, the Middle East, the Far East and Commonwealth Africa. The Govt. of India awarded fellowships to 24 of these trainees under the Technical Co-operation Scheme of the Colombo Plan, under the Special Commonwealth African Assistance Plan (SCAAP), under Indian Technical and Economic Co-operation (ITEC) programme and under Aid to Sri Lanka Scheme. The remaining two were from the Indian Air Force and were supported by their employers. Twentyfive of the trainees completed the Regular Course and received the Statistical Training Diploma.

In addition to the above, ISEC organized a Special Course in Advanced Data Processing for one trainee of the previous Term.

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The printing and publication of Sankhyā-Series A and B, made satisfactory progress and work on Vols 62 and 63 were nearly completed.

The Institute continued its activities in fundamental as well as applied research, much of which is interdisciplinary. One of the highlights of the research activities of the Division of Theoretical Statistics and Mathematics was some important work done by Dr. V. S. Sunder of the Bangalore Centre, who made significant contributions to one of the frontier areas of mathematics and physics where the theory of knots, Von Neuman algebras, quantum mechanics and statistical mechanics come together. Sunder worked on the problem—initiated by Jones, one of the Fields Medallists of 1990—of which positive real numbers could arise as the 'dimension of an irreducible finite extension of the hyperfinite factor'. He identified certain mathematical structures called hypergroups, which contain groups and unitary duals of compact groups as special cases, constructed several non-trivial examples of such hypergroups and used them to show that several new numbers could arise as possible values of the dimension of an extension as above : examples of numbers so realized by him are ϕ^2, ϕ^4 (where ϕ is the golden ratio) and more generally,

$$(1/2)(N + \sqrt{N^2 + 4K})^2, \text{ where } K = 1 \text{ or } 2, N \text{ any positive integer.}$$

The Institute's scientists worked on a variety of multi-disciplinary projects taken up at the request of different agencies.

In a project sponsored by the Reserve Bank of India, statisticians and economists of ISI developed the basic concepts relating to the demand for currency, and one model and two methods based on it for forecasting the aggregate demand for currency as well as the demand for different denominations of currency in the country. It may be mentioned that while standard regression techniques fail dramatically for forecasting demand for particular currencies, the methods developed by the ISI team seem to work well. A report on the project was submitted to the RBI.

In another project, funded by the ONGC, statisticians and economists of ISI used deterministic and stochastic methods for relating exploratory and other costs to magnitude of discovery of hydrocarbon for various basins in India. A report on this, containing an evaluation of various strategies and projections for future scenarios, was submitted during the year under review, but many challenging scientific questions remain to be settled.

A number of projects sponsored by the ICSSR, the British Overseas Development Agency (ODA) and the Rockefeller Foundation, were concerned with various agricultural, socio-economic and ecological aspects of the rainfed and irrigated farmlands of West Bengal, Bihar and Orissa.

The project on "Differential Impact of Modern Rice Technology on favourable and unfavourable environments", sponsored by the Rockefeller Foundation, made considerable progress. The main aim of this project is to examine the determinants of the adoption of modern rice technology in West Bengal and also the impact of such adoption on the economic well-being of the people. During the year 1990-91, a report on the Benchmark Survey of cultivator households was submitted to the Foundation, and the field work for the Intensive Survey of households was completed.

Satisfactory progress was also made on the project funded by ODA, UK, where ISI scientists drawn from Social Sciences, Biological Sciences and Applied Statistics

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Divisions of the Institute collaborated with the Hindusthan Fertiliser Corporation for working out risk averse strategies for agriculture in rain-fed villages of West Bengal, Bihar and Orissa.

At the instance of the Department of Statistics, Govt of India, a team of economists of ISI embarked on a survey-based project in an attempt to evolve simple criteria for identifying the rural poor.

Institute's experts continued to be associated with the National Sample Survey Organization (NSSO) in many ways. Some of them collaborated with officials of NSSO in analyzing NSSO data collected through a Pilot Survey on household income, consumption and saving. The first report on the income data was submitted during the year. Others developed a software for editing survey data and this could be of immense help to the NSSO.

The Leaf Protein Unit of the Institute completed the first phase of the project on production and adoption of leaf protein at the village level, sponsored by the Dept. of Science & Technology.

The Nodal Centre for Knowledge Based Computing System (NCKBCS) Technology and Fifth Generation Computer System Development Project, sponsored by DOE/UNDP, was working well under the leadership of Professor D. Dutta Majumdar. It began an important joint project with SAIL during 1990-91. Scientists in the Nodal Centre and in the Electronics and Communication Sciences Unit continued their important work on pattern recognition, image analysis and speech recognition, for which the Institute is well-known. Dr. Sankar Pal worked on fuzzy models for pattern recognition and on the implementation of fuzzy set theoretic methodologies for the management of uncertainty in space station autonomous operations. Mention may be made in this connection of the work of Dr. B. P. Sinha of the Electronics Unit, who was able to obtain rigorously a lower bound to the worst case complexity for Bottom-Up-Heapsort, settling a conjecture made a few years ago. Also, Sm. Tandra Rao developed a Bengali word-processor in connection with a computer-based statistical and linguistic study of Tagore's works.

The Institute celebrated during the year the birth centenary of Sir Ronald Fisher, a long time friend, philosopher and guide of the Institute, by holding a one-day seminar and arranging a special lecture at the Science Congress. Professor C. R. Rao and others spoke at the seminar and elucidated Fisher's influence on the statistical world, in general and the Institute, in particular. Preparations were also started for celebrating the birth centenary of Professor P. C. Mahalanobis, the founder of ISI, in 1993, and also that of Professor J. B. S. Haldane, who worked in the Institute for several years, in 1992.

On the administrative side, negotiations were continued between the Government and the Institute on revised pay-scales for administrative and supporting technical staff belonging to (non-faculty) A, B, C and D categories. The Government removed the constraints on direct recruitment and promotions to these categories towards the end of 1990-91, thereby facilitating the normal functioning of the Institute.

After long negotiations, Govt. of India finally agreed to allow the take over of Statistical Publishing Society (SPS) by the Institute, and took necessary steps for effecting the take-over, expected to be finalized during 1991-92.

Part I Teaching, Training, Research, Projects and Publication

1. TEACHING AND TRAINING

Degree and Training Courses

A brief account of teaching and training activities during the period from April 1990 to March 1991 is given below :

During the academic session 1990-91, 8,844 candidates applied for admission and were called for written selection tests for the various courses offered by the Institute, viz., B.Stat. (Hons.), M. Stat. (M-stream and S-stream), M.Tech. in Computer Sciences, M.Tech. in Quality, Reliability and Operations Research, Two-year Part-time Post-Graduate Diploma in SQC and OR (Bombay and Madras), Research Fellowships in Statistics, Mathematics, Economics, Computer Science, Physics, Fluid Mechanics, Anthropology and Geology, One Year Part-time Course in Statistical Methods and Applications and the course on Operation and Programming of Automatic Data Processing Equipment. Admission tests were conducted at 21 different centres all over the country. A total of 5,172 candidates finally appeared for admission tests and a total of 640 candidates who qualified in the written tests were called for interview. Based on the performance in the written tests and the interview, 315 candidates were offered admission to various courses during the academic session under review. (July 1990-June, 1991).

There were five foreign students who applied for admission to our courses. Admission tests conducted through the Indian High Commissions in Colombo and Dhaka.

The annual examinations for all the regular courses were held in May/June 1990. The 1990-91 academic session commenced on 9 July 1990.

Eleven trainees in Engineering and Technology from various Universities (Jadavpur, Banaras Hindu University, Aligarh Muslim University) received a six-week practical training in the Electronics and Communication Sciences Unit and the Electronics Unit.

One hundred and four candidates received their degrees and diplomas at the Twenty-fifth Annual Convocation of the Indian Statistical Institute held on 23 February 1991 and eighty-two candidates who passed the various regular courses of varying duration (one-year or less) received the certificates during the year. Eleven research fellows were awarded Ph.D. degree of the Indian Statistical Institute.

The number of candidates admitted to the different degree, diploma and training courses during 1989-90 and 1990-91 and the results of the examinations held during the period are given below :

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**NUMBER OF STUDENTS ADMITTED AND PASSED IN DIFFERENT COURSES
APRIL 1990—MARCH 1991**

Courses	Number of students			
	enrolled* in 1989-90	as on March 1990	enrolled* in 1990-91	passed in annual examina- tion in 1990
	(1)	(2)	(3)	(4)
<i>Degree :</i>				
1. Bachelor of Statistics with Honours (B. Stat. (Hons.))				
1st year	18	18	24	18
2nd year	10	10	18	10
3rd year	21	21	10	21
2. Master of Statistics (M.Stat.)				
1st year (M stream)	8	8	9	4
1st year (S stream)	30	30	20	24
2nd year	25	25	23	24
3. M.Tech. in Computer Science				
1st year	20	20	28	14
2nd year	14	14	14	14
4. M.Tech. in Quality, Reliability and Operations Research				
1st year	21	21	23	16
2nd year	—	15	15	16
				course started from 1989-90
<i>Diploma/Certificate/Association :</i>				
5. Statistical Quality Control and Operations Research (1-year)		course discontinued		10
6. Course on Operation and Programming of Automatic Data Processing Equipment :				
1st year	27	27	18	22
2nd year	5	5	22	4
7. Part-time Certificate/Diploma in Statistical Quality Control and Operations Research (Bombay and Madras)				
Bombay—1st year	1	1	7	1
2nd year	2	2	—	1
Madras—1st year	5	5	10	8
2nd year	2	4	8	4
8. Association in Documentation and Information Science				
1st year	8	8	8	7
2nd year	5	7	8	7
9. Part-time course in Statistical Methods and Applications				
(i) Calcutta	65	35	65	19
(ii) Delhi	15	15	18	2
(iii) Hyderabad	40	23	27	course started from 1988-90
10. Six-month Part-time Course in Statistical Quality Control :				
Bangalore Jan.-June	—	—	8	NA
July-Dec.	13	NA	10	9
Hyderabad Jan.-June	—	—	25	NA
July-Dec.	28	NA	23	5
11. Intensive Course on Programming and Applications				
1st year	17	17	17	16
12. Junior Certificate Course in Statistics (Jointly with C.S.D.)				
Fellowship :	14	NA	11	11
13. Junior and Senior Research Fellows, Visiting Fellows in different disciplines				
1st year	80	80	107	NA
14. SDP fellows	8	8	18	NA
Grand Total	458	418	587	273

*Including those admitted in the first year of the course.
NA = Not applicable

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International Statistical Education Centre (ISEC), Calcutta

A brief report on activities of the International Statistical Education Centre during the year 1990-91 follows.

It may be recalled that the Centre was opened in 1960 and is operated jointly by the International Statistical Institute and the Indian Statistical Institute under the auspices of the UNESCO and the Government of India. The Centre functions under a joint Board of Directors. The Directors represent International Statistical Institute, Indian Statistical Institute and the Govt. Of India. Professor P. G. Mahalanobis was the Chairman of the Board of Directors since its inception in 1960 until his death in 1972. Since then National Professor C. R. Rao, F.R.S., has been the Chairman of the Board.

The Centre provides training in Theoretical and Applied Statistics at various levels to selected participants from the countries in the Middle-East, South and South-East Asia, the Far East and the Commonwealth countries in Africa, sponsored by respective Governments. The major training programme of the Centre is a 10-month Regular Course. In addition, Special Courses of varying duration are also organised. Facilities exist for research work and advanced study by senior statisticians from abroad. Since inception, the Centre has provided training to 1185 trainees from 56 countries.

One trainee of the 43rd Term attended and completed a Special Course of two months duration in Advanced Data Processing.

During 1990-91, a total of 46 candidates from 21 different countries were nominated by respective Governments for admission to the 44th term of the Regular Course of this Centre. Of these 46 candidates, 29 were offered admission and 26 participants from 17 countries actually joined. Twentyfour trainees were supported by fellowships awarded by the Government of India under the Technical Cooperation Scheme of the Colombo Plan, under the Special Commonwealth African Assistance Plan, under Indian Technical and Economic Cooperation Programme and under Aid to Sri Lanka Scheme. The remaining 2 were from the Indian Air Force and were supported by their employers.

Teachers of Calcutta, Bangalore and Delhi Centres of the Indian Statistical Institute and Officers of the Government of India participated in teaching the Regular Course during the year. Three trainees went to the Bangalore Centre of ISI to undergo specialization in SQC and OR and 12 trainees went to the Delhi Centre to undergo one part of the specialization training in Economic Planning.

Of the 26 Regular Course trainees, one had to discontinue the Course under unforeseen circumstances. The remaining 25 trainees received the Statistical Training Diploma at the end of the course.

During the term Professor J.K. Ghosh, Director, Indian Statistical Institute who is one of the members of the Board of Directors for ISEC, constituted a Review

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Committee to critically examine the syllabus and other aspects of the Regular Course and suggest improvements of this Course in the perspective of changing needs and backgrounds of the participants from different countries.

Professional Examination in Statistics

During the period under report, examinations for the Statistical Assistantship Certificate, Junior Diploma in Statistics and Senior Diploma in Statistics were held at Bangalore, Bombay, Calcutta, Delhi, Hyderabad, Lucknow and Madras centres for the June 1990 and the November 1990 terms.

The total number of candidates who registered and appeared in these examinations and their results for June 1990 and November 1990 terms are shown below.

Examinations	Number of candidates					
	registered		appeared		passed*	
	June 1990	November 1990	June 1990	November 1990	June 1990	November 1990
1. Statistical Assistantship Certificate	7	10	6	6	2	3
2. Junior Diploma in Statistics	50	34	17	22	10	13
3. Senior Diploma in Statistics (New)	3	5	2	2	2	—
4. Senior Diploma in Statistics (Old)	1	2	1	—	—	—

*Passed in one or more papers only, but not necessarily completed the examination.

The total number of candidates who have so far qualified for the award of the Certificates and Diplomas in the Professional Examinations in Statistics including the results of the November 1990 term are 462 and 256, respectively.

2. RESEARCH WORK

The research activities of the Institute are grouped in the following Divisions : Theoretical Statistics and Mathematics ; Applied Statistics, Surveys and Computing ; Physical and Earth Sciences ; Biological Sciences ; Social Sciences ; Statistical Quality Control and Operations Research ; and Library, Documentation and Information Sciences. In addition, the Computer and Statistical Service Centre (CSSC) has the responsibilities of management of in-house computer system of the Institute and of providing computing and Statistical Services to scientific workers.

A brief account of the progress of research in different Divisions and Units of the Institute during the year under review is given below :

Theoretical Statistics and Mathematics

The Division of Theoretical Statistics and Mathematics has Units at Calcutta, Delhi and Bangalore Centres, besides one Unit at Hyderabad. The Division is bas-

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ally engaged in research in different areas in theoretical statistics, probability theory and mathematics, besides providing theoretical support for a number of applied problems that arise in different projects undertaken by ISI and other institutions. One major responsibility of this Division is to provide instruction in theoretical statistics, probability and mathematics for the B.Stat. (Hons.), M.Stat., M.Tech. (Computer Science), M.Tech. (Quality, Reliability and OR) and various short-term training programmes of the Institute. The Division also conducts advanced courses in mathematics, probability and statistics for the Research Fellows. A strong feature of the Division is to organise Summer/Winter Schools and Workshops in a variety of advanced and current topics in statistics, probability and mathematics. Details are given below. Besides, colloquium talks and seminar talks by faculty members and visitors are organised regularly.

During the period 1990-91, the members of this Division were engaged in research in the following areas :

(a) *Theoretical Statistics* : Asymptotic theory in statistics, nonlinear regression, Bayesian statistical methods, inference in stochastic processes, theory of estimation, sequential analysis, ranking and selection, multivariate analysis, analysis of dependence, directional data analysis, nonparametric methods, optimal designs, survey sampling, reliability theory, competing risk theory, linear models.

(b) *Applied Statistics* : Statistical methods for geological data, Statistical analysis of social networks, statistical models for oil exploration, statistical quality control, and applications of statistics in physics.

(c) *Probability and Stochastic Processes* : Large deviations, limit theorems, characterizations of distributions, probability inequalities, characteristic functions, stochastic integrals, martingale theory, Markov processes, diffusion processes, percolation theory, stochastic differential equations, stable laws, quantum stochastic processes, finitely additive measures.

(d) *Mathematics* : Geometry of Banach spaces, general topology, algebraic topology, differential topology, descriptive set theory, automata theory, theoretical computer science, harmonic analysis, ergodic theory, theory of operators and spectral theory, linear algebra, generalized inverses, perturbation of eigenvalues, game theory, graph theory and combinatorics.

During 1990-91, 73 papers were published by members of this Division in leading international and national journals, and many other papers have been accepted for publication. Three books have been authored by the members of this Division. Three international conferences and four Winter/Summer Schools and Workshop have been organised by this Division in 1990-91. During this period, about 45 distinguished scholars visited the Division and presented seminars besides collaborating with the faculty.

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This Division also organized UGC Refresher Training Course in Statistics for College/University teachers.

Details of the research activities of the Units of this Division at different Centres are given below :

Details of Research activities :

1. *Division of Theoretical Statistics and Mathematics (Calcutta Centre)*

(a) *Statistics and Probability* : asymptotic minimax selection procedure a multivariate multinomial distribution ; two and multi-stage selection procedure for Weibul distribution, search for Bayes optimal Bernoulli sequential sampling plans ; least favourable distributions and asymptotic efficiency at multivariate rank procedures ; efficiency of prediction in future sample with correlate observing characterisation of distribution of r.v.'s whose sum of sequences is chi-square ; non-parametric estimates of regression quantities and their local Bahadur representation global nonparametric estimation of conditional quantile functions and their derivatives multivariate location estimation ; optimal design and reference based on likelihood on nonlinear experiments ; regression trees and function estimation ; on the distribution at sequences and coentropy ; sharper speed of convergence to normality for some independent processes ; speed of convergence of LSE in autoregressive models ; Cauchy equation on discrete domain and some characterizations analysis of process control of proportion wastage ; Cesaro uniform integrability, The seen and 40 convergence ; higher order asymptotics for the LR, Rao's and Wald's tests ; characterization of priors under which Bayesian and frequentist Bartlett corrections are equivalent in the multiparameter case ; reliability of growth models ; efficient estimation with many nuisance parameters, asymptotic distribution of generalized M -estimates characterization of stopping times through the distribution of sequential CR statistics ; confidence ; coefficient in Stein's two-stage procedure ; Linnik's unlinking proportion ; characterization of uniform distributions through order statistics ; maximum likelihood characterization of Von mises-Fisher matrix distribution ; a definition of circular sample median ; Bahadur-type representation of circular median ; shrinkage estimates ; asymptotics of regression estimators in survey sampling ; asymptotics of empirical processes in sample surveys ; estimation of domain parameters using inverse SRSWOR and partial stratification ; use of multivariate uniformization for obtaining near optimum probabilities of selection m varying probability sampling, double sampling for PPS estimation ; use of auxiliary uniformization for estimating the coefficient of variation ; analysis of balanced incomplete multi-response designs ; construction of BIB row-column designs ; construction of robust non-orders of treatments ; ϵ -optimal block designs under heteroscedastic model universal optimality and non-optimality of row-column designs ; optimal varian ; and efficiency-balanced designs for one-way and two-way elimination of heteroscedity.

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(b) *Mathematics* : Covering morphisms between nets ; binary codes related to $O(5, 2)$ generalized quadrangle ; quasi-symmetric designs ; the plane of order five inside Petersen's graph mazer intersection property for families of closed bounded convex sets in Banach spaces ; on a topology of the set of bounded tight contents ; topologies between compact and uniform convergence on function spaces ; on a theorem of Scott and Watson ; coincidence theory for manifolds with boundary ; equivariant cohomology with local coefficients ; generalized automata.

(c) *Applications* : Relative importance of different factors for boundary of reciprocity in social networks ; spin measurement ; analysis for process control of proportion wastage ; suspension models in geology ; several network.

2. *Division of Theoretical Statistics and Mathematics (Delhi Centre)* :

(a) *Statistics and Probability* : approximations of solutions to stochastic differential equations ; infinite-dimensional s.d.e ; realisation of some master processes through Schrodinger and Heisenberg type evolutions in Hilbert space ; parametric and nonparametric statistical inference for stochastic processes ; percolation theory quantum stochastic processes ; functional equation in probability theory ; characteristic functions competing risk theory ; inference under order restrictions ; combination of independent estimators of a common location parameter, goodness of Yaxis-Rao procedure for recovery of mixer-block uniformation ; optimal design theory and robustness of designs.

(b) *Mathematics* : Latin squares, numbered graphs ; Moore-Penrose universe and group universe of a matrix over an integral domain ; perturbation of eigenvalues of matrices via some symmetric ; matrix partial orders based on outer universe, square matrices with Drazian index larger than one ; Q -matrices in linear complementary problem ; theory of operators and spectral theory.

3. *Division of Theoretical Statistics and Mathematics (Bangalore Centre)* :

(a) *Statistics and Probability* : Generalized M-estimates ; asymptotic distribution of an estimate of change point in hazard rate ; strategies admitting non-negative unbiased variance estimators.

Positivity of densities of stable laws ; prediction of stochastic process ; diffusion processes, stable and semi-stable processes and the theory of large deviation.

(b) *Mathematics* : Spherical functions on symmetric spaces ; Riemann surfaces and hyperbolic geometry ; extensions of C^* -algebras, hypargroups and Von-Neumann algebras, generalized universes ; geometric aspects of Banach spaces ; functional analysis.

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Applied Statistics, Surveys and Computing

The Applied Statistics, Surveys and Computing Division consists of two units Computer Science Unit and Biometry Research Unit. Research activities in the Division include both theoretical investigation of methodology and application of existing methods to the solution of real life problems. The research activities of the Division broadly cover the areas of Applied Statistics, Computer Science and biometry. A brief account of these research activities is given below :

Sample Surveys: Properties of generalized regression estimators of finite population means under varying probability-sampling in two phases have been investigated. Lower bounds for asymptotic model-expected design mean-square errors of these estimators have been derived and model-based design which attain these bounds have been characterized under infinite sequence of finite population models. Sarndal et al's (1980) and Kott's (1990) variance estimators for regression predictors have been, respectively, shown to coincide with and approximate, for large samples, to different known variance estimators. Efficiencies of two estimators based on randomized responses from pps samples have been examined.

Optimal variance estimators have been derived under general linear models and their robustness examined. Superiority of Horvitz-Thompson (HT) strategy over some optimal model-dependent strategies, based on balanced samples has been demonstrated. Alternative estimators of variance of HT estimator have been proposed and examined empirically. Comparative study has been made of Deshpande's sampling strategies and their competitors and of Midzuno and Hansen-Hurwitz strategies. Ratio of sample means as an estimator for population ratio of totals has been studied under different sampling schemes like ppswr, ppswor, stratified sampling etc. The effect of sampling from imperfect frame and the use of independent subsamples for improving the estimator have also been studied.

Life Testing and Reliability: Non-parametric methods for estimation of life-time distributions for the components of a parallel system using censored/uncensored data have been developed. Estimation of the theorem of number of bugs in a software system and its reliability after removal of such bugs under general distributions have been investigated. For the shape parameter of a Weibull distribution, efficiencies of alternative estimators have been examined. An efficient estimator for the mean of a two parameter Inverse Gaussian distribution is proposed and examined. Work on the characterization of different life time distributions for comparing two or more brands of products with respect to their average life time is in progress. Similar study on various aging properties and partial ordering of life distributions of different populations is also going on. Nonparametric estimation of component life distributions with observations from a parallel system is under way. Research on inferential procedures in competing risk problems with incomplete cause of death data is also being considered.

Multivariate Analysis : Studies have been carried out on (i) optimal tests for no contamination in non-identifiable mixtures with exponential, curved exponential and non-exponential components, (ii) optimal tests for uniformity against wrapped stable distributions in directional data, (iii) geometric stable distributions and mixtures, and (iv) signal detection and asymptotic inference. An interactive method based on Q-procedure for finding the maximum likelihood estimators of correlation matrix has been proposed and studied. Certain centro-symmetric covariance structures have been characterized as an auto-regressive process and some methods for estimating parameters of such structures have been examined.

Linear Models : Recursive inference in general linear model—with possibly singular dispersion matrix—was studied and its applications to regression diagnostics and optimal designs were given. In this context, a study was made on the mixed effects models also. Detailed study of regression diagnostics is in progress.

Pattern Recognition and Image Processing : Application of neural network for image processing is being studied. Studies on statistical image processing and shape recognition are going on. An efficient algorithm for general system diagnosis has been derived. Studies on efficiencies of imperfect supervision in statistical pattern recognition were carried out.

Genetics and Biomathematics : Use of the EM algorithm in genetics has been studied. Studies on the distribution of the number of premalignant and malignant tumours and their sizes using a two-stage model for carcinogenesis have been carried out.

Computer Science : Some observations have been made on one-dimensional and two-dimensional cellular automata theory. An Expert System Shell has been developed which can work in any general domain-field. A general software package was developed and implemented in the micro-processor for scrutiny and editing of survey data.

Iszyme activity of Indian Major Carp seeds : A problem on the investigation of genetic marker isozymes of Indian Major Carp Seeds including the Cat fish *H. fossilis* was pursued during the year. The genetic mapping of the aforesaid species is lacking and this would be an important contribution to the fisheries science in the Indian context.

Aetiological studies of catabolic diseases : Studies with experimental observations of immunological profiles have revealed a prominent role of malnutrition as one of the causative factors of young insulin dependent diabetics. The possible role of the common medicinal plant *V. rosea* as hypoglycaemic agent is being examined.

Theoretical studies on the onset of diabetes mellitus : The "two pool" theory of insulin secretion has been successfully employed to prepare mathematical models to mimic the oral glucose tolerance. A possible correlation between viscosity and early onset of disease is envisaged.

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Project work :

1. The project funded by Rockefeller Foundation on the "Differential Impact of Modern Rice Technology across Production Environments" is going on. A preliminary report on the Benchmark Survey of Rural Households was submitted during the year. Field work for phase II of the Project the "Intensive Survey of Households" has been completed and the data are being analysed.

2. Analysis of the data collected for the "Fish Farmers Development Agency Project" is going on and the report is under preparation.

3. The National Sample Survey Organization (NSSO), Govt. of India, has generally avoided the collection of data on household income in the belief that data collected would be unreliable. It has, instead laid emphasis on collection of data on household consumer expenditure. There has, however, been constant pressure from different users for collection of data on household income, and in response to this, the NSSO decided to conduct a Pilot Survey on collection of data on household income, consumer expenditure and savings from matched samples of households with a view to examining the reliability of income data collected by different approaches. At the request of the NSSO, the Indian Statistical Institute agreed to process, analyse and report on the data collected through this Pilot Survey. A team of scientific workers of the Institute has been collaborating with some officers of NSSO on this job. The final report on income data collected through Schedule 1.1A (Household Income) was submitted to NSSO authorities during this year.

4. Determination of growth and survivability of three major Indian carps : The first part of this project, with particular emphasis on hatchery, bundh-bred and riverine sources, was sponsored by the Directorate of Fisheries, Government of West Bengal, and this has been completed and the report submitted to the sponsors. On further request from the Government, a continuation of this study has been undertaken to incorporate the effects of pollutants and selective foods on the growth of the carps. The studies on lactate dehydrogenase activities of the carp have also been pursued.

5. Modelling of visco-elastic properties of blood : The structural viscosity of rabbit blood is being estimated under different stresses, viz., physical, radiational and chemical, with the aim of finding out the variation in haemostatic values, proteins and immunological fractions.

6. The medicinal plant *vinca rosea* as hypoglycaemic agent : Preliminary studies on albino rats have revealed an initial breakdown of protein content with a subsequent elevation of urea level by I.P. injection of aqueous extract of the leaves. The possible reasons of this protein degradation along with hypoglycaemia are being investigated.

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7. An investigation on young insulin dependent diabetes mellitus patients within 20-30 years of age. This project deals with the problem of malnutrition related diabetic patients. The aim is to find out the causative factors of this problem. These factors may be genetic or immunologic. The experiments conducted so far reveal that IgG and IgM level is very high in the case of these patients while IgA level lies almost within the normal range. HLA studies are now being conducted.

8. Variations in response to Radiotherapy produced by differences in nutritional status in patients with malignancies of head and neck : This is a new project taken up with aim of finding out (i) where co-nutritional status affects the response to radiotherapy and (ii) to compare the radiotherapeutic responses between mal-nourished and normal nourished patients.

The Computer and Statistical Service Centre (CSSC)

The Computer and Statistical Service Centre (CSSC) manages the central computational facility of the Institute. It houses a VAX-8650 computer system installed in 1989. It supports about 400 users including the students, research scholars and scientific workers of the Institute. There are some external users from other institutions also. NSSO, Government of India, is also using this computational facility. CSSC has started crossing an archive of NSSO data for use by researchers from various agencies.

Statistical and computational consultancy services are also provided by CSSC to its users. The Centre organizes courses for its users on programming languages and software packages available at the Centre. The Centre originally had about 2000 MB of disk space, 16 MB of main memory and 20 terminals. During the year under review, CSSC added another 16 terminals.

The Centre has completed the work of interconnecting the different scientific Units of the Institute with the central VAX system by providing intelligent terminals (PCs) to the Units. The terminal network is working satisfactorily. An E-mail facility has been installed at CSSC and this is being used by scientific workers of Institute and also by its administration.

This year the Centre has updated its operating system software by the recent versions provided by the manufacturer. Other software packages have also been updated. SPSS-Trends has been acquired during the year.

Teaching : The staff members of CSSC have served as faculty in various courses of the Institute and have also guided projects of the students.

Physical and Earth Sciences

The Division comprises the Chemistry Unit, the Electronics Unit, the Electronics and Communication Sciences Unit, the Geological Studies Unit, and the Physics Unit. Faculty members of the Division are engaged in teaching and training, besides research and project work. Researches carried out in these units are described below :

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Chemistry

1. *Distribution, Characterization and reaction of allophanic materials in soils of West Bengal* : Tropical soils developed from acid rocks under high rainfall conditions often contain varying quantities of non-crystalline minerals called allophanes which impart properties of far-reaching consequences to the bulk soil. Systematic investigation of such important constituents in Indian soil is almost absent. Efforts have been directed at identifying, isolating and characterising allophanic materials from West Bengal soils and studying their effect on soil properties.

2. *Adsorption of organic substances on clays and related minerals* : Adsorptive interaction between clays and organic materials is a very important and much researched topic. Investigations on such interaction with mica, feldspar, metamorphic rock and modified talc have been undertaken to fill a void. This is likely to throw light on rock weathering through organic adsorption desorption reaction.

Electronics

A. Digital Systems Research :

1. *Parallel Algorithms and Parallel Architectures* : Parallel algorithms for finding the all-pairs of shortest paths and diameter of a graph, binary multiplication and their mapping on systolic architecture have been proposed. Methodology for testing bilateral bit-level systolic arrays has also been developed. Two new tree-type architectures have been proposed :

- (a) by connecting leaf processors of a simple tree in the form of lattice, and
- (b) by connecting root processors of several trees according to certain rules.

An efficient parallel algorithm for ternary multiplication with its implementation on a systolic architecture has been proposed.

Extension of algorithms and architectures proposed earlier for fault-tolerant binary arithmetic are under study.

2. *Network Topology* : An incrementally extensible network has been proposed. Properties of some dense trivalent graphs as network topologies has been studied. Studies have also been carried out on the quantification of network reliabilities. A stochastic model of fault in the network has been considered and an algorithm has been developed to compute the reliability of the network. Some optimality criteria have been proposed to minimize the diameter of loop networks. Algorithms have also been proposed to find the shortest path between any two nodes of a loop network, in fault-free case as well as under single fault. An algorithm has been proposed to find maximal subcubes in a residual hypercube.

3. *Interconnection networks* : From the analysis of conflict graphs, an optimal graph coloring algorithm has been developed to find out the optimal number of passes for a set of permutations. This has been studied on baseline network and

then generalised for other types of full-access unique path MIN's. It has been found that the set of all possible permutations can be partitioned into a number of equivalent classes. For each class, we define a seed-permutation. The conflict graph of any permutation is isomorphic with that of the seed-permutation belonging to the same equivalent class.

Several self-routing techniques on rearrangeable networks (Benes network) have been studied. Work has been done towards the classification of the permutations according to different self-routable techniques.

4. *VLSI Layout Design-phase II* : Graph-theoretic characterization of inherently nonslicing (INS) floorplans has been explored. An entirely new family of INS floorplans have been discovered. In the placement area, efficient algorithms for optimal linear placement of parallel graphs have been developed.

5. *Systems diagnosis* : New properties of a *t*-diagnosable system have been discovered and reported. Based on these results, an algorithm for diagnosis has been proposed which fares comparably well with respect to existing algorithms.

B. *Theoretical Physics* :

1. Topological aspects of fermions are being investigated and these are being studied in the context of anomaly, fractional statistics, high T_c super-conductivity, superfluidity and Quantum Hall effect. The relationship of Berry phase with these phenomena are being studied. Also, these topological features are being investigated in the context of quantum gravity. Various quantization procedures are being utilised to have the relevance of Berry phase. Topological investigations are being carried on in various statistical systems. Besides, stochastic quantization is being thoroughly investigated in the realm of dissipative systems. Some related fractional problems of quantum mechanics are also being studied.

2. Results of supersymmetric Quantum Mechanics have been used to find exact solutions of the cut off Coulomb potential $V(r) = \frac{-Ze^2}{r+\beta}$ and $V(r) = \frac{a}{r} + pr + p_2r^2 + p_3r^3 + p_4r^4$. In quantum field theory, a finite temperature formula with chemical potential μ has been derived and used to study spontaneous symmetry breaking in curved space-time. In plasma physics, ion-acoustic solitary waves has been studied for a plasma in presence of intense relativistic electron beam which has many useful applications.

3. *Quantum Gravity* : A project has been undertaken (jointly with Professor H.H.V. Broseakowski, Einstein Laboratory of Theoretical Physics, Germany) to study the Einstein-Markwell Theory. The cut-off length arising in Quantum General Relativity implies also a cut-off of the electromagnetic spectrum. It raises new possibilities to quantize different fields without adopting renormalisation procedure. The work is complete only in case of electromagnetic fields but work is going on to

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investigate the effect of fluctuation of gravitational field on other fields. It is an important step towards the understanding of the quantization of gravitational field as well as the measurement process in Quantum Mechanics.

C. Fluid Mechanics

1. Some studies regarding the effect of helicity on turbulent flow have been undertaken. A deductive theory for a homogeneous turbulence possessing helicity has been worked out. A closed set of equations for the velocity-velocity and helicity-helicity correlation functions are obtained. These equations are solved following Kolmogorov's principle. Acceleration correlation is also determined in such a turbulent flow. Development of some models regarding the effects of rotation on the homogeneous turbulent shear flow is in progress.

2. *Blood flow in Cardiovascular System*: Normal blood flow is sometimes disturbed by abnormal and unusual growth formed at any location of cardiovascular system resulting in arterial diseases. It is necessary to study the effect of this abnormal growth on the flow characteristic of blood.

One model has been developed for studying separation of blood flow in a constricted tube. The present investigation is concerned with the study of blood flow through a stenosed artery in the presence of magnetic field.

3. *Scattering problems*: A number of problems on water wave scattering by obstacles of various shapes and related mathematical methods have been studied. The problems considered are mostly concerned with nearly vertical barriers, deformation at bottom etc. The first order corrections to reflection and transmission coefficients were obtained by perturbation technique in each of these cases.

4. *Radiation problems*: Problems on generation of water waves due to small oscillations of a floating or submerged body have been considered, the floating body being in the form of an immersed nearly vertical plate, or a thin submerged or partially immersed two-dimensional thin plate, and the submerged body being in the form of a two-dimensional thin plate.

5. *Wavemaker problems*: Problems on generation of water waves due to a plane vertical wavemaker as well as a cylindrical wavemaker are being studied. The effect of surface tension at the free surface is considered in all these problems. A regularity property of integral transforms has been suitably exploited to calculate the wave amplitude at infinity. Further work in this area is being continued.

6. *Source problems*: Water wave potentials due to sources of various kinds are of immense importance in the theory of water waves. Problems concerning ring sources submerged in water with an inertial surface and a line source in the presence of a nearly vertical cliff have been considered.

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D. *Mathematical Methods*

1. *Integral transforms* : Integral transforms with Legendre functions as kernel are generally known as Mehler Fock transforms. Mehler Fock type integral transforms with associated Legendre functions as kernels with the superscripts as the integration variable in the inverse transform formula, are being examined.

2. *Integral equations* : Integral equations play very important role in tackling any boundary value problem arising in quantum mechanics, mathematical physics and other areas of applied mathematics. Singular integral equations, Fredholm integral equations and Dual integral equations are being studied, some for exact solution, and some for approximate analytical as well as numerical solutions and these are being applied to various problems of water waves.

E. *Operations Research*

1. *Inventory models* : Some deterministic inventory models are being studied under various assumptions about the consumption rate, about the nature of the item (e.g. deteriorating items) etc. The economic order quantity in each of these models is usually obtained by solving certain nonlinear equations. Further work in this area is being pursued.

2. *Queueing models* : Many queueing problems are modelled mathematically on the assumption of Markovian arrival and service processes. A pre-emptive priority queueing model with two classes of customers having different priorities have been considered. The Laplace transform in time and the method of generating functions are used to attack the problem. The steady state results are deduced by using Abel's theorem in Laplace transform.

Some queueing problems can be modelled as boundary value problems almost similar to those arising in continuum mechanics. These boundary value problems are reduced to singular integral equations which are sometimes successfully handled by the function-theoretic method, generally known as the method of Riemann-Hilbert problem. Some research work in this area is being pursued.

Project Work

Externally Funded Projects

1. *Problems in the linearised theory of water waves and related mathematical techniques* : This project is sponsored by the Third World Academy of Sciences, ICTP, Trieste, for a period of one year from October 1989, being administered through the Calcutta Mathematical Society. This is concerned with further mathematical work in the linearised theory of water waves involving problems on scattering of water waves by obstacles of various geometries, asymptotic analysis of unsteady motion in water generated due to various types of disturbances inside the water or on its surface or a boundary.

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2. *Integral transforms, integral equations and applications* : This project is sponsored by the Council of Scientific and Industrial Research, New Delhi, and is being administered through the Calcutta Mathematical Society, since August 1988. This is concerned with the development of integral transforms involving various special functions as kernels and also a study of the various properties of the transforms. It is also concerned with the integral equations (singular, second kind, dual) and their applications to various problems arising in continuum mechanics and other areas of applied mathematics. Already a Mehler Fock type integral transform involving associated Legendre function has been developed. Explicit solutions to a Fredholm integral equation of second kind and to dual integral equations with associated Legendre functions as kernels have been successfully obtained. Further work in these areas is in progress.

Internally funded projects

1. *Development of an efficient data structure to support VLSI layout tools* : A new data structure based on interval trees which efficiently solves many VLSI design problems has been developed. Software tools have been developed to characterize valid slice paths and to develop algorithms for identification of all such paths. Theoretical results characterizing valid slice paths have been obtained. Investigations on channel graph and the cycle breaking problem have been completed.

2. *Development of efficient algorithms for design for testability, test generation and fault simulation in VLSI circuits* : An efficient method of transforming a gate level circuit description of a single output combinational circuit to an equivalent design with DCVS has been formulated. This design also yields circuits with good testability. The proposed method has been successfully implemented in PASCAL on PC AT. Efficient algorithms for generating test vectors for detecting stuck-open and stuck-on faults on the transistors in the logic tree of a DCVS circuit have been developed. New results on design for testability for combinational circuits based on fault behaviour have been explored and reported. Studies on logical redundancy and non-checkpoint target faults have also been made thoroughly. Design for testability in systolic arrays have also been investigated.

Electronics and Communication Sciences

Research

Investigations for the methodology and algorithms development of various problems related to the application area of computer science and communication technology with relevant software/instrumentation backing were carried out during the period under report.

1. *Studies on Pattern Recognition, Pattern Classification and Learning Algorithm* : (i) As a part of man-machine interaction, a computer-based system for recognition of alphanumeric characters using decomposition technique and invol-

ing only local processing has been implemented and tested with a CCD camera. The algorithms developed for the purpose are parallel with fast implementation possibilities and extendable to other script recognition problems.

(ii) Biomedical studies related to the automatic diagnosis of malignant cells from various parts of human body and to find suitable algorithms for the detection of cancerous cells/sections are continued. Extended studies on the effect of thiourea on brain neurosecretory cells and chromosome of the mammalian is under consideration and the chromosomes for these plantmates have successfully been extracted and digitized. Some works on histological section grading and cell classifications, on the basis of image featuring and texture analysis, have been completed.

2. *Development of methodologies for Analysis and Understanding of Image, Shape and Texture* : (i) An exactly recoverable type of 2-tone thinning algorithm for the extraction of 2-tone images have been developed and this could be fruitfully utilized for data compression purpose besides the extraction of structural features. Generalization of parallel mode thinning algorithms was developed and tested with real life data. In another experiment, the data compression of binary contour images as well as extraction of contours from gray images have been completed and the algorithms are in the stage of development.

(ii) Algorithms development for extrema detection and gray level ranking in moving window regarding texture analysis have been completed using statistical, fuzzy and deterministic methods. Current research is concentrated on segmentation and classification of textured images with continuous gradation for textured to non-textured images. This has applications ranging from satellite imagery to microscopic image and biomedical images. In another experiment, from the intensity of multiple images the depth of the physical surfaces, has been continued.

(iii) Pre-processing part of the low cost image processing and analysis of fingerprint data have been completed and a demonstration package of this portion on IBM-PC/AT is ready.

(iv) A library of satellite image processing routines on PC/AT based system was developed and implemented with satellite images using 4th spectral band. This is done by the following steps : (a) enhancement for making linear features to be clearer using additive/multiplicative score—for better segmentation exact statistical distribution of the multiplicative score is to be found out— (b) thinning for producing 1-pixel thick curvilinear pattern from one to four pixel thickness pattern, and (c) inferring from the representation of thinned output in the form of graph.

In another project, linear structures like roads, small rivers etc. are isolated from their gray level images. Directional masks have been used to enhance the linear structures and then certain segmentation techniques used to isolate these structures from the background. Developed algorithms for this purpose can be used in parallel machine for automatic preparation of road maps from the satellite images.

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3. *Signal Processing, Microwave Propagation, Atmospheric Studies with appropriate application* : (i) Detailed investigations of microwave signal propagation in LOS were completed and further extended to beyond-the-horizon mode in studying and characteristic analysis of microwave signal (F.V. signal) transmitted from Khulna, Bangladesh, 160 km away from Calcutta. The design and commissioning of a special type of omni directional Yagi antenna has been completed and the said microwave signal has been recorded during mid-night period. Performance analysis of the received signals and correlational factors of these with the meteorological/climatological condition of the lower atmosphere during that period would be considered later.

(ii) Huge volumes of recorded sound radar data reflected/scattered back from the lower atmosphere (1 km vertical) have been processed for different observations/analysis of lower atmospheric structures. Special features of ABL dynamics like gravity wave perturbations, ground-based and elevated layer inversions were analysed and reported. Atmospheric modelling and detailed investigations on plume characteristic and stability/unstability criteria for the ABL have been continued. Development of an expert system for the detection, recognition and classification of atmospheric structures revealed from solar echogram will be considered.

(iii) Procurement of laser unit and its accessories for setting up of constrained laboratory experiment on aerosol and the size of other suspended particles and their distribution in the atmosphere has been completed. Literature survey and planning and programming for this experiment is continued. Continuation of the experiment is not possible for the not-yet complete laboratory infrastructure.

4. *Speech Analysis and Synthesis, Music Analysis and ASR research* : (i) Acoustic analysis of non-nasal vowels and nasal consonants, uttered individually in Bengali language by 3 male and 3 female informants, which were stored in spectrograms of 350 multi-syllabic words, has been completed. Acoustic phonetic study of non-nasal consonants and diphthongs is going to be started. These studies will meet the requirements of establishing a statistical database of reliable acoustic-phonetic data for computer recognition, speech synthesis and assistance for standardisation of phonetic quality.

(ii) Microprocessor-based text to speech synthesis, especially of Bengali speech sounds, has been completed. Procedure of speech-event concatenation is being used for the generation of Bengali sentences and the phonetic scripts are being typed over the console of PC-AT 386. Intonation patterns are to be introduced for more natural output which will have immense application in industry, as communication aids for blind and dumb people etc.

(iii) Studies related to cues of nasality and their spectral characteristics of song vowels in Hindusthani Shastriya Sangeet have been completed. Work on identification of Indian 'ragas' as well as automatic transcription of music into nota-

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tions is being continued for further development. To detect pitch for extracting the notation of songs sung by human being, software algorithm has been partially developed that attracts future collaborating work to be undertaken by Viswa Bharati University, Santiniketan, on standardisation of the style and other aspects of Rabindrasangeet.

(ii) Phonetic transcription of 20,000 Bengali words have been entered into lexical tree regarding the development of Bengali lexicon for ASR system. A man-machine directed ambiguity driven lexical tree for word hypothesis verification and disambiguation related to ASR is continued with collaboration from Universitat di Torino, Italy, from where the knowledge shell ML-SMART has been acquired but installation is pending because updating of OS, SUN-workstation has yet to be done. An expert system for specific tasks in man-machine interaction like speech mode communication, script, and sketch for interaction and acquiring of suitable knowledge of engineering environment for the purpose is continued. Further development of the knowledge shell by collaborating scientists on their expected visit to ISI may provide a more efficient way of tackling certain existing problems of speech recognition.

3. Research on Computational Geometry, Computer Vision Technology :

(i) As a part of 3-D shape description and matching project, algorithms for normalizing the orientation symmetry identification and size of simple 3-D objects have been developed. Characteristic planes provided from the 3-D object are used to define shape distance having all metric properties and useful in classifying an unknown 3-D shape into 1 of several known shapes. In another scheme, a computer vision algorithm based on the concept of differential geometry has been developed to locate/recognise partially occluded 2- and 3-D rigid objects. For the best possible recognition, a computer vision algorithm is derived using hypothesis generation and verification of features and will be implemented in a prototype robot model. Both the schemes have potential application as computer vision system in industrial environment.

(ii) An efficient algorithm has been developed to implement optimized error of fit for objects by fitting rectangles, ellipses and their 3-D versions. Computational geometric techniques has been applied to isolate boundary points from the sample set of points not necessarily convex. A new fractal geometry based criteria was developed and was applied to the performance evaluation of digital image magnification techniques. The criteria will be applied in natural scene analysis and computer graphics.

(iii) For any computer-based vision system, the ultimate aim of preprocessing technique should be the human visual system (HVS). A model based on HVS response has been proposed for edge extraction and quality enhancement. An automatic thresholding of edge detector was developed and different effects and types of transformation used were studied on the quality of extracted edges. Based on fuzzy measurement, selection of mapping functions used in contrast enhancement have been developed.

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6. *Artificial Intelligence and Expert System methodologies:*

(i) Natural language processing (NLP), a major topic in AI, is concerned with the building of computer models either to achieve an intelligent system capable of human like user interfaces or to gain a better understanding of how humans communicate using natural languages. Creation of large lexicon and some morphological/syntactic level of analysis of Bengali sentences were achieved.

(ii) Based on approximate reasoning, a linguistic recognition system has been formulated and tested with real type data. Afterwards a multivalued recognition system based on fuzzy set theory and approximate reasoning has been designed and found capable of handling various imprecise/uncertain input patterns and provide a natural decision system.

(iii) To mimic human performance in pattern recognition/image processing fields, artificial neural network—a massively parallel interconnection of simple, robust, fault-tolerant processing elements, has been successfully employed. Though human reasoning is inherently fuzzy, it often recognises incomplete and noisy patterns quite efficiently. Fuzzy set theory is capable of efficient modelling of uncertainties. Obviously, fuzzy extension to the multilayer perception model and the self-organising Kohonen's net model have been developed and tested for their applicability to pattern classification problems and found quite satisfactory as compared to Bayesian classifiers.

7. *FGCS activities in New Computer Architecture for Signal Understanding and Intelligent Interfacing* : The National Nodal Centre for Knowledge Based Computing at ISI, Calcutta, is engaged in research and developmental work in the field of Pattern Recognition, Image Processing, Computer Vision and Artificial Intelligence, in connection with the Fifth Generation Computer Systems development (the FGCS/KBCS programme of DoE/UNDP). The main activities of the Centre are :

(i) Application of pattern recognition, image processing, computer vision and expert system techniques in remote sensing and natural resources studies :

(a) Application of Knowledge Based Computer System (KBCS) Approach for Geological Information Extraction. (b) Statistical Learning with Neural Nets for Applications to Remote Sensing Data. (c) Knowledge Based conclusion drawing techniques for Remotely Sensed Images. (d) Modelling of Basins and Development of the theoretical tools for Prospect Evaluation (Oil and Gas Exploration).

(ii) Application of Pattern recognition, image processing, computer vision and artificial intelligence techniques in industrial inspection for relevant Indian Industries : (a) Intelligent Visual Inspection System (IVIS) for Iron and Steel Industry ; (b) development of a P.C.-based Image Processing System for Coal Quality Analysis, and (c) development of a P.C.-based Image Understanding System for Analysis and Interpretation of Ferrograms.

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(iii) Parallel architectures, connectionist models and algorithms for image processing and computer vision : (a) On-line PCB Inspection and Verification ; (b) development of Robot Vision Algorithm for Manipulating Objects in Cluttered Scene ; (c) development of morphological tools for Image understanding ; (d) parallel KBS Application Test Bed ; (e) studies on Connectionist Models for Object Recognition, and (f) Image Processing and 2-D vision.

(iv) Microprocessor-based expert system for mass screening/health care and related public health applications : (a) Development of PC Based System for Automatic Detection and Estimation of Malaria Parasites in Blood-film ; (b) Expert System on ONCOLOGY (CANCER) ; and (c) Development of a Microcomputer Based System for Automatic Determination of Drinking Water Quality in Public Health Application.

Externally Funded Projects

Research work carried out for externally funded projects in collaboration with other institutions is briefly described below :

1. To develop and instal a sound radar (SODAR) at BHU for monitoring the atmospheric dynamics and to relate these parameter to monsoon activities in the northern part of India, the Centre is engaged in a project entitled, "Studies on the Tropical Boundary Layer Meteorology (STBLM)". This national project has been funded by the Department of Science and Technology (DST), New Delhi, as a part of its main programme on 'Monsoon Through Boundary Layer Experiment (MONTBLEX)' which aims at predicting the behavioural pattern of monsoon activities. Three observing centres had been selected at IIT, Kharagpur (eastern India), BHU, Varanasi (northern India) and CAZRI, Pilani (north western India) and have been provided with a variety of facilities for measuring atmospheric parameters. Moreover, a number of institutions and organisations of national importance like ISI, IISc, IITM, IIT's, NPL, IAF and IMD, have been directly involved in this programme.

ECSU has successfully shouldered the dedicated task of installation of a portable sound radar, specially designed, developed and fabricated by the scientists/technical staff of ECSU attached to this project. A portable SODAR was installed at the Geophysics Department of Banarus Hindu University (BHU), Varanasi, in May 1990, and since then it has continuously operated in specified monsoon periods. A technical report containing the details of Sodar design-development-operation is in preparation.

2. The National Centre for Knowledge Based Computing System (KBCS) has been established at ISI, Calcutta, with Professor D. Dutta Majumder as Principal Coordinator-cum-Project Director for Fifth Generation Computer Systems (FGCS) Programme of UNDP and Government of India (DOE). A part of the project on

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"Some Applications of Artificial Intelligence in Developing Expert System" has been successfully continued with the following programmes : (a) Parallel architectures and algorithms for image processing, pattern recognition, and computer vision ; (b) Model studies for high level vision system (HLVS), and the application of HLVS in remote sensing studies, (c) Simulation of lower level vision system (LLVS) for geological applications, algorithms for middle level vision system (MLVS) for geology and natural resources management, (d) Development of algorithms for industrial inspection system with special attention to occluded 2D-3D scene recognition, and (e) Acquisition of state-of-the-art computing resources and the setting up of a well-equipped machine vision laboratory.

3. Defence Grant-in Aid Scheme Confidential Project entitled, 'Systems and Algorithm Development for Pattern Recognition and Shape Analysis for Object of Defence Interest' is being carried out in collaboration with DRDO, Dehra Dun. It involves the identification of objects (of defence interest) from its shape in some direction using principal component analysis and various filtering and transformation techniques.

Teaching and Training

Faculty members of ECSU are also engaged in teaching and training in some of the regular courses in ISI like the M.Stat., M. Tech. (Computer Science) and the newly introduced M. Tech. (Quality, Reliability and Operation Research) programmes, and also in supervision of M. Tech. projects/dissertations besides supervision of PhD work. A number of external undergraduate/post-graduate students of Computer Science, Electronics and Telecommunication, Electrical Engineering and also of Master in Computer Application (MCA) from different universities and IIT's undergo their vocational/semestral training under the supervision of faculty members of this Unit.

Geological Studies

Research was undertaken in the following broad areas during 1990-91 :

Tectono-stratigraphic study of the Delhi Supergroup of central Rajasthan ; Proterozoic tectonics, stratigraphy and sedimentation in the Pranhita-Godavari Valley ; Stratigraphy and Palaeontology of the Gondwana sequence of the Pranhita-Godavari Valley ; Dinosaur and Fish faunas from the Maastrichtian beds of Maharashtra ; Amphibians of the Satpura Gondwana sequence ; Lameta Beds of Jabhalpur ; empirical statistical study of preferred orientation of line in 3-D space-applications in geology (Quantitative Geology).

The most significant findings in these broad areas of research are highlighted below :

Delhi Supergroup : The Delhi Supergroup of central Rajasthan has been described as either geosynclinal or shallow water epihaline. The epihaline model is generally accepted for the north-eastern part of the Delhi belt. The present work suggests that the succession of the fold and fault sets that are developed in the Delhi metasediments around Kharwa can be best interpreted in terms of two broad tectonic events, interspersed by a thermal high.

Proterozoic Geology of the Pranhita-Godavari Valley : (a) The Proterozoic sequence of the Pranhita-Godavari Valley has been classified into (i) carbonate-dominated Pakhal and Penganga Groups and (ii) siliciclast-dominated Sullavai Group. The stratigraphical relationship between the Pakhal and the Sullavai Groups and that between the Penganga and the Sullavai Groups have been established. Also, the Pakhal group of rocks is interpreted to have deposited in shallow marine environments whereas the Sullavai Group of rocks had deposited in continental environments, such as in extensive braid plains and deserts. The Penganga Group of rocks seems to have deposited in deep marine environment.

(b) The Proterozoic Albaka group of rocks, an enigma over a long time, is now interpreted to be a current-dominated shore facies to a storm- and fair-weather wave-dominated shallow marine shelf deposit.

(c) In the course of the laboratory experiment conducted to understand the process(es) leading to the formation of structures similar to the vertically oriented structures that have been located in the Proterozoic rocks of the Pranhita-Godavari Valley, it is found that the vortex did scour out a similar looking cylindrical hole in a semi-consolidated sandy substrate and filled it up with well-sorted coarse grained material. The experiment, therefore, throws light on the 'possible' creation of the scoured holes along with the nature of texture of the fill-in material as observed in the Proterozoic rocks.

Gondwana Stratigraphy and Palaeontology of the Pranhita-Godavari Valley :

(a) Several morphological varieties of the trace fossils that occur in abundance in the Triassic red beds of the Pranhita-Godavari Valley have been recognized. The varieties have been identified to be those of *Skolithos*, *Palaeophycus*, *Taenidium*, escape burrows and 'small stuffed' burrows. The distribution of the trace fossils is facies controlled. (b) Detailed study of the fossil remains of rhynchonellid bryozoans discovered from the red clays of the upper part of the Upper Triassic Marri Formation has led to the erection of two new taxa.

Maestrichtian Fish and Dinosaurs : (a) A paper on lower percid *Eoterranus hislopi* from Indian non-marine Maestrichtian is under preparation. This centropomid fish is of importance in the history of the Mesozoic Acanthopterygians as the only pre-Palaeocene percid. A closely resembling form has been described from the Palaeocene of Saudi Arabia a few years ago.

(b) Laboratory work on titanosaurid sauropod collected a few years ago was continued. In addition, research into the world-wide titanosaurid records and an evaluation of the skeletal material available in India was undertaken.

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Lameta Beds of Jabalpur : The shock metamorphosed quartz from the Lameta Beds of Jabalpur has been interpreted to be the fall out material of the ejecta from a massive meteorite impact on the surface of the Earth 65 million years ago. The crater site seems to have been located. A field trip to the Bombay coast led to the understanding that the Paucal flexure perhaps represents a part of the rim of the crater the crater itself being filled up with volcanic material. The other part of the circular rim is presumed to lie under sea south of the Seychelles Islands east of the African mainland. The two parts are on either sides of the Mid-Oceanic Ridge from which the African plate and the Indian plate got separated away from each other.

Quantitative Geology : The exponential function derived from the investigation of the variation in the nearest neighbour density estimates in C-axis fabric in some quartz tectonites has been tested against the available quartz C-axis orientation data for compatibility. Some observations on the effect of impurity phase on the C-axis orientation development have been made. These indicate that for natural quartz tectonites with phyllosilicates upto 16 per cent, the C-axis fabric pattern with respect to the girdle organisation is essentially the same as that for the quartz tectonites with insignificant micas.

Physics

During the period under review, the research activities of the Physics Unit have been on problems of 'Bio-engineering and Dermatophysics' and the Unit worked mainly on the following topics :

1. *Sorption-desorption studies of skin with water* : These include measurements of skin impedance, hydration state of the skin and the transepidermal water loss in various skin disorders. A statistical model that was developed in this regard for the ichthyotic skin is being improved upon with the help of statisticians. These studies have also thrown light on the quality of the skin and its barrier function.

2. *Dermatologic iontophoresis* : This is an on-going activity of the Unit. Iontophoretic application of drugs under carefully controlled conditions on certain skin disorders, e.g., hyperkeratosis of the palm and sole has been found in the Physics laboratory to show excellent results and this is now being used in some dermatologic clinics in the country. Studies have been continuing with vitiliginous spots.

3. *Skin characterisation* : Studies on quantitative characterisation and objective evaluation of skin quality with a number of biophysical parameters such as skin pH, hydration state, sebum level, electrical conductance, hydro-Scoplicity, skin friction etc. were in the final stage of reporting.

4. *Studies of epidermal extensibility in vivo* : This project was taken up recently and the instrumental set up has been completed.

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Biological Science

The Biological Sciences Division is engaged in studying the varied biological processes covering plant and animal kingdoms, including humans. It comprises the following units: Agricultural Science Unit, Anthropometry and Human Genetics Unit, Biochemistry Unit, Embryology Unit, Entomology and Leaf Protein Unit. Laboratory Research activities carried out in these Units are described below :

Agricultural Sciences

Six research projects were being conducted at two distinct ecological zones, namely, Giridih region of the Bihar plateau and the saline areas of Sunderban in West Bengal. In Giridih, ongoing projects (sl. nos. 1 to 3) were carried out on ISI's experimental farm where the central theme is increasing productivity through rainfed farming. The other three projects (sl. nos. 4 to 6) aimed at adaptation of promising coconut and oilpalm cultivars in the saline tracts of West Bengal as well as in-depth ecological studies on the mangrove vegetation. During the period under review (1990-91), the following interesting findings were obtained in these on-going projects :

1. *Crop sequence studies under mid-upland situation* : (i) Paddy based system is better suited to medium land, whereas in mid-upland maize based system is more productive and remunerative. (ii) Paddy-barley, paddy-toria and paddy-linseed systems produced reasonably well under strictly rainfed conditions where paddy-straw mulching of winter crops proved to be effective. (iii) In mid-upland situation, however, winter crops like barley and toria could be grown with two life-saving irrigations and in this light soil-type mulching gave better results. In both the situations, the beneficial role of organic manure (another variable) could be distinctly noted.

In collaborative long-term paddy-based studies, soil and plant nutrient data as also yield data revealed the usefulness of indigenous rock phosphates, mainly for its residual effect in this phosphate-deficient, low land and acid soil.

2. *Intercropping studies on upland situation* : (i) Maize-groundnut, both as alternate or paired row treatments, were highly remunerative with regard to different evaluation criteria (biological and economic). (ii) Paddy and pigeon-pea-based intercropping studies clearly revealed the advantages of legume inclusion. Soil/plant analysis is in progress to find out the treatment effects on nutrient uptake, soil fertility and follow-up winter crops.

3. *Studies on performance of different potential crops* : Superfast, short duration I.A.R.I. paddy varieties, i.e., Pusa Jaldi strains, could be effectively introduced in medium land situation with 2.0 to 2.5 t/ha grain yield in 60-65 days. Other important varieties of different summer and winter crops with good production potential under water and fertilizer resource constraints could also be identified.

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4. *Exploratory work on Palms* : Anatomical studies on 20 species of palms were completed. In levo and dextrorotatory plant studies also revealed the anatomical differences. Statistical analysis are being carried out to examine the magnitude of differences as also the possible causes of these characteristics.

5. *Studies on the adaptability of coconut and oilpalm* : These studies indicated the suitability of these plantation crops in the saline areas of Sundarbans. Periodic growth data as also other botanical characteristics are being studied and these are to be correlated with soil nutrient data.

6. *Mangrove vegetation project* : Palynological work and studies on epidermal structures of different species were completed. Anatomical investigations on roots, stems, leaves and tracheary elements are in progress.

Externally Funded Projects :

In an on-going I.C.S.S.R.-funded project undertaken in collaboration with the Sociological Research Unit of ISI, attempts were being made to evaluate farmers perception and potential of agro-ecosystem productivity in a micro-watershed of Bihar plateau. The project was initiated in January 1990 and will be continued till June 1992. Primary survey work covering villages and households were recently completed. Data tabulation and analysis is in progress.

Anthropometry and Human Genetics

Human Adaptability Programme : This programme comprises the first five projects in the account given below, namely, (1) Health status and labour productivity, (2) Effects of micro-environmental factors on health in rural populations, Phase II, (3) Psychological stress and health of mother and child, Phase II, (4) A study on the determinants of fertility and mortality in an urban setting : An anthropological perspective, and (5) Human biology of Himalayan populations.

All the five projects are long term ones, concerned with human adaptability, i.e., the capacity of humans to adapt to various environmental conditions. Adaptability is to be assessed from observable facts of adaptation. The environmental conditions encompass the whole spectrum, viz., the stressful conditions associated with terrestrial high altitude at the one extreme, and those associated with modern, urban way of life, at the other.

The 1½ decade-long study of Himalayan populations (Project-5) shows that the biological response of these people to the high altitude stresses are quite different from those of Andean highlanders. This finding implies that each population responds to its environment in a unique way, even through the environmental conditions may be similar, presumably because of its unique genetic endowment. This inference stands out in sharp contrast to the results obtained from experimental animal populations showing a generally uniform pattern of responses to altitude stresses, and emphasises the need for detailed micro-level study of individual populations, rather

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than using results obtained elsewhere, for policy formulation. The study also shows that micro-sociocultural factors may have considerable effect on biomedical traits, indicating that such factors should be taken into cognizance in formulating developmental (health, nutrition etc.) policies. The effects of micro-economic factors on biomedical traits (e.g., diet/nutrition, infant and childhood mortalities, child growth, anemic status, etc.), indicating similar policy implications has been shown in Project 2. Project 3 examines the common notion that working women, because of the necessity of taking care of the two worlds (home and workplace) and the consequent tight time schedule, suffer from impairment of physical, mental and social well-being. Our results show that the common notion is not valid in the case of middle class urban women (like women college teachers of Calcutta). In practical terms, these are encouraging results, in view of the fact that middle class urban women are increasingly taking up out-of-home jobs over the last several decades. Project 1 also produces unexpected results, viz., while it may be intuitively expected that a labourer's health status is positively co-related with his/her work output, data collected from a tea labourer population does not show such a co-relation. Obviously, the managements cannot be coaxed into improving the labourers' health facilities on the basis of these results. The questions that are now asked in connection with this problem are : (1) to what extent, if at all, these results can be generalized ? and (2) were the right health parameters selected for this study ? The thrust of Project 4, which is presently at the stage of collection of primary data, is on (1) the determinants of infant and childhood mortality, and (2) perception of parents about these bio-events. There are many studies on the determinants of fertility and actual measurement of demographic variables in different populations, but the present study, when completed, will provide information on the rather neglected aspects of determinants of mortality and parental perceptions in an urban slum-dwelling population. Such information will hopefully help in planning health and family planning policies and programmes. Project 2 also examines the common notion that in the Indian society females (especially female children) are discriminated against in respect of intra-household food distribution while the males are favoured. A small scale study on this aspect showed that the common notion may not be true. The present study, when completed, would (1) provide further information on this social evil (if it exists), and (2) place this phenomenon of gender discrimination in the context of an overall pattern of gender bias in respect of nutrition, health, education and such other facilities as well as property rights, etc..

Five Ph.D. theses have already emerged out of these projects, in addition to numerous publications in reputed journals and edited volumes.

1. *Health status and labour productivity* : Further analyses of the data leading to publications were continued.
2. *Effects of micro-environmental factors on health in rural populations, Phase II* : Anthropometric data have been collected, family-wise, for estimation of the heritability of the traits. Further analyses and reporting on extant data were continued.

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3. *Psychological stress and health of mother and child, Phase II* : A Ph.D. thesis has been submitted. (The degree has recently been awarded). Further analyses of the data and reporting on them were continued.

4. *A study on the determinants of fertility and mortality in an urban setting : An anthropological perspective* : Data collection on demographic aspects of a slum-dwelling Muslim population was completed. Data collection on health, hygienic practices and socio-cultural aspects was in progress.

5. *Human biology of Himalayan populations* : Data collection on demographic aspects from the Lepchas of North Sikkim was started.

6. *Epidemiological study of Rheumatoid Arthritis* : Rheumatoid arthritis is generally a disease of the connective tissue, but its aetiology is unknown. Genetic constitution, environmental condition, psychological stress etc. may be the causative factor for the disease.

With the help of 12 probands, who were earlier diagnosed by the National Institute for the Orthopaedically Handicapped (NIOH), Govt of India, Calcutta, 2,500 families were investigated covering about 12,904 individuals from different areas. Amongst them, approximately 200 subjects were suspected to be Rheumatoid Arthritis patients. After the doctor's diagnosis, 90 subjects were confirmed and they were advised for screening of their blood in I.S.I. So far 88 subjects from the field and 97 from NIOH OPD have been screened for different parameters.

After screening the patients in the laboratory, the following salient points were noted :

- (a) The number of female patients is much higher than that of male patients. The ratio is nearly 4 : 1.
- (b) ESR value is high in the Active phase of rheumatoid disease.
- (c) ESR value is moderate in the Burnt-out case of rheumatoid disease.
- (d) In the cases of rheumatoid arthritis, the globulin level is high, especially the gamma globulin of serum protein.
- (e) Immunoglobulin level IgG, IgH, IgM are also high.

Rheumatoid disease produces a large number of orthopaedically handicapped persons every year. The results of the project would be helpful in formulating possible preventive measures for this disease and rehabilitation programmes by NIOH, Government of India, who are the collaborators in this project.

Population Variation Programme.

Population genetics of HbE : Because of the political turmoil in north India it has not yet been possible to carry out the field work for the project, "Genetic Survey.

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of Some Endogamous Groups of Northern India", under the Population Variation Programme as earlier planned. Some funds for this project were utilized for a related project, "Genetic Structure of the Kooches of North Bengal with special reference to HbE".

The major findings of the work done on the three descendant groups have already been reported. The salient points are the following :

Among the Deahi, the HbE is found to be as high as in the Bodo-Kachari population, which has the highest reported HbE frequency in the world. No evidence of changes with age could be traced in the present series of data. Genetic diversity, involving 11 genetic markers, within populations was found to be greater than the between populations diversity. Genetic distance measures showed Poliya and Tiyor were closer to each other than the Deahi and the Rajbanshi of West Bengal and the Rajbanshis of Assam were set apart from these populations. No relationship of HbE of individuals with humoral immunity, i.e., IgG, IgH, IgM, levels, was observed in these populations. A lower level of Hb concentration was observed among the HbE homozygous individuals compared to normal HbA of heterozygous HbAE individuals.

Further field investigation was recently carried out on the Koch to study the distribution and number of subgroups of Koch, their population sizes, marriage pattern, migration, ethno-history, etc. in the four districts of North Bengal.

8. *Bio-statistical study on vitiligo : A skin disease* : Efforts were concentrated on data collection covering phenotype status of sib-pairs and family members, collection of blood samples and extraction of DNA, IEF-immuno-blotting for factor XIIIb, along with red cell enzyme analyses for biochemical markers.

9. *Chimpanzee dermatoglyphics* : A study was undertaken to examine the nature and extent of variation in the size of palmar and sole patterns in chimpanzee. The analysis showed that the palm and sole of chimpanzees and humans display noteworthy differences in pattern intensities, size of the patterns and total patterned surface. As compared to that of the chimpanzee, the human palm is characterized by reduced pattern intensity, smaller size of the patterns in all configurational areas and significantly reduced total patterned surface. The soles on the other hand of humans and chimpanzees possess identical pattern intensities, but differ in total patterned area, humans being significantly smaller. Apparently, phylogenetic and functional differences in hand and feet in chimpanzees and humans are also reflected in patterns of variation in ridged skin of their palms and soles.

10. *Joint management of forest lands in West Bengal* : Detailed studies undertaken in 62 forest Protection Committees (FPC) in Midnapore District of West Bengal showed that the best functioning FPC's were the ones where only one village was involved, ethnic composition was tribal, each household was represented in the FPC

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and the forest lands were regenerating (as opposed to plantation). One of the main reasons for sustained interest in protecting the regenerated forests in the region is the flow of bio-diversity which meets the fuel, fodder, medicinal, small timber, and other needs of the people. These results have far-reaching implications as several states in the country have agreed to adopt Joint Management Systems. These studies and studies carried out by others have greatly influenced the Ministry of Forests and Environment to take a historic policy decision for the forestry sector, by issuing an order on 1 June 1990, asking all states and UTs to initiate joint management of forests on the lines of the West Bengal model.

11. *Studies in the area of dermatoglyphics (finger, toe, palm and sole)*: These include studies on (1) the development of new ridge counting techniques of palmar and planter patterns, scoring of hypothenar triradii and design of a few new variables; (2) population variation; (3) bilateral asymmetry; (4) sex variation; (5) inheritance of dermal traits; (6) inheritance of asymmetry, and (7) genetic diseases.

The results obtained in population variation confirm that (a) the dermatoglyphic traits, in general, and palmar characters, in particular, do help in understanding the biologic affinities among different ethnic groups; (b) the different types of traits, which are likely to be influenced by different genetic/environmental factors, give rise to different clustering patterns.

Recent interest in the study of asymmetry has been focussed towards better understanding of the hypothesis of developmental homeostasis.

12. *Study of the physical growth of the Bengali children (Phase III): Anthropometric and socio-economic survey among Bengali boys and girls*: The anthropometric study of families carried out in an endogamous Mahisya caste population has generated intrafamilial correlations and estimates of heritability for 28 anthropometric traits. For example, in triceps skinfold thickness father-daughter correlation is 0.21, mother-daughter 0.15, father-son 0.05 and mother-son 0.19. The sib-sib value is 0.12.

Growth study of Bengali girls has generated data on menarcheal age of around 1000 sample individuals of lower middle class urban Bengali girls. The findings will throw up important information for this population on menarche and its relationship with body development and other socio-economic and demographic variables.

13. *Man-environment interactions in coastal ecosystem*: The entire Orissa coast was surveyed during 1990-01, and the distributional patterns of both indigenous and migrant humans were mapped, along with the historical, occupational, technological and linguistic backgrounds. This will be followed by the study, to be taken up during the current year, of parental areas of the migrant fishermen who are currently staying on Orissa coast, to throw light on adaptational patterns.

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14. *Genetics of complex disorders* : Disorders which are primarily determined by genes but are not inherited in a simple Mendelian fashion are termed as complex disorders. Such disorders have in the past been often classified as polygenic/multifactorial. However, it is possible to construct simple genetic models involving two or three loci for such so-called complex polygenic disorders. With the availability of high-speed computing facilities and the development of numerical algorithms, statistical inference for such multilocus models is now feasible. The focus in the present study has primarily been on developing such concrete genetic models, on testing these models on family data of various complex disorders (e.g., Vitiligo, prelingual deafness, abdominal aortic aneurysm, etc.), and on developing statistical strategies for mapping loci controlling such disorders. Usefulness of covariate information on modelling mode of inheritance is being investigated on a group of psychiatric disorders. The motivation for these efforts is that now the concept of polygenic inheritance for complex disorders is being questioned. It has been partially possible to evolve simple and concrete genetic models even for disorders that do not exhibit a simple Mendelian mode of inheritance. The utility of these efforts is that if the segregation patterns of a complex disorder can be shown to be compatible with segregation of alleles at a few loci, then it is possible to map the disorder. Further, such modelling helps in probabilistic genetic counselling, which otherwise would heavily rely on empirical risk estimates.

Other projects in progress :

1. *Biological Affinities of some Telegu-speaking populations of contrasting socio-economic backgrounds* : This research is being pursued in collaboration with Dr. P. Chengal Reddy, Reader, Department of Anthropology, S. V. University, Tirupati, and is in the final stages.

2. *Probable implications of migration for the biological composition of the fishing communities on the East Coast* : This project is being pursued in collaboration with Institute of Human Biology, University of Hamburg, Germany. The statistical analysis of the data is in progress.

3. *Extended family study of the dermatoglyphic traits : Data from Vadde fishermen of Kollen Lake, Andhra Pradesh* : Statistical analysis of the data on 100 extended families is being pursued in collaboration with Institute of Human Biology, Hamburg University, Germany.

4. *Graphical representation of the multivariate finger ridge count data of the populations at different hierarchical levels* : The finger ridge count data on about 250 Indian and Western populations are being analysed with the help of *BI PLOT* and *constellation* graphical techniques to delineate the usefulness of the graphical techniques in portraying the population differentiation, on one hand, and to delineate the dermatoglyphic affinities of populations at different hierarchical levels, on the other. This project is being pursued in collaboration with Professor T. Krishnan of the Applied Statistics, Surveys and Computing Division of the Institute.

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8. *Association between sickle cell and phalangeal crease patterns* : This project is being carried out in collaboration with scientists from the Anthropological Survey of India, Dibrugarh University, Sambalpur University, etc. Data on crease patterns of the sicklers, as well as for the general population from the same ethnic background, were gathered from some tribal populations of Gadchiroli districts in Maharashtra. In addition, data were gathered from about 25 populations with different ethnic/ racial backgrounds, and these have already been analysed for their phalangeal crease patterns.

Biochemistry

The Biochemistry Unit has been currently pursuing research mostly in the area of Biochemical Epidemiology. The following areas were being investigated under this programme during the year 1990-91 :

1. *Genetic Epidemiology of blood pressure* : An investigation of both genetic and environmental factors with the special reference to the lipid profile of blood/serum was taken up to help in understanding the etiology of blood pressure. 43 Marwari families including 268 individuals were studied in 1990-91. From partial analysis of these data it appears that Cholesterol : HDL cholesterol ratio is generally well within the risk factor limit (5 : 1). The above finding leads to the concept of some repressor gene which may be responsible for the blockage for breaking down the edible triglycerides into glycerol and fatty acids/or enters into the path of arachidonic acid while the "Atherosma" fats (in heart) are being metabolised.

2. *Epidemiological study on Rheumatoid Arthritis* : This is a collaborative project taken up by I.S.I. and the National Institute of Orthopaedically Handicapped (NIOH) (under the Ministry of Welfare, Government of India). This is also partially financed by NIOH. The study is being done to obtain information on the magnitude and risk factor of the disease. About 2500 families have been studied with the proband (known RA cases) and about 225 patients (SRA) have been examined for Rheumatoid Arthritis, and analysis of blood/serum have been done on the patients in 1990-91. The project is designed to throw light on the following aspects : (a) to find the prevalence of the disease ; (b) to study the nature of inheritance ; (c) to study the risk factor(s) ; (d) to study the environmental factors ; and (e) to confirm the RA cases through laboratory investigation (haematological, serological, biochemical and immunological examinations) to locate proper probands.

3. *Cancer Chemo-prevention : An approach toward cancer control, Dietary Risk factor(s) and Cervical precancerous and Neoplastic disease* : (a) *Hospital-based study* : Four hundred fifty female subjects were screened with pap cervico vaginal smears for cervical dysplasias (pre-cancerous lesion) at Calcutta Medical College Hospital during 1989-91. Detailed epidemiologic and dietary information was collected on these subjects to find out any associated risk factor(s) for cervical dysplasias.

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(b) *Population-based study*: Pap smears were taken on 250 subjects for the screening of dysplasias. Detailed epidemiological and dietary information were also collected on these subjects. Approximately 3% of the screened population showed cervical dysplasias and almost 75% of women either had an inflammatory smear or infection with low to high degree of leucorrhoea. Blood level of several vitamins such as vitamin C, folic acid, vitamin A and beta-carotene will also be determined for these subjects.

CSIR-Funded Project

Evaluation of cytotoxicity of tin on plant system (Allium sp.) in vivo: Prevalent occurrence of heavy metals in earth's crust is responsible for spontaneous existence of metal compounds in different plants and plant-parts, which is exclusive food material for animals and human beings. Such atmospheric and biological contamination of metals has led for the screening of the efficiency for tolerance of plants and higher organisms to the heavy metals. In this ongoing project-which was started recently cytotoxicity of tin (a commonly used heavy metal) is measured so far in bulbous plant-Allium Cepa. The roots of fresh and healthy bulbs are treated with different concentrations of trimethyltin chloride for different durations. Somatic chromosomes from root tips are prepared following usual aetoeorcin schedule and 1000 and 80 cells are scored for mitotic index and chromosomal abnormalities respectively. The frequencies of dividing cells are depressed and the trend is dose and duration dependent. However, the frequencies of chromosomal abnormalities are significantly elevated compared to control. Trimethyltin chloride induced chromatid and chromosome breaks, alicbridge laggards, early as well as late separation of chromosome in metaphase and anaphase. Therefore, it can be suggested that the present metal compound has effects on spindle formation as well as on chromosomes of plant cells. Thus, it can arrest the growth along with loss of DNA content of the cells.

Embryology

During the year under review further analysis has been made of the free fatty acids, chemical signals in the Tiger. The very difficult question of whether these chemical signalling molecules reflect the *individuality* of the animal has been tackled and preliminary support for the theory has been obtained.

The synthesis of the molecule that is responsible for both the aroma of fragrant rice and Tiger marking fluid was accomplished in the laboratory, though with a poor yield.

In the studies on Mathematical and stochastic modelling of Cellular growth, differentiation and morphogenesis, it was demonstrated that Turing systems are far more general than chemical networks with explicit activation/inhibition. Indeed, all two-component Turing systems are mathematically equivalent to an extent which has so far gone unnoticed.

This is important in applications: First, experimentalists should not confine themselves to look for evidence of explicit activation/inhibition properties in the

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biochemical networks of interest for morphogenesis. Instead, it has been observed in this laboratory that such networks should have a Jacobian with a very specific sign combination of the elements. Second, the generality of Turing systems suggests that computer results obtained by using an explicit chemical network to a wide extent may carry over to other Turing systems.

In the studies of Carcinogenesis and Tumour growth it was observed that the growth of normal cells and the growth of tumour cells differ due to the spatial variability in the ratio of self-diffusion and cross-diffusion.

The formation of the primary layers of differentiation, e.g., Ectoderm, Mesoderm and Endoderm, has been mathematically exhibited in the three-dimensional geometry, i.e., in the cylindrical and spherical-shaped embryo with the help of non-linear reaction-diffusion models.

A reaction-diffusion model of tumour tissue growth with spatially variable diffusion coefficient of the mitotic inhibitor (Chalone) has been constructed. This model has been analysed on one-two- and three-dimensional coordinates and has been observed to explain tumour growth with its characteristic mitotically active peripheral zone surrounding quiescent (mitotically inactive) central layers.

In another model based on negative feedback epigenetic control system, the mechanisms of three types of cellular development, namely, ordered structure during embryonic development, normal tissue growth and tumour growth, respectively, for different ranges of values of the ratio of self-diffusion and cross-diffusion, have been revealed.

Also, some other models have been proposed to find the roles of Chalone (mitotic inhibitor protein) during cellular development and tumour growth.

Furthermore, some models on epidemiology have been constructed and explored.

Further field experiments on intervarietal interaction between two varieties of wheat and two varieties of rice were conducted. Inter-crop interaction experiments between mustards and wheat were also conducted. Both in the inter-varietal and inter-crop interaction significant differential effects at different spacings were observed. Simultaneous laboratory experiments with labelled precursors confirmed the secretion of root exudates by plants during growth; thus, the laboratory experiments jointly with field trials strongly indicate the existence of a growth promoting (or inhibiting) factor which exists in the root exudates and diffuse through soil to undergo chromatographic separation.

Entomology

Research was carried out in connection with the following project:

Situation in Mosquito-Japanese Encephalitis research in India: The picture of Japanese encephalitis in India is not so clear as in Japan. The species of vector mosquito (*Culex tritaeniorhynchus*) is the same as in Japan. But there are reasons

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to believe that other vector mosquito species exist in India. Like malaria Japanese encephalitis does not spread from man to man. Some of the infected mosquitoes bite pigs, which are called *amplifier host*, as they can infect a large number of mosquitoes. In India, the virus of this disease circulates in the pig-mosquito-pig cycle. Cattle are not related to this disease. Curiously, this vector species shows preference for cattle blood. It is contended that the large cattle population in India act as a brake in the dissemination of the virus of this disease by deflecting vector mosquitoes. This is why Japanese encephalitis in India is a menace rather than a big problem like malaria.

Leaf Protein

Research activities of the Leaf Protein Unit carried out during the year are briefly described below :

1. Among 36 tree leaves studies for protein extraction, 8 species were found promising. Among the 8 species, *Ailanthus excelsa* appeared to be very promising so far as nitrogen content, *in vitro* digestibility of chloroplastic, cytoplasmic and unfractionated leaf protein parts are concerned.

2. Thirty aquatic weeds were tested for the presence of some anti-nutritional factors. The qualitative presence of alkaloids having poisoning properties, specially nitrates and polyphenolic compounds, in all plant samples have been worked out.

3. Chemical analysis of five-pressed fibrous residue, a by-product of leaf protein production plant, was undertaken. The pressed residue consists of lignin, cellulose, pentosan, pectin and minerals. Various trials were rendered using the pressed residue as a basic substrate along with other agricultural wastes such as rice straw, bagasse and saw dust for growing mushrooms. The yield of edible mushroom was 1300 g when sun-dried fibrous residue (500 g) was fortified with 500 g of rice straw.

4. The community kitchen programme—a small leaf protein acceptance trial was carried out for 4 days. The main meal was *kichdi* along with some green leafy vegetable, chilli, onion, ginger and 5-7% leaf protein. The response was quite satisfactory.

5. Research on sugar beet (*Beta vulgaris* L.) was initiated in the rabi season of 1990-91 with the objective of studying whether sugar beet can grow even in coastal saline region. The crop was sown in randomised block 6. Five nitrogen doses along with 3 potassium doses resulting in fifteen treatment combinations were randomly distributed in 60 plots. The data on shoot yield, root yield, sugar yield and leaf protein yield were collected starting from 70 days after sowing.

Social Sciences Division

The Social Sciences Division includes the following Units : Economic Research Unit, Economic Analysis Unit, Planning Unit, Population Studies Unit, Linguistic Research Unit, Psychometric Research and Service Unit and the Sociological Research

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Unit. The Economic Analysis Unit is located at Bangalore, the Planning Unit is located at Delhi, while the remaining five Units are located at Calcutta. Faculty members of this Division were engaged in teaching and training activities at various levels, including Ph.D. supervision, and some of them taught at other Universities on a part-time basis. The research work done in these units during the year under review is described below :

Economic Research

The Economic Research Unit continued its teaching and training activities at various levels besides research work covering different areas of theoretical and applied economics and econometrics. The research activities of the Unit during the period under review covered fields like economic theory, economic planning and policy, industrial economics, demand analysis, income distribution, level of living and poverty in India, agriculture, economics of the informal sector, economic development etc., besides other investigations in applied economics and methodological studies in econometrics.

Project Work : Members of the Unit completed two projects taken up earlier, worked on some ongoing projects and also started work for new projects. These projects are described below in brief.

1. *ISI-ONGC Collaborative Project*

This project was undertaken by ISI in collaboration with the Oil and Natural Gas Commission (ONGC), Govt. of India. The main objective of the project was to develop a methodology for estimation of discovery and production cost of hydrocarbon taking into account the uncertainty involved in the discovery of hydrocarbon. Two different types of models for discovery and production of hydrocarbon, viz., an econometric and a statistical model, were developed and used for projecting future discovery of hydrocarbon and the associated costs. The econometric approach to make the forecast on the basis of an analysis of the past observations on exploration, discovery and production of hydrocarbon and the related costs. The statistical approach, on the other hand, dealt with the uncertainty involved in the discovery of hydrocarbon by explicitly specifying probability distribution of relevant variables and obtaining solutions by simulation methods.

This project was completed during the period under review and the project report was submitted to ONGC in May 1990. The ISI team included scientists from Economic Research Unit and Computer Science Unit and the Director (Professor J. K. Ghosh) was also actively associated.

2. *Currency Requirement by Denomination : A forecasting Model for India*

This project was sponsored by the RBI, Bombay, and taken up in 1988. The primary objective of the project was to evolve a method of prediction of denomination-

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wise demand for currency and to obtain projection of currency requirements by denomination for future years. The study was carried out in three stages. The first stage was concerned with the prediction of requirement of total currency in circulation —i.e., total value of all denominations of currency taken together. In the second stage, a method for deriving the "appropriate" denominational composition of total currency was developed. The results of these two stages were finally integrated and requirements of currency by denomination were projected for the future years. Obviously, the difficulty of carrying out a study like the present one arose from the fact that there was neither any information on the denomination-wise demand for currency in India at any point of time in the past nor any standard method for estimating the gap between the denomination-wise requirement and availability of currency. A prototype sample survey had been carried out on the currency transactions taking place in the commercial banks within the Calcutta postal area which might serve as a basis for estimating the extent and nature of discrepancy between the requirement and availability of currency by denomination. This prototype sample survey constituted the third and the final stage of the study.

The project was completed during the period under review and the report of the project was submitted to the RBI in November 1990.

3. *Reliability and validity of income data collected by different approaches*

The National Sample Survey Organisation (NSSO), Govt. of India, conducted a Pilot Survey on household income, consumer expenditure and savings, collecting data on these characteristics from matched samples of households selected from different states of India. The aim was to examine the reliability of data on household income collected by different approaches. At the request of the NSSO, the Indian Statistical Institute agreed to analyse and report on the data collected through this pilot survey. A team of scientific workers of the Institute drawn from Economic Research Unit and Computer Science Unit has been collaborating with some officers of NSSO for this job. The final report on the income data collected through Schedule 1.1A was submitted to NSSO authorities during 1990-91.

4. *Identification of Rural Poor*

A team of scientists of the Unit, with Professor A. Rudra as consultant, has started this survey-based project, which was taken up at the request of the Department of Statistics, Govt. of India. The objective of this project is to evolve simple criteria for identifying rural poor which could be used in anti-poverty programme instead of conventional criteria based on per capita household income/consumer expenditure or per capita household intake of calories. During the year under review, field work for the survey was started and completed to a great extent. The survey covered random samples of households in four purposively selected rural areas of West Bengal, including hilly and tribal areas. The households were interviewed for filling up the main questionnaire on fulfilment of basic needs covering some simple indicators of level of living, such as intake of cereals in physical terms, stock of clothing,

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bedding and of durables like cooking utensils, housing conditions, availability of public goods etc.. The standard consumer expenditure schedule was also filled up for all the sample households. Attempts would be made to define poor households on a joint consideration of multiple indicators of absolute poverty and to examine how well a subset of indicators could be used to reach a reasonable classification of households by poverty status.

5. *Linguistic Analysis of Works of Rabindranath Tagore based on complete Statistical Counts*

A team consisting of linguists, statisticians and computer scientists has been engaged in a statistical-linguistic analysis of Tagore's works. This project is being conducted in collaboration with the Institute for the Study of Languages and Cultures of Asia and Africa (ILCAA), Tokyo University of Foreign Studies, Tokyo. ILCAA has been transferring Tagore's works to computer tapes and preparing and publishing word-counts and concordances for individual poetical works. The team in ISI has been carrying out various types of analysis starting either from the computer outputs supplied by ILCAA or from the texts themselves. These include finding the relative frequencies of Sanskrit, Bengali, *Mishra* and *Vidishi* words, studies on compounds, compound verbs, pronouns, verbal roots, suffixes and prefixes etc..

During the year under review the work on this project made considerable progress. Steps were taken to print the first report on *Gitanjali*, based on such analyses. Work on three other poetical works—*Prabhat Sangesh*, *Sandhya Sangesh* and *Manasi*—were in progress. Work on prose works of Tagore had just been started using the Bengali word processor developed by one member of the research team.

Economic Analysis (Bangalore)

The following research projects were continued under the leadership of faculty members of the Unit :

1. *Studies in Poverty and Inequality : Regional dimensions* : A comprehensive study of pre-revised and post-revised salary structures of technical and non-technical workers of ISI, Bangalore Centre, was completed. The results support the hypothesis that the revision had a favourable impact on the lower categories of workers in terms of pay as well as D.A.. Among other important studies in this broad area, mention may be made of one on a test for expenditure elasticity estimates from survey data, and another on an analysis of earnings and consumption expenditure of Indian rural labour households, in which an extension of the LES was employed. These studies have led to a number of papers submitted to reputed journals.

2. *Studies in Economic Theory* : Efforts in this area concentrated on the following : (i) Reconstruction of economic theory on classical foundations. (ii) Perception of reality concept of production and schemes of social accounting—a study in History of Economic Thought.

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Both of these are essentially writing projects given to conceiving Economic Theory in relation to its classical foundations and therefore to relevant historical conditions. The work done consisted mainly of a critical re-examination of the works of some 'greats'—of Keynes, Smith, Ricardo and Marx (of the 'past') and of Kalecki (of the 'present').

In addition to the above, faculty members were engaged in Ph.D. supervision and also helped in teaching the M.Stat. (M.-stream) course at Bangalore.

Planning (Delhi)

The members of the Unit continued research in a number of fields in applied as well as theoretical economics, regional planning and analysis of social movements.

Research in applied economics covered diverse topics such as developmental planning, problems in estimation of poverty, estimation of labour force and unemployment, foreign trade and economic development, health and family planning, amongst others. Work was continued on the development and application of macro-economic models for analysing policy issues.

A survey project on the Disparity in Income and Level of Living among teachers in Delhi was completed and a similar project for medical practitioners is under progress.

Research in economic theory revolved around game theory and its applications, economic inequality, industrial organization models of unemployment and the design of contracts and mechanisms.

Linguistic Research

During the period under review the Linguistic Research Unit continued its programme of research in the areas of fundamental and applied linguistics. There are five main headings under which the Unit's research projects may be grouped, namely :

1. Studies on the phonetic structures of major Indian languages and application of the results in the areas of : (a) speech pathology ; (b) second language acquisition and (c) cultivation of mother-tongue.
2. Socio-linguistic aspects of convergence.
3. Language, class and cognition.
4. Bengali syntax and semantics.
5. Application of statistics in linguistic problems.

A brief account of research work done in 1990-91 is presented below :

Fundamental research : A survey of the articulatory and acoustic structure of the Tamil language was in progress. Fundamental research on the suprasegmentals of Bengali, Hindi, Oriya and Telugu was also in progress.

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Applied research : Studies were continued on the following problems :

(a) Development of articulation of speech sounds during the period of language acquisition by the pre-school-age child.

(b) Factors leading to convergence between the numerous major and minor languages belonging to the three major language families in India, namely Indo-Aryan, Dravidian and Munda, from a socio-linguistic perspective.

Studies were continued on the academic achievement of hearing-impaired children attending general schools along with normal hearing children.

Studies were also in progress on the comparative intonation patterns of Indo-Aryan and Dravidian languages as well as between languages within the broad Indo-European group. Studies on pitch and intensity were carried out, utilising the Visi-Pitch. In-depth statistical studies, initiated almost four decades ago on the vocabulary of Tagore's novels and short stories were also continued. Finally, research was initiated in the areas of language and cognition in the context of class, code, control and also on Bengali syntax.

Project work (On-going) :

I : Study of Suprasegmentals of the Hindi Language : Syllable stress in words, sentence melody and intonation patterns were studied and some preliminary analysis carried out. Further data were collected from native speakers of the language, from Delhi, Allahabad and Agra.

II. Study of the Suprasegmentals of the Telugu Language : Syllable stress in monosyllabic, disyllabic and polysyllabic words was studied and some preliminary analysis carried out with the help of the Visi-Pitch.

III : Comparative Suprasegmentals of the Slavic, Indo-Aryan and Dravidian Languages : In the first phase, data on suprasegmentals of Hindi, Telugu, Bangla and Serbo-Croatian have been collected. The analysis would depend on the availability of necessary equipment.

IV : Statistical studies of the vocabulary of Tagore's short stories : Data for a quantitative analysis of the vocabulary of each volume of *Galpaguchha* has already been completed.

V : Study of the phonetic structure of the Tamil language : Preliminary data were collected for the purpose of identifying the phonemes of Tamil.

VI : Survey of the articulatory norms in Bengali-speaking children of pre-school age : Special tests for articulatory evaluation of children under the age of four years were completed.

VII : Educational problems of hearing-impaired children attending schools for normal children : School texts have been analysed with a view to obtaining a realistic picture of the linguistic requirements of the school-going child.

VIII. Socio-linguistic aspects of convergence—A quantitative study: Some preliminary surveys were conducted in the Hyderabad-Scunderabad area and also in some border areas between Orissa and Andhra Pradesh.

IX. Verb-centric Parsing of Bangla Sentences on Computer: Verb-centric parsing of Bangla sentences has been done. Verbs have been categorised in such a way that the categorisation will rigger the structure of sentences, including compound verbs and composite verbs. This might be a pioneering work in Natural Language Processing as far as South Asia is concerned.

Population Studies

Externally Funded Project

Attainment level of primary school children at the end of class IV in West Bengal:

A collaborative study was undertaken with the State Council of Educational Research and Training (SCERT), Government of West Bengal, for evaluating the level of learning attained by students completing Class IV in Bengali medium schools of the State. Besides language, mathematics and environmental studies, other aspects such as creative, productive, and physical education were also included for the purpose of evaluation. The administration of tests in various subjects to students of more than 1,000 primary schools belonging to 17 districts was completed. Besides the tests, a guardian schedule was also canvassed for collecting information on the socio-economic back-ground of the households to which the students belonged. After the scoring work is completed, the data will be computerised for processing and analysis.

This study was undertaken in collaboration with the Scientific staff of Psychometric Research and Service Unit.

Other Projects

1. *Effects of socio-cultural and behavioural factors on proximate determinants of fertility and on acceptance of family planning:* This project adopts the "proximate determinants of fertility" approach, which permits a mathematically tractable decomposition of fertility levels and expresses fertility in terms of a few intermediate determinants: (1) the onset of the period of exposure to the risk of conception, (2) the period of postpartum sterility, (3) the onset of secondary sterility, (4) fecundability, (5) pregnancy wastage, and (6) effectiveness of contraception. With this scheme one can simulate the fertility experience of a woman with given reproductive parameters. The approach provides a method for integrating various assumptions about biological and behavioral interdependencies that sum to reproductive performance.

2. *Micro-regional statistical surveys in India upto 1875: An evaluation:* Massive volume of materials on population with various classifications and land use and other aspects were collected from records of old surveys conducted by the Britishers during the 19th century. These materials would be used to reconstruct the past in quantitative terms. One analytical study was actually completed using such materials.

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3. *Determinants of infant mortality in India :*

The study points out that a major weakness of the analysis of data on early age mortality in the use of the overall infant mortality rate. This is because the component rates of neo-natal and post-neo-natal mortality are determined by different types of factors which the overall rate fails to identify. Thus, early infant deaths are largely dependent on endogenous factors related to the birth process or congenital phenomena. On the other hand, the exogenous causes, such as environment, are the predictors of post-neo-natal mortality.

The strength and consistency of the relationship between birth spacing and infant mortality suggests that the priority in national population policy should shift significantly from permanent methods of control to spacing methods. The study gives a quantitative illustration which shows to what extent infant mortality can be reduced through changes in birth spacing patterns.

4. *Couple fertility and migration :*

One common assumption in the derivation of probability models for number of births to a woman during a given segment of her reproductive period, say $(0, T)$, is that the spouses stay together throughout the period of observation. Thus, the woman is exposed to the risk of conception at any time $(0 < t < T)$ if she is not pregnant nor in the state of post-partum amenorrhoea at that time. Therefore, the aforesaid models may not be suitable for explaining variation in the number of births to couples having a physically interrupted married life.

In India, the pressure of increasing population on limited land have accelerated migration from rural areas, and usually the males migrate and visit their homes at varying intervals of time. This physical separation between the spouses affects their reproductive pattern. The number and duration of such visits can be assumed to be of random nature.

Under a set of assumptions, a model is proposed for the number of births to a female whose husband has migrated, but visits home at certain intervals of time

5. *On the distribution of last closed birth interval :*

It has been the practice in recent retrospective fertility surveys to collect information on birth intervals only for a specified period preceding the survey instead of recording all birth intervals between marriage and the date of survey. Of particular interest is the last closed birth interval, which is expected to be more reliable than earlier intervals because of smaller recall bias.

Theoretical distributions of the last closed interval derived earlier require information on parity, marriage duration, and knowledge of the distributions of the earlier birth intervals. The expressions often become too complicated, making their application difficult. Further, reporting parity erroneously and/or making unrealistic assumptions about the distributions of lower order closed intervals, etc. may lead to results of doubtful quality.

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In this study a distribution of the last closed interval was derived under suitable assumptions. This distribution is independent of parity of women whose last but one birth occurred during a specified period prior to the date of the survey. The application of the model was also illustrated with reference to real data.

6. *A profile of migration pattern in West Bengal, 1971-81 :*

This study analysed the census data on migration during 1971-81. The purpose of the study was to investigate (i) the pattern of inter-district migration in West Bengal and (ii) the inter-state in-migrant and out-migrant pattern during 1971-81, and possible factor contributing to such movement.

Psychometric Research and Service

The research work done in this Unit during 1980-81 is briefly summarised below. All of these were projects funded by ISI or external agencies.

1. *Personality pattern of different occupational groups :* The objective of the study is to develop personality profiles of different occupational groups based on Indian population.

It was decided that the different aspects of personality would be measured through a standardised personality inventory. Five different occupational groups of individuals, viz., (i) Executives, (ii) Medical Representatives, (iii) School Teachers, (iv) Doctors, and (v) Artists, would be the subjects of the study. Five hundred individuals, 100 from each of the five groups, would be studied, and 16 personality Factor Questionnaire of Cattell would be administered on the subjects of this study. Data have been collected so far from 75 Teachers, 33 Doctors, 37 Artists and 23 Executives. Currently, data collection work is going on in the southern region.

2. *Consequences of Social and Economical Deprivation on Academic Achievement :* The objective of the study is to investigate the effect of socio-economic deprivation upon the scholastic achievements of school-going children. Several psychological and environmental factors which are expected to be related with scholastic achievement would also be brought under the scope of the study. Subjects for the study would be the students reading in Class X in different schools of West Bengal. The intelligence level, achievement motivation and prolonged deprivation of the subjects would be ascertained with the help of standardized tests. Such a study may throw light upon the problem of school dropouts in our country and the results of the investigation may be utilised to make our educational system more effective especially in rural areas.

Data for the study were collected from 64 schools located in both rural and urban areas of West Bengal, covering 1608 cases from 16 districts. Data collection was completed and the analysis of the data was taken up.

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3. *Assessment of minimum learning in primary education* : For this study data were collected on the socio-economic status of guardians and other related information for about 1700 Class-I students studying in 87 primary schools selected by systematic sampling from the Hooghly district in West Bengal. The scoring and analysis of the data collected during previous years were in progress.

4. *Attainment level of primary students at the end of Class-IV* : At the instance of the Government of West Bengal, a team of scientists of this Unit and of Population Studies Unit of ISI undertook this study in collaboration with the State Council of Educational Research and Training (SCERT), Govt. of West Bengal. The aim of the study was to evaluate the attainment of primary students of the State of West Bengal at end of Class-IV. It was decided to cover all aspects of the primary school syllabus, viz., language, mathematics, environmental studies and creative, productive and physical aspects of education.

The questionnaires for the study were evolved through a series of seminars and workshops attended by primary school teachers and subject matter experts besides representatives of ISI and SCERT. These were tried out in a number of schools in and around Calcutta before using them for conducting the tests in March 1991 simultaneously at about 1,000 primary schools covering nearly 2,000 pupils of Class-IV representing all the 17 districts of West Bengal. Data were also collected on socio-economic and other related aspects of the students and also about the schools. Analysis and reporting of the huge amount of data would be taken up in 1991-92.

Sociology

Members of the faculty participated in the teaching of sociology and sociometry in the B.Stat. (Hons.) course of ISI.

The research activities of the Unit during the year 1990-91 are outlined below :

1. (a) Collaborative researches with scientists of Bio-Sciences Division and statisticians of the Theoretical Statistics and Mathematics and Applied Statistics Divisions of ISI have been undertaken on the following topics : (i) Farmer's perception and response to rain-fed farming system (including potential and constraints) in East Indian plateau region ; (ii) Vulnerability of rain-fed farmers and their strategies of risk management ; (iii) Conditions of development of sustainable agriculture in mono-crop rice producing villages of Eastern India including exploration of endogenous sources of change and development in local cropping practices; and, (iv) Methodology of assessing degree of impact of exogenous inputs for induced development while developmental activities are going on.

(b) Collaboration has also been going on with scientists of Theoretical Statistics and Mathematics Division of ISI for researches on : (i) Identifying boundaries of social interaction by graph-theoretic method ; (ii) Decomposition of reciprocity in a social network among the villagers by their various primordial and new characteristics

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like caste, community affiliation, class, etc.; and, (iii) obtaining measures of reciprocity in weighted di-graph of a social or economic network as in case of volume/value of flow of goods between rural/urban within a country/between various countries engaging in international trade, or, frequencies or intensities of interaction among villagers in different dimensions.

2. Survey materials and field data are being analysed for preparing a report entitled, "The Desperate Delta", on the social ecology of the Sundarban.

3. A project on the "Social ecology of the minority/marginal groups" has revealed the emergence of social polarization over and above the economic differentiation between castes of different strata.

4. (a) Data collected through a project on the "Value system and social change" are being processed on computer for a detailed multivariate analysis. The results of analysis show a high correlation between value-orientation and the daily behaviour in rural society.

(b) An analysis of data collected from rural Giridih concerning the aged people raises doubts regarding the empirical validity of the "Disengagement Theory" in agrarian society.

5. Research work was continued in the following areas:

(a) Analysis of data related to continuity in peasant uprisings in Bengal since the introduction of the colonial rule; (b) Explication of the impact of popular upsurges during the terminal years (1945-47) of British rule, leading to the transfer of power in the subcontinent; and, (c) Stresses and strains in the communal situation in contemporary India—their variations and the process of historical evaluation of these variations.

6. Another investigation was undertaken to study people's perception about risks and development, the carrying capacity of land in terms of human population and the on-going changes at the grass-root level.

Project work: Externally funded projects

1. *Evaluation of Rain-fed farming (ISI-HFCL Project).*

Sponsored by the Overseas Development Administration (ODA) of Government of U. K., the Hindustan Fertiliser Corporation Ltd. (HFCL) in consultation with the Overseas Development Group (ODG) of the University of East Anglia at Norwich, U. K., has undertaken a project on how to promote and stabilise farmer participatory, sustainable agriculture under rain-fed condition of the East Indian plateau region. With this aim project activities are being undertaken in villages located in 8 districts of three states of Eastern India—namely, West Bengal, Bihar and Orissa.

As requested by HFCL and ODA, ISI has agreed to evaluate the impact of these activities as well as evolve appropriate methodology in this regard. Scientists

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from Social Sciences, Biological Sciences, and Applied Statistics Divisions of ISI are working as a team in this regard.

First year's field work for the Base—Line Survey (BLS) and Annual Monitoring and Evaluation Survey (AMES) was completed. A report was prepared based on first year's work. Second year's for AMES was in progress.

2. *Perception, performance and potential of development in Uri water-shed area of Bihar plateau—An eco-systemic approach* (ICSSR—Funded project).

Bihar although immensely rich with natural resources, is considered one of the poorest states of India with near stagnation in terms of growth rates by gross domestic product and agricultural productivity. Again, when we focus on Chhotanagpur plateau in Bihar accounting for 46 percent of the State's geographical area, the picture turns further dismal.

This study was taken up in the watershed of Uri flowing through Giridih district in the eastern part of Chhotanagpur plateau. As a component of agro-ecosystem, it represents a major part of the plateau. It is mostly inhabited by tribals. This study intends to explore linkages between cropping system and ecology in an area, generally held as socially and economically backward, and to suggest ways and means for improving upon man-environment relationships in accordance with the perceptions and involvement of the people of the area.

Finalization of questionnaires, check lists and mapping were completed. The field work for the study was also nearly completed.

3. *Guidance and Consultancy services in Data Processing* (funded by ICSSR)

Since 1988, the Sociological Research Unit (SRU) has been conducting a programme. "Guidance and Consultancy Services in Data processing", under the auspices of ICSSR, New Delhi. The faculty of SRU have been providing guidance to Ph.D. scholars from different Universities in Eastern India.

4. *ICSSR Post-doctoral Fellowship Programme*

Dr. Anil Kumar Choudhuri, Post-doctoral Fellow of ICSSR, worked on the project of ICSSR. "Socio-economic mechanism for the survival of landless agricultural labour in rice areas of West Bengal : Two case studies" under the guidance of the Head, Sociological Research Unit. Field work for the study was completed and analysis of data and report writing was in progress during 1990-91.

Other projects

1. *Peasant movements during the early phase of colonial rule in Bengal :*

Data collection from the State Archives and records preserved in the District Collectorate of West Bengal was completed. The final report was under preparation. Three papers based on the study were published and three others were presented to seminars.

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2. *A study of educational wastage (stagnation and drop-out) at primary and middle school levels :*

This project was conducted in collaboration with the Population Studies Unit. Field work for rural areas was completed. Data editing and tabulation work was in progress.

3. *Application of reciprocity measure as an indicator of balance in international trade by countries and commodities :*

This research project was undertaken in collaboration with the scientists of Theoretical Statistics and Mathematics Division of ISI. A technical paper was under preparation.

Statistical Quality Control and Operation Research

Introduction :

The SQC and OR Division was started in 1953. Over the years it has grown to 11 operating units scattered throughout the Country. They are located at Bangalore, Bombay, Baroda, Calcutta (2 units), Coimbatore, Hyderabad, Madras, New Delhi, Pune and Trivandrum. The SQC & OR Division is primarily devoted to professional work in the field of Quality Control, Operations Research, Reliability and soft-ware development programme in Quality Control work. It renders assistance and expert advice to manufacturing industries, takes up project assignments in the field of Quality Control, Operations Research and other related areas. The main thrust of the Division is to promote and propagate SQC and other quantitative techniques, helpful in augmenting production and productivity. These are carried out through plant visits, organising Seminars and by organising training programmes at the plant level from operators to the top management. Training programmes are mostly directed towards motivating the work force and getting support from the top management in carrying out quality activities as a routine exercise.

The specialists of the Division also take up regular teaching assignments in academic courses of the Institute, e.g., M.Tech (QR & OR), M.Stat. B.Stat. ISEC courses and evening courses at many of the Centres and Units of ISI listed above.

The specialists of the Division are also engaged in theoretical as well as applied research in their respective fields besides routine activities of teaching and professional work.

A few soft-wares developed by the SQC and OR Division have successfully been operated in a few plants and were demonstrated at seminar organised independently or jointly with other organisations, such as Confederation of Engineering Industries.

A comprehensive package on SPC (Statistical Process Control) tools and other statistical methodology for suitable routine work, have been developed. It has been

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demonstrated successfully, at various industries with live data from the respective units. The package is now ready for use.

The Division has initiated work in two major directions and steps have been taken to set up a Research Cell at Bangalore and a Centre for Training of Managerial Personnel at Hyderabad.

The Division, besides carrying out regular activities have maintained liaison with other organisations and universities in exchanging technical and teaching expertise. The Division has close relation and collaborative activities with the Bureau of Indian Standards, National Productivity Councils and local Productivity Councils, Indian Institute of Management, Defence Organisations, Universities and professional organisations, such as the Operational Research Society, IAPQR, NIQR, CEI, etc.

2. *Consultancy Service and Projects*

During the period under review 63 organisations were availing themselves of the services of the Division ; 29 new organisations were taken up for service, 88 training programmes were organised, 72 organisations were visited for promotional work, 22 surveys were carried out, and 28 promotional reports were sent.

Projects involving SQC and OR methods were carried out in various organisations involving various types of problems. Some of the areas of work are : computer application in Quality Management, general purpose computer software on simple statistical tools, design and analysis of mixture experiment, and utility package for disc screen management, optimal control of conductor dimensions for telecommunication cables, sampling scheme for carrick detonator, evaluation of outgoing quality and development of system of control for foils, control of cabinet shrinkage in PU foam process, and energy conservation in plant.

3. *Education and Training*

In-plant training programmes for executives, technologists and other production personnel including operators were continued during the period under review. The training programmes for executives BHEL at various levels continued. One year special programme at Madras for BHEL Executives continued.

During the period under review, 2176 managers and technologists were given training in SQC methods. In addition, 215 trainees at post-graduate/post master's degree level underwent training at Calcutta, Delhi, Bangalore and Madras, and in part-time Certificate Courses in Hyderabad and Bangalore. Further, 12 SDP Fellows were trained during the period.

The Division shared a fairly heavy load of teaching in the academic courses of the Institute, at all the centres. The faculty members of the Division have taken all the courses prescribed for the Diploma in SQC and OR and M.Tech. (QR and OR)

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at Calcutta, and for the Diploma in SQC and OR at Madras and Bombay (part-time). The Division also assisted in the following teaching programmes :

- (a) M.Tech. in Computer Science,
- (b) B.Stat. and M.Stat. Courses,
- (c) Part-time Certificate Courses at Bangalore and Hyderabad,
- (d) ISEC Courses at Calcutta and Bangalore,
- (e) Part-time Courses on Statistical Methods at Calcutta, Hyderabad and Delhi,
- (f) One year special programme at Madras for BHEL,
- (g) Junior Certificate Course at Calcutta, and
- (h) Training of SDP.

4. Research :

Applied and theoretical research were carried out in different areas. Some of the areas of work are : Bayesian three decision accepting sampling plans, sampling plan under stratified random sampling schemes for in-process inspection, Fuzzy goal programming in acceptance sampling, Optimum investment in drilling, approximations of doubly non-central Z distribution, strongly balanced uniform measurement design, Life testing experiment and minute analysis, parametric design and global optimisation, trim-loss problem, optimisation of fuel injection system, Linear Complementarity problem with N and N_0 matrices, characterisation of P-matrices, optimum, allocation of parallel-series and series-parallel systems, Optimisation of bicriteria, quasi-concave function, control of rotor-stator gap. A Ph.D. has been obtained in the field of optimum decisions in geological exploration on mining investment. A book on coherent structures was also published. During the period under review 20 papers were published, 10 papers were accepted for publication, 16 papers were sent for publication, 21 papers were read at conferences and/or were accepted for conference proceedings, 10 technical reports were published and 16 manual were prepared.

5. Promotional Activities :

Introductory visits were paid to 73 factories ; 22 surveys and/or pilot projects were carried out and 28 promotional reports were sent. The surveys covered various types of industries. These include : textiles, printing press, aluminium, cell dry battery, refractory, aluminium foil, textile machineries, explosives, telephone cables, automobiles, antibiotics, electronics, heavy machinery, machine tools etc.

The specialists of the Division delivered 397 lectures and talks to various organisations/institutions on different aspects of Quality Control and Operations Research, including Quality Management.

The specialists from the Division attended 42 seminars in the field of quality control and relevant statistical techniques/theories. During the period under review, 56 seminars were organised by the various Units of the Division.

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Library, Documentation and Information Sciences

Documentation Research and Training Centre (DRTC),
Bangalore

The activities of DRTC have been organised under the following heads : (1) Research programme ; (2) Advisory services programme ; (3) Extension programme ; (4) Publication programme ; (5) Educational and training programme ; (6) Employment Information programme ; (7) Continuing Educational and Training programme and (8) Faculty Development programme.

The following is the report of the activities of DRTC during the period from April 1990 to March 1991 :

1. *Objectives and Programme of Activities :*

The objectives of DRTC are the following : (a) To contribute to the development of the different branches of the discipline. "Information Sciences" including "Documentation" and "Library Science", by carrying out, guiding, and supporting research and development activities in the concerned fields, aiming at the development of expertise and excellence in the different branches of Information Sciences.

(b) To promote the development of "Information Centres" including Libraries, Documentation Centres, Data Centres, Information Clearing Houses, Information Analysis and Consolidation Centres, Archives, etc., by offering advisory services in designing specific development plans ; professional tools ; professional techniques, method and procedures ; information service products ; etc., as a particular situation warrants it and admits of, specially in response to specific formal requests.

(c) To disseminate results of research, information analysis and consolidation, advisory services, and of compilations in the different branches of "Information Sciences" including "Documentation" and "Library Science", through publications and extension services, as the case may be.

(d) To develop manpower equipped with appropriate professional knowledge, understanding and skills, that is capable of participating efficiently and effectively in: the (i) Management, i.e., design, development, organisation, implementation, operation, control, evaluation, etc. of information service systems, centres, programme and projections ; and (ii) In advanced teaching and research in the field of "Information Sciences" including "Documentation" and "Library Sciences" by conducting appropriate professional educational and training programme.

(e) To ensure and promote the professional advancement of the educated and trained manpower by organising and conducting continuing educational and training programmes on professional topics and disciplines.

2. *Training in Documentation and Information Science :*

Course Leading to "ADIS Award" : Under its Educational and Training Programme, DRTC conducts a course of 24-month duration leading to the Award of

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"Association in Documentation and Information Science" (ADIS). This award is recognised by the Govt. of India as equivalent to a Master's Degree in Information Science. Normally, the entry qualification for ADIS course is a post-graduate degree in "Library and Information Science", BLIS or its equivalent. Not more than ten students are admitted in each academic session of 24-month duration.

Seven students had been selected for the academic session, 1988-90 (24 months) on the basis of All-India admission test and interview. They appeared in the final examination in 1989 after completing their formal residential part of the course of 12 months. Subsequently, they were engaged in their respective guided research projects. They submitted their dissertations in August 1990. The final results of the course were declared in November 1990. All the seven students were passed and obtained first class.

For the academic session 1989-91 (24 months), eight students had been admitted. All the eight students completed their formal residential part of the course in August 1990 and appeared in the final examination held in 1990. They were then assigned to work on their respective guided research projects.

The academic session 1990-92 (24 months), commenced on 1 September 1990. Six students were selected for this session, and all of them joined the course.

Educational Study Tour by ADIS Students. 1990-91 : It was not possible to conduct any educational study tour for the ADIS students during the financial year 1990-91 due to stringent economic measures.

90A Short-term Course on Computerized Information Work and Service :

This course was conducted during the period from January 16 to February 28, 1991. Fifteen candidates satisfying the necessary conditions were admitted. All the candidates completed the course successfully by meeting all the requirements.

3. Research Activities :

The main areas of research in which the different members of DRTC faculty were engaged during 1990-91 are indicated below :

1. Preparation of the State-of-the-art report on the "Methodology of Constructing Vocabulary Control Devices", such as Schemes for National Depth Classification, Thesauri and Classauri.
2. The preparation of a Manual for the construction of a Classaurus.
3. The designing of a "Classaurus for the depth indexing of micro subjects going with the base, Agriculture and related Sciences and Technologies".
4. The demonstration of the use of the above-mentioned Classaurus.
5. The application of the "Colon Classification, Ed 7", for the purpose of (a) arranging documents ; and for (b) documentation work and service.

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6. The designing of a "Multi access Thesaurus".
7. The study of the varieties of "Thesaurus-Structures/Formata" from the point of view of their impact on information retrieval.
8. The study of various methods of knowledge representation, such as semantic nets, frames, and predicate calculus; and of their related features, to ascertain their relationship to the classificatory language of colon classification.
9. The designing and development of Notational Depth indexing classification schemes, Thesauri and Classauri, for the depth indexing of micro subjects going with various disciplines.
10. The application of modern scientific Management Techniques to the planning and Management of Information Systems, Centres, and Services.
11. The study of the methodologies of Information Analysis and Consolidation.
12. The preparation of a state-of-the-art report on "Performance Standards in the field of Secondary Information Work and Service".
13. The development of bibliometric measures for evaluating the use of Library and Information Services.
14. The preparation of guidelines for developing software and application packages for house-keeping operations of information centres, such as, Circulation Control, Serial Control, and Acquisition Control.
15. The development of a Computerized tutorial for CDS/ISIS (Mini, Micro Version).
16. The development of a computerized manpower planning model for Information Centres.
17. Restructuring of curricula and syllabi specially for the advanced courses on information science including documentation and library science with a view to accommodating essential contents pertaining to the appropriate advances in information technologies.
18. Applications of computer-based natural language processing in identifying descriptors for contents of documents.

4. *Project Work (Externally funded project)*

Short Term Course on Computerized Information Work and Service (Sponsored by the NISSAT):

Under the sponsorship of the National Information System for Science and Technology (NISSAT) forming part of the Department of Scientific and Industrial Research (DSIR), Government of India, New Delhi, DRTO has been conducting a

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six-week course on "Computer Applications to Library and Information Work" since 1986. Normally, two such courses are conducted during each financial year. During the period from April 1990 to March 1991, only the 9th course could be conducted as the sponsoring agency could not provide funds for conducting two courses. (See also Section 2 above).

Central Library (Calcutta)

The Institute maintains a Central Library at Calcutta. With the addition of 925 books and 2 new journals to the stock, the total collection of the library rose to 1,82,377.

Acquisition : The Central Library accessioned 925 books during the period under report, out of which 642 were purchased, 38 received on subscription, 211 received as gift and 34 were received on an exchange basis. It also acquired 171 books for the Statistical Workers' Circulating Library.

Periodicals : The Central Library received 1,337 periodicals out of which 244 were received as gift, 612 against subscription and 481 on exchange arrangement with national and international organisations. The Library also acquired 28 new journals. 13 new journals were subscribed under NBHM grant. It accessioned 733 journals and completed the technical processing of 561 journals.

Circulation and Stack Maintenance : The Central Library issued 45,690 books and journals to the users on loan and reference. The total membership of the Library was 1772 (after the introduction of New Library Rules from May 2, 1988), out of which 109 memberships were withdrawn. The total membership includes ISI staff, research scholars, project assistants, students of B.Stat., M.Stat., and M.Tech. courses, ISEC trainees etc., as well as outside students and Institute members. In addition, 402 readers were given special permission to use the Library for short periods. During the year 1990-91, 45 books and journals were borrowed from other libraries and 19 books and journals were loaned to other libraries, under the inter-library loan arrangement.

Reports and Records : The Central Library accessioned 607 titles and processed 598 titles. During the year under review, 1567 titles were issued to the borrowers.

Circulating Library : The Statistical Workers' Circulating Library acquired 171 new titles bringing the total collection to 34,331. It issued 24,641 books to the members.

Technical Processing : The Central Library classified 363 books and catalogued 706 books.

Reprography and Photography : The Central Library provided 5,27,828 xerox prints for the users during the period under report. In addition, 731 frames of photographs of different nature, 3,945 prints of photographic enlargements, 524 frames of

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microfilming from drawing books, charts, journals etc., 180 frames of lecture slides and 28,200 off-set prints were made during the year 1990-91.

Bangalore Centre Library

Acquisition : During the year 1980-91, 829 books were added to the library by purchase and 25 books were received on gratis.

Periodicals : As regards periodicals, 495 volumes were bound and added during this period to the existing stock of 4135 bound volumes. In addition to 264 titles, 5 new periodical titles were ordered. There was no cancellation of periodical titles. All the titles subscribed for 1990 were continued for 1991 subscriptions also.

Stock position : The total stock position as on 31 March 1991 was as follows : Books—11,808 ; Books on gratis 833 ; Bound volumes of periodicals—4,630 ; No. of periodical titles subscribed—271 ; No. of periodicals received on gratis—27.

Technical Processing : About 800 books were classified and catalogued during the year. Nearly 4000 catalogue cards were filed.

Circulation Statistics : During the year, library facilities were enjoyed by 160 readers, and 95 of them availed themselves of the lending facilities. 5 visiting Professors/Scientists of ISI were also provided with the lending facilities. A total of about 8,800 books and periodicals (including loose issues) were issued by the Library. The in-house use of books and periodicals was around 28,500. About 196 inter-library loan transactions were registered.

The membership includes ISI staff, research scholars, project assistants and M.Tech. students, SDP Fellows, D.R.T.C. students, trainees of DRTC short-term Computer Course etc.

Inter-Library Loan Service : Inter-Library loan facilities were availed of by staff, students etc. of Indian Statistical Institute, Bangalore Centre. The library also extended inter-library loan facilities to users from different local libraries.

Reprographic Service : Modi xerox machine model 1025 Z was installed in the library on 11 September 1990. From then onwards, reprographic service was provided to the users. From the date of installation to 31 March 1991, the number of xerox copies supplied was 35,530.

Documentation Service : Bi-monthly lists of additions to the stock of books were issued from time to time. The monthly list of current periodicals was also brought regularly.

Delhi Centre Library

Acquisition : Due to budget constraints, only 174 new books could be purchased and added to the stock during the year 1990-91. In addition, 250 publications were received as gift from various sources and agencies. The personal collection of about

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600 publications belonging to Late Professor Prem S. Puri received as gift by Delhi Centre Library. Besides these, 47 publications were procured by the Acquisition Section for use of students and researchers of the Institute. About 150 Technical reports/Discussion papers/Reprints etc. were received during the period from different institutions of India and abroad.

Periodicals : 287 titles of journals, foreign as well as Indian, were subscribed during the year. In addition 19 titles of journals were received as complimentary or against exchange programme. Further 6098 sets of loose issues of journals, duly bound, were added to the stock. Some new titles of the journals were subscribed while some other titles were discontinued. In addition, exchange programme of journals was established with various Institutes for exchange of their Technical papers/journals with Discussion Papers of the Institute.

Circulation : During the period under review, 544 persons enjoyed the Library membership with 401 as temporary members availing themselves of the reading room facilities only and 143 as permanent members availing themselves of the lending facilities. Approximately, 7282 publications were circulated during the period among its members.

Under the inter-library loan service programme, about 114 publications were lent out to the neighbouring institutions and libraries and 48 publications were borrowed from them for use by members of the Delhi Centre Library.

Reprographic Services : 32,830 photocopies were made during the period on the request of users of the library. Reprographic facilities were also provided to researchers of other institutions on a nominal payment of Rs. 0.50 per page.

Other activities : As in other years this year too Library Trainees with remuneration were appointed. At the end of their training, each trainee was given an experience certificate.

3. SYMPOSIA, SEMINARS, LECTURES AND CONFERENCES

Among different conferences, symposia, seminars, workshops and lectures organised by the Institute during the year 1990-91 mention may be made of the following :

3.1 *Symposia, Conferences, Workshops etc.*

A Workshop on Linear Models and Design of Experiments was held during 27-29 December 1990, at Calcutta and was organised by the Theoretical Statistics and Mathematics Division (Stat-Math Division). The following persons presented talks on recent developments in these areas : Professor K. V. Mardia, Professor J. S. Rao, Professor K. R. Shah, Professor D. Majumdar, Professor A. Mukhopadhyay, Professor S. K. Mitra, Professor T. Mathew, Professor R. Mukherjee, Professor C. R. Rao, Professor P. K. Sen, Professor M. Ghosh and Professor S. K. Chatterjee.

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The Winter School on Algorithms and Computational Complexity was held at Calcutta during 10 December 1990 to 11 January 1991 and was organised by the Stat-Math Division. The following persons gave lectures on modern developments and research problems in the above areas: Professor A. Bagchi, Professor R. Lasker, Dr. Aditya Bagchi, Dr. Rana Barua, Dr. B. B. Bhattacharya, Dr. A. Goswami, Professor S. B. Rao, Professor A. R. Rao, Dr. K. Sikdar, Dr. S. M. Srivastava, Dr. K. S. Vijayan, S Bri S. C. Nandy and Mrs. S. Sur. This programme was organised by Dr. K. Sikdar.

R.A. Fisher Birth Centenary Seminar was held on 30 December 1990 and this was organised by the Stat-Math Division. Professor S. Dasgupta gave an introductory lecture following on Fisher's work in a social perspective. Professor C. R. Rao, Professor P. K. Sen and Dr. P. P. Majumdar discussed the important contributions of Professor R. A. Fisher.

An International Workshop on Quantum Probability and Applications was held at New Delhi during 31 December 1990 to 4 January 1991 jointly with NBHM. Forty delegates participated in the Workshop. It was organised by Professor K. R. Parthasarathy and Professor K. B. Sinha.

A Conference on Recent Developments in Probability and Statistics in Memory of Professor C. G. Khatri was held at Delhi University during 22-24 December 1990 jointly with the Department of Statistics of the Delhi University. Sixty delegates participated in the Conference. This conference was organised by Professor S. K. Mitra.

The International Conference on Game Theory and Economic Applications was held at ISI, New Delhi, during 18-22 December 1990. Eighty delegates participated in the Conference. The Conference was organised by Professor T. Parthasarathy.

An Instructional Conference on Operator Algebras was organised at the Bangalore Centre of ISI during 11-30 June 1990. About twenty-five external delegates and ten local scholars participated in the Conference. Besides Dr. V. S. Sunder, Dr. V. Pati and Dr. G. Misra of the Stat-Math Unit of ISI Bangalore Centre, Professor Klaus Thompson from Denmark gave lectures in the Conference. This Conference was funded by the National Board for Higher Mathematics.

A three-week Workshop on "Mixed Hodge Structures" was organised by Dr. V. Pati at the Bangalore Centre during 22 July 1990 to 4 August 1990. Four scholars from TIFR, Bombay, participated in this Workshop.

A Seminar on "Problems of Large Scale Sample Surveys in India" was held at ISI, Calcutta, during 20-27 December 1990. It was organised in 3 sessions by the Applied Statistics, Surveys and Computing Division and 69 scientists participated in these sessions. The first two sessions were held on 26 December 1990, and the

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third on 27 December 1990. Papers were presented by invited speakers and each presentation was followed by observations of the official discussants and then by floor discussion. In addition to participants from RBI, (SO, IIMC etc., Dr. P. Visaria, Chairman—designate and Professor B. S. Minhas, outgoing Chairman of the Governing Council of NSSO, were also present. Also theoreticians like Professor H. Steyer, University of Mannheim, Professor P. K. Sen, University of North Carolina, Professor A. R. Sen, University of Calgary, Professor S. P. Mukherjee, Calcutta University, Professor Rahul Mukherjee, IIM, Calcutta, Professor A. Goon, Presidency College, Calcutta, Dr. Dibyen Majumder, University of Illinois and other scientists from ISI participated. The seminar was organized by Dr. Anup Dewanji of ISI Calcutta.

In session I, which was presided over Prof. J. Roy (ISI), papers of theoretical results on sampling strategies were presented by Professors Rahul Mukherjee (IIMC), Arijit Chaudhuri (ISI), H. Steyer (University of Mannheim), Shibdas Bandyopadhyay (ISI), A. K. Adhikari (ISI) and Dibyen Majumder (University of Illinois). Discussants in this session were Professors Debesh Roy (Presidency College), S. Sengupta (Calcutta University), Rahul Mukherjee (IIMC), T. Krishnan (ISI), J. Roy (ISI) and Bikas K. Sinha (ISI). Session II, chaired by Prof. B. S. Minhas (NSSO), was devoted to papers stressing on the applied aspects of sample surveys and the contributors were Professors S. P. Mukherjee (Calcutta University), V. N. Reddy (IIMC), J. Roy (ISI), K. V. R. V. Rao (NSSO), V. K. Rajagopalan (NSSO) and S. Roy (NSSO). Discussants in this session were Professors A. M. Goon (Presidency College), Prabir Chaudhuri (NSSO), S. P. Mukherjee (Calcutta University), Arijit Chaudhuri (ISI), T. Krishnan (ISI) and N. R. Pal (ISI). Session III was specially meant for papers relating to problems of large-scale surveys like NSS and Prof. A. R. Sen (University of Calgary) presided over this session. Contributors of this session were Professors V. Anandan (NSSO), R. Sathyanarayana (RBI), A. M. Goon (Presidency College), Parimal Mukhopadhyay (ISI), K. Sankaranarayanan (NSSO) and P. Chattopadhyay (NSSO). Discussants in this session were Professors P. Mukhopadhyay (ISI), T. Krishnan (ISI), Shibdas Bandyopadhyay (ISI), Pulakesh Maiti (ISI), A. K. Adhikari (ISI) and R. Mukherjee (ISI).

An International Workshop on Application of Statistical Methods in Theoretical Physics and Fluid Mechanics was organised by the Electronics Unit at Calcutta during 8-15 January 1991. About 65 delegates participated in the Workshop.

A Symposium on Cultural and Genetic Diversity in Indian Population (jointly organised by Professor K. C. Malhotra, Anthropometry and Human Genetics Unit of ISI, Calcutta, and Professor Madhav Gadgil of Indian Institute of Sciences, Bangalore) was held at Bangalore centre of ISI during 27-29 January 1991.

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The Economic Analysis Unit of ISI Bangalore Centre conducted its second Summer Course in Quantitative Economics from 26 April 1990 to 25 May 1990, for the benefit of research scholars, college teachers of various universities and State Government Officers engaged in quantitative analysis of economic data.

A one-day Workshop on "Economic Theory and Rural Institutions" was organised by the Economic Analysis Unit at Bangalore on 29 December 1990. Speakers included Professors V. M. Rao and Abdul Aziz from the Institute for Social and Economic Change (ISEC), Bangalore, and Dr. S. Shivakumar from Madras University, Madras.

The Economic Research Unit at ISI, Calcutta, organised an Economic Institute Workshop under the auspices of the United States Educational Foundation in India (USEFI) during 16-31 May 1990. In this Workshop, faculty members of ERU and some invited speakers from other institutions in Calcutta delivered lectures on statistics, econometrics, mathematical methods in economics, Indian economic problems, etc., to 26 participants who were teachers of economics in colleges and universities in different parts of India.

A Workshop on Computer applications in Quality Management and Control was organised by SQC Unit of ISI, Calcutta, during 16-16 January 1991. 35 executives from different industries participated in the Workshop.

A Workshop on Quality Cost Evaluation, Control and Management was organised by SQC Unit of ISI, Calcutta, on 23 June 1990. About 70 persons participated in the Workshop.

A two-day Workshop on Quality Assurance for Senior Executives of HAL at Bangalore Complex was organised by SQC Unit of ISI Bangalore Centre, at Bangalore, during 6-8 November 1990 for a batch of 30 Executives.

A Workshop for the Top Management at Madras was organised on Company wide Quality Management and on ISO 1000 Series. C. A. Setty and A. N. Nankana delivered talks at the Workshop.

A two-day Symposium was organised by the SQC Unit of ISI, Calcutta, jointly with the Confederation of Engineering Industries at Taj Bengal during 15-16 January 1991, on 'Statistical Process Control Tools—A Software Package', developed by SQC Unit, Calcutta. About 40 Executives from different organisations participated in the programme.

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A seminar on 'Industrial Information Systems and Services' was organised by DRTC, Bangalore Centre from 21 to 23 May 1990. The leading presentations were made by Sri B. S. Ramananda, Adviser, Titan Watches, Bangalore. Professor S. Seetharama presided over the seminar. About 30 participants attended the seminar.

Every year, DRTC organizes special seminars on the occasion of Professor Ranganathan's birthday. This year too, seminars on 'Ranganathan's Teaching Methods, and on 'Developments in Informetrics' were organized, one in the morning and the other in the afternoon on 8 August 1990. Professor G. Bhattacharyya made the leading presentation in the morning seminar and Dr. I. K. Ravichandra Rao made the leading presentation in the afternoon session. About 30 participants attended the seminars.

A Chinese delegation from China Society for Scientific and Technical Information (CSSTI), Beijing, consisting of six scientists under the leadership of Mr. Ting-Jiong Wang visited DRTC on 6 September 1990 for the purpose of knowing in detail the objectives, functions and achievements of DRTC, and to inform us about those of CSSTI. A Seminar on DRTC and CSSTI : Their Objectives, Functions and Achievements was held on this occasion at DRTC (Bangalore) on 6 September 1990. The leading presentation on DRTC was made by Professor G. Bhattacharyya; and on CSSTI, by Mr. Liu Yi. About 30 participants attended the seminar.

Every year, on the death anniversary of Dr. S. R. Ranganathan, DRTC organizes a special seminar under the title "Five Law Lectures". The 18th lecture in this series on Information Systems and Services for International Tendering, was organized by DRTC in the Institute of Information Studies, Rajajinagar, Bangalore, on 27 September 1990. Dr. (Mrs.) Ranjita Chandran, Manager, Information Systems, HMT Ltd., Bangalore, was invited to deliver the lecture. About 60 participants attended the lecture.

A Seminar on the 'Latest Developments on Depth Indexing' was held on 22 October 1990 for the participants from Afro-Asian countries who attended a short-term "International Course on Information Storage and Retrieval" conducted by the National Institute for Small Industry Extension Training (NISLET), Hyderabad, during their visit to DRTC for study tour. The leading presentation was made by Professor G. Bhattacharyya. About 10 participants attended the Seminar.

3.2 Lectures and Seminars

The following lectures/seminars were arranged during the period :

Theoretical Statistics and Mathematics, Calcutta

Professor V. Ramaswami, Bell Communications Research Inc., U.S.A. (\$6.6.90) :
Applied Probability in Telecommunications.

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Dr. Anis Maitra, Statistical Advisor, UNO (12.7.90): Statistical Training as promoted by United Nations.

Professor N. D. Chakraborty, University of Burdwan (23.7.90): A survey of results related to Pittis integration.

Dr. Prabir Burman, University of California, Davis, U.S.A. (3.9.90): Some issues in cross-validation.

Professor M. S. Raghunathan, T.I.F.R., Bombay (7.9.90): Flows on homogeneous spaces.

Professor K. V. Mardia, University of Leeds, U. K. (27.12.90): Statistics of shape with image analysis, applications.

Professor T. Mothew, University of Maryland, Baltimore County, U.S.A. (28.12.90): Non-negative variance component estimation.

Professor M. Ghosh, University of Florida, Gainesville, U.S.A. (29.12.90): Hierarchical and empirical bayes multivariate estimation.

Professor S. K. Chatterjee, University of Calcutta (29.12.90): Multivariate general linear model with applications to design.

Professor P. J. Lahti, University of Turku, Finland (18.1.91): Quantum probability and theory of measurement.

Professor Rahul Mukherjee, Indian Institute of Management, Calcutta (18.3.91): Conditioning and power: higher order asymptotics.

Delhi

Dr. Girish A. Aas, University of Santa Barbara (1.8.90): Randomly stopped averages and their applications to sequential estimation.

Mr. Pradipta Bandyopadhyay, ISI Calcutta (7.8.90): Mazur Intersection property in Banach Spaces—An overview.

Dr. Rahul Roy, ISI Delhi (8.8.90): Percolation of Poisson sticks on the plane.

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Dr. Bikas Sinha, ISI Calcutta (7.9.90) : Statistical methods for combining expert opinions.

Dr. O. P. Sharma, IIT Delhi (10.9.90) : A new approach to the $M/G/1$ queue.

Dr. A. V. Nageev, Institute of Mathematics, Uzbekistan (21.9.90) : Asymptotic properties of location scale invariant tests.

Dr. Trilochan Shastri, M.I.T. (15.10.90) : Polyhedral structure of the product cycling problem.

Professor Ed Green, University of Minnesota (12.12.90) : On Pseudo random inference.

Sir Michael Atiyah, F.R.S. (27.12.90) : Interacting Solitons.

Professor Malay Ghosh, University of Florida (8.1.91) : Bayesian Pitman Closeness.

Dr. S. C. Kochar, ISI Delhi (16.1.91) : Statistical inference for the k -sample Hazard rate ordering problem.

Professor P. K. Sen, University of North Carolina (18.1.91) : Pitman closeness of statistical estimates.

Professor S. C. Kochar, ISI Delhi (23.1.18) : Testing for the proportionately of cause specific hazard rates in the competing risk problem.

Professor B. L. S. Prakasa Rao, ISI Delhi (30.1.91) : Cramer-Rao type integral inequalities.

Professor A. Dey, ISI Delhi (6.2.91) : Minimally connected optimal block designs.

Dr. C. G. Bhattacharya, ISI Delhi (20.2.91) : Estimation of a function of scale parameters of two gamma distributions with applications.

Mr. P. K. Srinivasan, Secy., Asst. Math Teachers of India (28.2.91) : Mathematics education in Indian Schools.

Mr. Saunak Sen (6.3.91) : Exponential random variables and the PPSWOR sampling scheme.

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Professor T. Parthasarathy, ISI, Delhi (13.3.91) : An operator solution to stochastic games.

Mr. Arusharka Sen (20.3.91) : Uniform strong consistency of conditional L -statistics.

Dr. H. L. Manocha, ISI, Delhi (31.8.90) : Lie theory of hypergeometric functions on solutions of 4-variable wave equation.

Dr. Rajendra Bhatia, ISI, Delhi (28.8.90) : Eigenvalues with symmetries.

Shri Arvind Lal, ISI, Delhi (4.9.90) : Coxeter graphs and path positivity.

Shri T. Bhattacharya (11.9.90) : The Hilbert matrix.

Dr. H. L. Manocha, ISI, Delhi (18.9.90) : Lie theory and special functions.

Dr. H. L. Manocha, ISI, Delhi (18.9.90) : q -representation of $sl(2, \mathbb{C})$.

Dr. T. Parthasarathy, ISI, Delhi (25.9.90) : Linear complementarity problem and completely mixed games.

Dr. Kalyan B. Sinha, ISI, Delhi (16.10.90) : Interpolation of operators.

Dr. G. B. Folland, University of Washington (7.11.:90) : Wavelets and their applications.

Ms. Snehlata, ISI, Delhi (13.11.90) : L -sequential graphs.

Abhay Bhat, ISI, Delhi (12.3.91) : Martingale problems and Markov processes.

Bangalore

Professor M. S. Raghunathan of TIIPR, Bombay (8.6.90) : Arithmetic Groups.

Dr. Girish Aras, University of California (10.8.90) : Moments of randomly stopped averages and their applications to sequential estimation.

Professor K. B. Athreya, Iowa State University (16.8.90) : Bootstrapping the empirical distribution function.

Professor G. B. Folland, University of Washington (26.9.90) : Meta-Heisenberg Group.

Dr. Vinod Sharma, Department of Electrical Engineering, I.I. So., Bangalore (8.11.90) : Stability of Communication Networks.

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3.2 *Applied Statistics, Surveys and Computing*

Dr. Shibdas Bandyopadhyay (3.4.90) : Impact of FFDA Scheme (WB Government sponsored sample survey project conducted by CSU).

Shri Joydip Mitra (10.4.90) : *QR*-Predictors in Survey Sampling.

Shri D. T. Ghosh (17.4.90 and 28.4.90) : The Optimum Continuous Sampling Plan that Minimizes the Amount of Inspection.

Shri P. Palchowdhury (24.4.90) : How to Identify Efficiently Dishonest Persons in an Ensemble of Honest and Dishonest Persons.

Dr. P. Mukhopadhyay (21.8.90) : Robust Estimation of a Finite Population Variance Under Some Linear Regression Models.

Dr. Anup Dewanji (28.8.90) : A Two-stage Model for Carcinogenesis.

Dr. C. Dattagupta (4.9.90) : Cancer Chemoprevention : An Approach Towards Cancer Control.

Dr. B. N. Mukherjee (11.9.90) : A Simple Iterative Procedure for the Analysis of Correlation Structures.

Dr. P. Mujumder (18.9.90) : Estimating the Age-of-onset Function for a Genetic Disease.

Dr. N. Sarkar (25.9.90) : A New Estimator Combining the Ridge Regression and the Restricted Least Square Methods of Estimation.

Dr. B. K. Sinha (9.10.90) : Statistical Methods for Combining Expert Opinions.

Dr. (Mrs.) S. Bhattacharya (18.10.90) : Predicting a Population Total under Balanced Samples.

Dr. T. Samanta (23.10.90) : Asymptotic Efficiency of Estimators.

Dr. (Mrs.) S. Bhendre (30.10.90) : On the Treatment of Outliers.

Dr. D. Sengupta (8.11.90) : How to Take a New Observation in a Linear Model.

Dr. A. Bagchi (18.11.90) : Object Recognition—a DAI Model and a Possible Software Architecture.

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Dr. T. K. Nayak, George Washington University, (20.11.90) : Comparison of Equivalent Estimators under Generalized Pitman Nearness Criterion.

Dr. S. K. Bhandari (27.11.90) : Multinomial Ranking Procedures : A Comparative Study.

Shri A. K. Adhikari (4.12.90) : On Interpenetrating Subsamples.

Dr. K. R. Shah, University of Waterloo, (11.12.90) : Miming Plots Technique.

Dr. H. Stenger, University of Mannheim, (18.12.90) : Asymptotically Minimax Strategies in Survey Sampling.

3.2 *Electronics*

Dr. Uma Basu, Calcutta University (10.4.90) : Application of Functional Analysis to Continuum Mechanics—Part—I.

Dr. Uma Basu, Calcutta University (17.4.90) : Application of Functional Analysis to Continuum Mechanics—Part—II.

Dr. Uma Basu, Calcutta University (24.4.90) : Application of Functional Analysis to Continuum Mechanics—Part—III.

Dr. K. Hajra, ISI, Calcutta (8.5.90) : Stochastic Processes—Part—I.

Dr. K. Hajra, ISI, Calcutta (15.5.90) : Stochastic Processes—Part—II.

Dr. K. Hajra, ISI, Calcutta (22.5.90) : Stochastic Processes—Part—III.

Dr. K. Hajra, ISI, Calcutta (29.5.90) : Stochastic Processes—Part—IV.

Dr. K. Hajra, ISI, Calcutta (5.6.90) : Stochastic Processes—Part—V.

Dr. K. Hajra, ISI, Calcutta (12.6.90) : Stochastic Processes—Part—VI.

Dr. K. Hajra, ISI, Calcutta (19.6.90) : Stochastic Processes—Part—VII.

Dr. K. Hajra, ISI, Calcutta (26.6.90) : Stochastic Processes—Part—VIII.

Mr. Ashim Roy, ISI, Calcutta (10.7.90) : Modern Differential Geometry—Part—I.

Mr. Ashim Roy, ISI, Calcutta (17.7.90) : Modern Differential Geometry—Part—II.

Mr. Ashim Roy, ISI, Calcutta (24.7.90) : Modern Differential Geometry—Part—III.

Mr. Ashim Roy, ISI, Calcutta (31.7.90) : Modern Differential Geometry—Part—IV.

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- Mr. Ashim Roy, ISI., Calcutta (7.8.60) : Modern Differential Geometry—Part—V.
- Mr. Ashim Roy, ISI., Calcutta (21.8.60) : Modern Differential Geometry—Part—VI.
- Mr. Ashim Roy, ISI., Calcutta (28.8.60) : Modern Differential Geometry—Part—VII.
- Mr. Ashim Roy, ISI., Calcutta (4.9.60) : Modern Differential Geometry—Part—VIII.
- Mr. Ashim Roy, ISI., Calcutta (11.9.60) : Modern Differential Geometry—Part—IX.
- Mr. Ashim Roy, ISI., Calcutta (18.9.60) : Modern Differential Geometry—Part—X.
- Mr. Ashim Roy, ISI., Calcutta (25.9.60) : Modern Differential Geometry—Part—XI.
- Mr. Ashim Roy, ISI., Calcutta (16.10.60) : Modern Differential Geometry—Part—XII.
- Mr. Ashim Roy, ISI., Calcutta (23.10.60) : Modern Differential Geometry—Part—XIII.
- Mr. Prabap Chandra Roy, Hooghly Mohain College (30.10.60) : Film Cooling on a Rotating Disk.
- Dr. P.K. Tapaswi, ISI., Calcutta (13.11.60) : Mathematical Modelling of the Epigenetic System.
- Dr. Asit Kr. Saha, ISI., Calcutta (20.11.60) : Pattern Formation and Morphogenesis—Part—I.
- Dr. Asit Kr. Saha, ISI., Calcutta (27.11.60) : Pattern Formation and Morphogenesis—Part—II.
- Dr. Asit Kr. Saha, ISI., Calcutta (4.12.60) : Pattern Formation and Morphogenesis—Part—III.
- Prof. B. P. Sinha, ISI., Calcutta (7.2.61) : A Worst-case Example for Bottom-up-Heaport.
- Dr. B. B. Bhattacharyya, ISI., Calcutta (14.2.61) : Testable Design of Bilateral Systolic Arrays—Part—I.
- Dr. B. B. Bhattacharyya, ISI., Calcutta (21.2.61) : Testable Design of or lateral Systolic Arrays—Part—II.

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Mr. S. K. Venkatesan, ISI, Calcutta (12.2.91): Chaos in Turbulence—Part—I.

Mr. S. K. Venkatesan, ISI, Calcutta (19.2.91): Chaos in Turbulence—Part—II.

Prof. B. N. Mandal, ISI, Calcutta (26.2.91): Explicit Solution to a Class of Fredholm Integral Equation.

Shri K. Mukhopadhyay, ISI, Calcutta (7.3.91): Design and Optimal Routing of Distributed Loop Networks.

Shri D. Kesava Ram, ISI, Calcutta (14.3.91): A Distributed Shared Memory System for Multiprocessors.

Shri Debashish Das, ISI, Calcutta (21.3.91): Parallel Matrix Algorithms on a Tree Type Architecture.

Shri Anupam K. Basu, ISI, Calcutta (28.3.91): A Discussion on Feature Extraction from 2-D Shapes.

Dr. B. S. Dandapat, ISI, Calcutta (6.3.91): Use of Variational Method to Solve the Integral Equations—Part—I.

Dr. B. S. Dandapat, ISI, Calcutta (12.3.91): Use of Variational Method to Solve the Integral Equations formed from Rotating Couette Flow.

Prof. K. P. Das, Calcutta University (26.3.91): Effect of Viscosity on Benjamin-Fier Instability.

Economic Research

Dr. Sunanda Roy, Jadavpur University (11.4.90): Obsolescence and Economic Lifetime of Machines.

Dr. Tamal Dutta Chaudhury, Calcutta University (18.4.90): Macroeconomic Model with a Binding Foreign Exchange Constraint.

Dr. Sharmila Banerjee, Calcutta University (26.4.90): Dumping and Trade Policy Under the Condition of demand Uncertainty and the Presence of Factor Specificity Together with Factor Inflexibility.

Dr. Chiranjib Neogi, ISI (2.6.90): Structural Changes in Indian Industry: An Empirical Study of Private Cooperative Sector, 1951-1980.

Dr. Tarun Kabiraj, St. Paul's College, Calcutta (8.6.90): Technology and Price in a Non-Cooperative Framework.

Dr. Nirmala Banerjee, Centre for Studies in Social Sciences, (8.6.90): Well-being and Work: Indian Women in Development.

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Dr. Suresh Bandyopadhyay, ISI, Calcutta (13.6.90): Capturing Gross-root Changes: Need for an Appropriate Descriptive Model.

Dr. Malabika Ghosh, ISI, (20.6.90): Credit Market, Sub-contracting and the Informal Sector.

Dr. Chitta Malakar, ISI (27.6.90): Child Mortality in West Bengal.

Dr. Arpita Dhar, ISI (3.7.90): Demand and Supply Constraints for the Indian Industrial Sector: A Disequilibrium Model.

Dr. Pradip Maiti, ISI (11.7.90): On forecasting the Demand for Currencies of Different Denominations in India.

Dr. Meenakshi Miers, ISI (18.7.90): Some Observations on the Role of Money as a Medium of Exchange.

Dr. Buddadeb Ghosh, ISI (25.7.90): A Survey of Studies on Agricultural Wages in India.

Dr. Ashok Maiti, ISI (1.8.90): Perception and Potential of Development: An Agro-Systematic Approach.

Dr. S. P. Mukherjee, ISI (8.8.90): Exponentially Decaying Inventory—I.

Dr. S. P. Mukherjee, ISI (22.8.90): Exponentially Decaying Inventory—II.

Dr. Kriahna Mazumder, ISI (29.8.90): An analysis of the Disproportionality in the Service Sector in India.

Dr. Sarbajit Sengupta, Visva-Bharati, Santiniketan (5.9.90): The Economics of Scale Regulation and Small Scale Industries Policy.

Dr. Sugata Marjit, Jadavpur University (12.9.90): Intersector Linkage and Rural-Urban Migration: Theory and Policy.

Dr. Sanjay Banerjee, Jadavpur University (19.9.90): Tournaments and Sharecropping.

Dr. Sugata Bhattacharya, Carnegie Mellon University (10.10.90): Ex Ante Vs. Interim Rationality and the Existence of Bubbles.

Dr. Satsya Ranjan Chakraborty, ISI, Calcutta (31.10.90): Concentration and Market Power.

Dr. Sugata Marjit, Jadavpur University (7.11.90): Intersectoral Linkage and Rural-Urban Migration.

Dr. Tarun Kaviraj, St. Paul's College, Calcutta (14.11.90): Transfer Under Potential Threat of Entry.

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Dr. Anindita Mukherjee, ISI (21.11.90) : Labour Typing : Some Counter Examples.

Dr. Abhirup Sarkar, ISI (28.11.90) : On the Formation of Agricultural Prices.

Dr. Sanjay Banerjee, Jadavpur University (6.12.90) : Inter-linkage and Adverse Selection.

Dr. Tanuka Bhowmik, Presidency College, Calcutta (12.12.90) : Investment Planning for the Indian Steel Industry.

Dr. Amita Mazumdar, ISI (19.12.90) : Sequential Purchase and Consumer Demand.

Dr. S. P. Chakraborty, University College of North Wales (26.12.90) : Structural Adjustment in Europe.

Dr. Manish Rajan Gupta, Jadavpur University (2.1.91) : A Theory of Two Tier Interlinkage.

Dr. Sanjit Bose, ISI (9.1.90) : Foundation of Kalecki.

Dr. Parimal Bag, Cornell University (16.1.91) : Efficient Allocation of Pie.

Dr. Deb Kumar Bose, West Bengal State Electricity Board, Calcutta (18.1.91) : Investment Planning in Power Sector.

Dr. Bhaswar Mitra, Presidency College, Calcutta (6.2.91) : Migration, Unemployment and Effective Demand : A Re-examination of the Harris-Todaro Model.

Dr. Sugata Marjit, Jadavpur University (18.2.91) : International Trade and Endogenous Production Structures.

Dr. D.S.P. Rao, University of New England, Australia (20.2.91) : An Econometric Approach to the Construction of Generalized Theil-Tornqvist Indices for Multilateral Comparisons.

Dr. B. Ghosh and C. Neogi, ISI (27.3.91) : Technology Intensive Industrialization in LDCs : An Experience of Indian Industries.

Economic Analysis (Bangalore)

Professor P. R. Brahmamanda (10.4.90) : Discussions on Planning Strategies.

Professor P. Chattopadhyay (14.8.90) : "Gorbachev's Economic Reforms : More Socialism or Response to Crisis of Capital Accumulation".

Professor Ian Preston (17.9.90) : "The Treatment of Income and Consumption in the Measurement of Household Welfare".

Professor Kirit S. Parikh (4.10.90) : "Sustainable Development".

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Professor A. Kumar Ganesh (12.12.90): "Methodological Comments on Studying History of Economic Thought".

Professor S. S. Shivakumar (28.12.90): "Agrarian Conditions in 18th Century Tamil Nadu".

Professor B. P. Vani (9.7.90): "Consumption pattern of the Rural Poor".

Professor N. S. Iyengar (9.11.90): "Asymptotic variance for Iyengar's Elasticities—Two examples".

Professor D. S. Praesada Rao (27.3.91): "Index number methods for International Comparisons—Some Recent Developments".

Population Studies

Professor B. D. Misra, Indian Institute of Technology, Bombay (12.6.90): Accelerating family planning performance in Indian States.

Dr. R. Bairagi, ICDDR, Bangladesh (23.7.90): Is discrimination against girls or preference to boys selective in rural Bangladesh?

Mr. Arjun Roy, UGC Research Scholar in ISI, Calcutta (9.10.90): Bongaarts' aggregate fertility models.

Mr. Shantanu Mukherjee, ISI Research Scholar (10.12.90): On derivation of a model for a number of births to a female whose husband is a migrant.

Dr. David R. Phillips, University of Exeter, U. K. (5.2.91): Maternal and child health and primary health care.

Statistical Quality Control and Operations Research

The following promotional lectures and seminars were organised during the period of report:

One day Seminar on 'Quality Management' for Senior Managers on 19.7.90 at Kerala Electric Lamp Works, Alwaye. 20 Managers including Chief Executive attended the Seminar.

One day Seminar for QC Circle was conducted on 20.7.90 at Kerala Electric Lamp Works, Alwaye for Trade Union Leaders. 25 leaders and Deputy Leaders attended the Seminar.

2-day Seminar on 'SQC Techniques and Approaches for higher Productivity and Quality' at Hindustan Latex Ltd., Trivandrum. 35 staff members attended the session.

A seminar on New concepts of Quality by Prof. Y. Kondo. Seminar on Project Scheduling under earliness and tardiness penalties for key events by Dr. N. R.

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Achuthan, School of Mathematics and Statistics, Curtin University of Technology, Bentley, Australia, at SQC Unit, Madras.

Company-wide Quality management by Prof. C. A. Setty, ISO 9000 by A. N. Nankana.

Two half day seminars were conducted in Kannada at M/s. Wiltek Ltd., Mysore by Shri R. Anantha Rao for the benefit of patrol Inspectors, on 20 June 1990. 25 persons attended.

A half-day seminar for the senior executives of HAL Lucknow Division on 23 November 1990. This was attended by 35 senior executives including the General Manager.

A half-day seminar on Canon production system at M/s. Widia (India), Bangalore. 20 senior executives attended.

A couple of seminars organised by Bangalore Centre by Dr. Nilotpal Chakraborty of IIM, Calcutta in March 1991 on 'Complexity of Mathematical Programming algorithms and related topics.

Project presentation of SPC applications dated 12, 13 November 1990 attended by Executives and Technologists at APPM Rajamundry, SQC Unit, Hyderabad.

Seminar on Taguchi Methods on 7 January 1991 attended by Chief Executives at Hotel Banjara, SQC Unit, Hyderabad.

Seminar on Vendor Quality Management on 12 January 1991, attended by Executives at CAFEL, SQC Unit, Hyderabad.

Seminar on organising for Quality improvements on 19 and 20 February 1991. The seminar was attended by Executives of HCL, by SQC Unit, Hyderabad.

A one-day seminar on CWQC at Kerala Electric Lamp Factory, Athani, Alwayse for senior managers by SQC Unit, Trivandrum.

Half day seminar on QC Circles for trade union leaders at Kerala Electric Lamp Factory, Athani, Alwayse by SQC Unit, Trivandrum.

Top Management Seminars dated 1 November 1990 at Oberoi Towers on Taguchi Methods, 11 participants, SQC Unit, ISI, Bombay.

Top Management Seminars on Quality Management dated 14 November 1990 at HAL, Nasik, 30 participants, by SQC Unit, ISI, Bombay.

A two-day seminar on 'Challenges of the Nineties' on 8-9 December 1990 by Shri K. M. Date.

Shri B. K. Pal (11.4.90) gave a talk on 'Emerging Trends in Quality' at M/s. Hindustan Motors, Calcutta.

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Shri C. A. Setty (13.4.90) gave a lecture on 'Role of Operators for Quality' at M/s. TVS Electronics, Tumkur.

Shri K. K. Chowdhury (16.4.90) gave a seminar on 'Quality Function Developments at Indian Telephone Industries Ltd., Bangalore.

Shri B. K. Pal (17.4.90) spoke on 'Quality Control and Human Relations' at the National Labour Institute, Bangalore.

Shri B. K. Pal (18.4.90) gave a talk on 'Sampling Techniques' at Hyderabad.

Shri C. A. Setty (18.4.90) gave a lecture on 'Japanese Production System for Quality' at the National Institution for Quality and Reliability, Bangalore Branch.

Shri C. A. Setty (24 and 27.4.90) delivered lectures in Kannada on 'Role Operators for Quality' at M/s. HMT Watch Factory, Tumkur.

Shri C. A. Setty (8.5.90) gave lecture on a Workshop on 'Company-wide Quality Control' at the Institute Headquarters, Calcutta.

Dr. V. Rajendra Prasad (25.5.90) delivered lecture on 'Linear and non-Linear Programming' at the Indian Statistical Institute, Bangalore Centre.

Shri C. A. Setty (11.6.90) gave a talk on 'Emerging Trends in Quality Assurance' at M/s. Indian Telephone Industries Ltd., Bangalore, and at the Hindustan Aeronautics Ltd., Bangalore on 18.6.90.

Shri A. S. Rajgopal (24.5.90) gave a lecture on 'Granite Exploration and Export' at SQC T & P Unit, ISI, Calcutta.

Shri N. R. Achuthan (8.1.91) gave a lecture on 'Routing Problem' at SQC T & P Unit, ISI, Calcutta.

Shri N. R. Achuthan (9.1.01) gave a lecture on 'Network Scheduling Problem' at SQC T&P Unit, Calcutta.

Shri T. K. Chakraborty gave a talk in the summer programme on 'Recent Developments in Statistical Quality Control' on 28 May 1990 and on 'Fuzzy Sets for Acceptance Sampling' on 8 June 1990 at SQC Unit, Bangalore.

Shri T. K. Chakraborty gave a talk in the summer programme on 'Recent Developments in Sampling Inspection by Attributes' on 8 June 1990 at SQC Unit, Bangalore.

Shri T. K. Chakraborty gave a talk in the seminar on 'The search of a model for Designing a unique single sampling inspection Plan' on 12 June 1990 at ISI, Bangalore Centre.

Shri T. K. Chakraborty gave a talk on Multiple objective programming in the Winter School on Optimisation and Design of Experiments at ISI, Calcutta.

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Shri S. K. Chaudhuri delivered a talk on 'Statistical Methods in QC' to the Managers and Technologists at Hindustan Motors Ltd., on 19 April 1960.

A lecture on some special cases of $2/2/F$ max was given by Shri D. K. Manna, SQC Unit, Madras.

Shri D. K. Manna delivered lectures on the project on 'A study on outgoing Quality Improvement of NPK : 17-17-17 fertilizer' conducted at Madras Fertilizers Ltd., Madras during the Intersession Seminar at ISI, Calcutta.

Shri D. K. Manna delivered lectures on the project on 'Scientific Inventory Management of spares at NPK Plant' conducted at Madras Fertilizers Limited, Madras during the Interaction Seminar at ISI, Calcutta.

Shri A. K. Chakraborty delivered lectures in the seminar on 'Software Reliability' to the faculty of ISI, Madras.

Shri P. R. Lakshminathan gave lectures on (a) 'Introduction to Quality Control' at Bharat Electronics Ltd., Ghaziabad on 19.4.90. (b) 'Tests of Significance' at Bharat Electronics Ltd., Ghaziabad on 21.4.90.

Shri A. Majumder gave lecture on 'Quality Improvement recent trend' at TELCO, Jamshedpur.

A seminar was organized and lectures were delivered by Mr. G.S.R. Murthy on 'Variation Flow Analysis' in which ISI faculty and students attended, SQC Unit, Madras.

A seminar was organized and lectures were delivered by Mr. G.S.R. Murthy on 'Optimal Integrated Surveys' in which ISI faculty members attended.

Lectures were delivered by Dr. Sridharan, IIT on 'Reliability Models' for the benefit of the faculty members of the SQC Unit, Madras.

A lecture on Scheduling—open Shop was given by Dr. T. S. Arthanari.

Shri V. D. Paluskar (30.4.90) gave a talk on 'Kaizer' at the SQC Unit Bombay.

Shri Rajiv Goel gave a lecture as a part of promotional activity for Hotel Windemoor National at Parwanoo, New Delhi.

Shri U. H. Acharya gave a series of lectures on 'Simple Problems Solving Techniques' at WIDIA, Bangalore.

Dr. V. Rajendra Prasad gave a series of lectures on 'Stochastic Scheduling' and 'Math. Programming' in March 1991 at SQC Unit, Madras.

Shri V. Narayana (13.4.90) gave a lecture on Quality in competition at Nagarjuna Coated Tubes, Hyderabad.

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Shri J. Venkappaiah (5.7.90) gave a lecture on 'Total Quality Management' at Hindustan Aeronautics Ltd., Hyderabad.

Shri N. T. V. Rao (25.7.90) lectured on 'Vendor Quality Management' at NISLET, Hyderabad.

Shri V. Narayana (9.8.90) lectured on 'SQC in Plastics' at CIPET, Hyderabad.

Shri N. T. V. Rao (21.8.90) lectured on 'Quality Management' at Bharat Dynamics Ltd., Bhanur, Hyderabad.

Shri B. Ramachandraulu (7.4.90) gave a talk on 'Quality management of video session of Jurau on Quality' at SQC Unit, Bombay.

Shri A. Roy Chowdhury (31.10.90) gave talks on 'Concept of Variation' at the R and D Engineers of Widia (India) Ltd., Bangalore.

Shri K. K. Chowdhury (24.10.90) lectured on 'Organising, Planning and Motivating for Quality' at M/s. Bharat Electronics Ltd., Bangalore.

Shri A. K. Chaudhuri (October 1990) gave a lecture on 'Total Quality Management' at the Arcot Plant of Keltron, Bangalore.

Shri P. K. Perumallu lectured on (i) 'Parameter Designing for Robust Product Design' and (ii) 'Improving Robustness of Tolerance Design' on 26 October 1990 at Taguchi methods for Quality Engineering organised by the SQC and OR Unit, Hyderabad.

Shri C. A. Setty (18.11.90) on 'Special Factors influencing Dormancy in Quality Circles' at BHEL Electronics Division, Bangalore.

Shri C. A. Setty (21.11.90) gave a half day seminar on 'Total Quality Management to the top management' of Hindustan Aeronautics Ltd., Bangalore.

Shri K. K. Chowdhury gave a lecture on 'Tolerance Design and Case Studies' at BHEL on 28.11.90 by SQC Unit, Bangalore.

Shri A. K. Chaudhuri (November 1990) gave a talk on 'Quality at Hindustan Aeronautics Ltd., Bangalore.

Shri A. K. Chaudhuri (November 1990) gave a talk on 'Quality Policy Formulation' at Hindustan Aeronautics Ltd., Korva Plant, Bangalore.

Shri K. N. Anand (23.1.91) conducted a half day seminar on 'Canaan Production System' at Widia, Bangalore.

Shri K. N. Anand conducted a half day seminar on 'Policy Management' for the Senior Management of K.B.L. Dowsa, Bangalore.

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Shri C. A. Setty conducted two one day training programmes for the workers of Gun Assembly Division of B.E.L., Bangalore.

Shri R. A. Rao (20.6.90) gave lectures on Seven Tools for Quality and (22.6.90) on 'Process Control charts including Master Control charts and Beta Partial Correction Technique' at Bangalore.

Shri U. H. Acharya lectured on 'Process Capability' in June 1990.

Shri A. Roy Chowdhury (26.6.90) lectured on 'Tools and Training for Quality Circles' on Quality Management for HMT in Bangalore.

Shri K. K. Chowdhury spoke on 'Upper Management and Quality' at Bangalore.

Shri A. Roy Chowdhury gave a talk on 'Tools and Techniques of Quality and Reliability' at Kirlokar Electric Co. Ltd., Bangalore during June—November 1990.

Shri K. K. Chowdhury (3.7.90) gave lectures for Diploma Holder Engineers of TVS Electronics Ltd., Tumkur.

Shri A. K. Chaudhuri (in August 1990) gave a talk on 'Quality Function Deployment' at Hindustan Aeronautics Ltd., Korwa.

Shri A. K. Chaudhuri gave a talk on 'Design and Quality' at HMT Watch Plant, Tumkur in August 1990.

Shri C. A. Setty (1.9.90) spoke on 'Quality and Profitability' at NGEP Ltd., Bangalore.

Shri A. Roy Chowdhury (5—7.9.1990) took lectures on 'Check Sheets and Stratification' at HMT Machine Tool Division, Bangalore.

Shri C. A. Setty and K. N. Anand lectured on 'Canou Production System' on 22 September 1990 at Widia (India) Ltd., Bangalore.

Shri K. K. Chowdhury (12.10.90) spoke on 'Acceptance Sampling and Demerit Rating' at M/s. TVS Electronics Ltd., Tumkur.

Shri S. P. Mukherjee delivered a talk on 'Bulk Sampling' in January 1991 at TISCO, Jamshedpur.

DRTCO (Bangalore)

A seminar on 'Information Marketing' was organized on 6th April 1990. The leading presentation was made by Shri N. K. Gopalakrishna, Chief, Centre for Documentation, Institute of Public Enterprises, Hyderabad. Prof. G. Bhattacharyya presided over the seminar. About 35 participants attended the seminar.

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A Seminar on 'Information Input for the Preparation of an Industrial Project Report' was organized on 12th June 1990. The leading presentation was made by Dr. N. S. S. Narayana, Economic Analysis Unit, Indian Statistical Institute, Bangalore. Prof. S. Soetharama presided over the seminar. About 30 participants attended the seminar.

A seminar on 'Information Inputs for Quality Management' was organized on 18th June 1990. The leading presentation was made by Shri A. K. Chaudhuri, Statistical Quality Control Unit, ISI, Bangalore. Prof. G. Bhattacharyya presided over the seminar. About 30 participants attended the seminar.

A seminar on 'Current Trends in the Development of Education and Training for Library and Information Science' was held on 5th July 1990. The leading presentation was made by Mr. Gatachew Birru, University Librarian, University of Addis Abba, Addis Abba, Ethiopia. Prof. G. Bhattacharyya presided over the seminar. About 30 participants attended the seminar.

A seminar on 'Classification of Indology' was held on 19 November 1990. Dr. Narender Kumar Sharma, Prof. and Head, DLIS, Kurukshetra University, Kurukshetra made the leading presentation. About 30 participants attended the seminar.

A seminar on 'Information Network' was held on 7 February 1991. Professor P. N. Kaula, Chairman, UGC Panel for Library and Information Science made the leading presentation. About 50 participants attended the seminar.

4. PUBLICATIONS

The following publications were brought out during April 1990—March 1991 :

(i) *Sankhyā* : The Indian Journal of Statistics and the official organ of the Indian Statistical Institute.

Series A : Vol. 52, Parts 1, 2 and 3

Vol. 53, Part 1

Series B : Vol. 52, Part 1

(ii) Fifteen technical reports from the Statistics-Mathematics Group have been issued during the period.

(iii) 2nd Volume of Selected Papers of Professor C. R. Rao.

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5. SCIENTIFIC PAPERS AND PUBLICATIONS

SCIENTIFIC PAPERS PUBLISHED

Teaching and Training Division

1. Das, P. K. (1990): H^∞ interpolation into a class of analytic functions. *Demonstration Mathematica*, 23.

Theoretical Statistics and Mathematics

Calcutta

1. Bagchi, Bhaaskar (1991): Corrigendum to 'No extendable biplane of order nine', *J. Combin. Theory*, (A).
2. Bagchi, S. C. (with Sitaram, A.) (1990): The Pompeiu problem revisited, *L'enseignement Mathématique*, 36, Fasc. 1-2, 67-91.
3. Bandyopadhyaya, P. (with Roy, A. K.) (1991): Some stability results for Banach spaces with the Mazur intersection property, *Indagationes Mathematicae*, 1, 2, 137-164.
4. Barua, R. (1990): On Borel hierarchies of countable products of Polish spaces, *Real Analysis Exchange*, 16, 1, 90-96.
5. Bhandari, S. (with Bose, A.) (1990): Existence of unbounded estimation in sequential Binomial experiments, *Sankhyā*, A, 127-130.
6. ——— (with Roychoudhuri, A.) (1990): On two conjectures about two-stage selection procedures, *Sankhyā*, A, 133-141.
7. ——— (with Purkayastha, S.) (1990): Characterization of uniform distributions by inequalities of Chernoff type, *Sankhyā*, 376-382.
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