In the curricula of the courses leading to degrees in statistics there is a fairly heavy emphasis on mathematical statistics. Even though a student has to take other social subjects for this first degree, there is sufficient emphasis on the theoretical background for the applied methods. There is, however, some time devoted to statistical applications to the sociological or technical fields required by each particular student.

Methods of Teaching

For all the courses in statistics, the method of teaching consists of lectures, practical exercises on calculating machines and seminars. For courses intended for economists, there is some field work but this appears rather limited. The importance of seminars is recognized in Swedish universities and all those preparing for higher degrees are usually required to attend seminars.

Methods of Testing Competence

To pass an examination, a student must undergo a separate test in every subject included in the degree. This may be oral or written; it is usually held by the professor or one of his colleagues.

The examinations for the *Fil.Kand* degree need not be taken by a student after any special period of study but when he considers himself ready. A Swedish university student is free to set his own position academically. Broadly speaking, he can decide for himself in what order he will study the different subjects and what lectures he will attend. Thus the time spent for different degrees varies with the students.

For higher degrees, a dissertation based on original work must be submitted and publicly defended.

Teachers

The following table shows the number of established posts in the departments of statistics of the Universities of Uppsala, Lund, Gothenburg and Stockholm, as of 1 July 1953:

	Uppsala	Stockholm	Lund	Gothenburg	Total
Professor	1	2	1	—	4
Preceptor	—	—	—	1	1
Lecturer	1	1	1	—	3
Assistant instructor	1	2	1	—	4
Assistant	2	2	2	—	6
First adjutant	1	2	2	1	6
Second adjutant	1	—	1	2	4
Third adjutant	1	—	—	—	1
Total	8	9	8	4	29

At the Stockholm University College, statistics is divided between two chairs, one being concerned with sociological and actuarial statistics. Information relating to the staff in other centres of teaching is not available.

The duties of teachers are to give lectures (professors, four hours per week, docents and assistant professors, six hours per week) to conduct practicals and also to hold examinations. Senior members of the staff guide students in research and also in conducting seminars.

Centralization of Teaching in Statistics and Co-ordination

From the report from Sweden, it is not clear whether the teaching of statistics in the three universities and Stockholm University College is centralized or whether the teachers in the faculties of sociology, psychology and pedagogics are responsible for teaching statistics to their own students.

TRAINING

Persons in employment can attend seminars if they are suitably qualified, but there do not appear to be regular courses for them. Information is not available about in-service training in Sweden.

RESEARCH

Research facilities are available at the universities, special colleges, and other centres like the Swedish Central Bureau of Statistics, the Royal Social Board and the Economic Research Institute.

Filosofie Kandidat with statistics as major subject is the required qualification for research work. *Filosofie Licentiat* and *Filosofie Doktor* are examinations which require research work. Twenty-five students took examinations requiring research work during 1954–55.

Research and teaching are considered as equally important functions of the universities in Sweden.

CONCLUSIONS

The importance of statistics as a university discipline is well recognized in Sweden. Considerable emphasis is placed on the teaching of sociological statistics in the universities, schools of economics and social institutes. An interesting feature is that courses include

independent work on a survey or a major computational programme and the preparation of a commentary or report.

The authorities responsible for the curricula have included sufficient statistical theory in the courses for economists, psychologists and sociologists. This is a great advantage in their work, for they can not only use standard techniques with a clear knowledge of the methodology and assumptions but they can modify these techniques for tackling new problems with confidence.

The courses of statistics in engineering and agriculture are quite extensive in scope and several of these are obligatory. In this respect, Sweden is ahead of many other countries. Mathematical statistics, however, does not appear to have developed as an independent university discipline except at Stockholm.

Training facilities for persons in employment have not been developed adequately either in the universities or the special schools. The Swedish Technological Association in conjunction with the Chair for Actuarial Mathematics and Mathematical Statistics occasionally arranges courses on such subjects as the planning of statistical surveys, quality control, etc. The extent of in-service training in statistical offices in government or private organizations is not known.

The number of students taking courses in statistics is rather small. Professor Wold's report mentions the following estimates of the numbers of students: Uppsala, 40 to 50; Lund 50; Stockholm, sociological statistics, 200, mathematical statistics, 20 to 30; Gothenburg, 20 (entrance limited); Royal Agricultural College, 45. The numbers of students who have successfully completed the units in statistics for the *Filosofie Kandidat* at Uppsala during the 10 years 1945–55 are: first unit (took required course for one term), 300; second unit (took required course for two terms) 125; third unit, 20.

Instruction in statistics at the various universities and colleges is financed by State grants. Grants are also available from the government for research workers.

At present there is no direct co-ordination between different departments offering statistics courses in a university nor is there co-ordination between universities and government or private organizations. In the larger interests of statistics and maximum use of available statistical resources, it is hoped that greater co-ordination will develop as regards teaching, research and consultative work.

APPENDIX

Specimen courses in statistics in Swedish universities

SOCIOLOGICAL STATISTICS

Instruction during the first half-year term of sociological statistics includes the following items:

Lectures: 25 to 40 lessons in statistical theory and methods, mainly based on S. S. Wilks' *Elementary Statistical Analysis*. Six to 15 lessons in formal population statistics and official statistics. Up to eight lessons in punch-card technique.

Calculation exercises: 20 to 40 periods of exercises similar to those in Wilks' book.

Training course: three to five weeks' work under the occasional guidance of instructors. The course is designed to give experience in numerical calculus, with some examples of fictitious samples of significance tests, population prognosis, survey preparation, life insurance calculus.

Pro-seminars: Discussion on survey planning and various statistical problems of an administrative-demographical nature (4 to 16 periods).

Requirements: About three-quarters of the time devoted to literature studies is spent on S. S. Wilks and calculation problems.

During the second half-year term, the teaching comprises the following additional items:

Lectures: 25 to 40 lessons in statistical theory and methods, at a level corresponding to P. G. Hoel's *Statistical Methods*, and in sampling theory. At Uppsala University, there are, in addition, 4 to 10 periods of lessons in econometrics and demand analysis. At Lund University, there are lectures on population statistics, official statistics and variance analysis. In addition, there are occasional special lectures on variance analysis, sampling, index theory.

Exercises: 20 to 40 periods, at a level corresponding to the exercises in Hoel's book.

Training course: three to five weeks. The subjects vary greatly between one university and another. At Uppsala and Stockholm, the training course comprises a major calculation problem, the planning of a statistical survey with main emphasis on the problematical side, the preparation of a critical commentary on a published work of statistics. Following upon the two last-named tasks, 15 to 30 periods are spent on discussions of the students' work.

Pro-seminars: As above.

MATHEMATICAL STATISTICS AT CHALMERS TECHNICAL COLLEGE, GOTHENBURG

The course includes two periods of lectures per week and two periods of exercises per week during the autumn term. It comprises the following items:

Numerical and graphic methods for the description of a statistical quantity.

Statistical units of measurement such as mean value, variance, standard deviation, width of variation, skewness and excess measure, dependency measure.

Basic concepts of the probability calculus and, in this connexion, the more important theorems on distribution functions.

Statistical testing methods and statistical control: variance analysis and analysis of linear regression.

Special discussion of the binomial distribution and the hypergeometrical distribution in connexion with statistical quality control.

SYRIA, LEBANON AND IRAQ[1]

FACILITIES FOR TEACHING

Teaching Centres and Courses

The teaching of statistics in Syria, Lebanon and Iraq began only recently. At a few centres introductory and intermediate courses are given, and one or two advanced ones. These are the American University of Beirut (Lebanon), the National University of Beirut, the Centre d'Études Mathématiques et Physiques (Beirut), Colleges of Arts and Science at Baghdad and the Syrian University, Damascus. The International Statistical Education Centre was also established in 1953, at Beirut.

At the American University, Beirut, the Department of Economics offers an applied statistics course to students majoring in economics. It is an elementary course requiring only high school mathematics. The course given in the Department of Education is also elementary. The Department of Psychology makes elementary statistics a prerequisite to a number of psychology courses for undergraduates and post-graduates. A similar non-mathematical course in medical statistics for students of medicine is available. All these applied courses are one-semester courses, with four hours per week for 15 weeks. Two hours per week are allotted to laboratory work.

The Department of Mathematics initiated in 1954 courses on theory of probability and on statistical inference. Three lectures per week are given for 15 weeks. The probability course follows closely Feller's *Introduction to Probability*, Volume I and J. U. Uspensky's *Introduction to Mathematical Probability*. The statistical inference course is of the standard of Mood's *Introduction to the Theory of Statistics*. Modern algebra and advanced calculus are prerequisites for these courses. The department is reported to be considering the introduction of a more elementary course. It is hoped that B.A. and M.A. degrees in statistics will be instituted in the near future. Research is conducted on an individual basis at present.

In the Lebanese (National) University, Beirut, teaching of statistics commenced in 1952 when a Statistics Institute was established. A three-year course was planned to cover the following subjects: sta-

1. Based on original papers by S. H. Khamis ('Teaching of Statistics in Lebanon and Iraq') and Hildegarde Kneeland ('Statistical Education in Syria').

tistical analysis; applications of statistics, economic statistics, mecanography; theory of economics, mathematics, financial statistics; economic geography and law. A government decree suspended admission of students in 1953, pending decision concerning a project to establish a school of finance, economics and public administration. It is expected that the programme of this school which would replace the institute would include one year of general statistics.

The Centre d'Études Mathématiques et Physiques follows a programme leading to one of the four certificates which constitute the *licence* of the University of Lyons. The certificate is called *Certificat de probabilité et de statistique* and the standard is of Kendall's *Advanced Theory of Statistics*, Volumes I and II. The duration of the course is one year.

In Iraq, the Department of Economics in the College of Arts and Sciences provides two elementary applied courses which are required for graduation. The Department of Mathematics gives courses in probability theory and statistics with a curriculum covering elementary probability theory, random variables, probability distributions, mathematical expectation, analysis of variance, testing hypotheses and estimation theory. Three hours a week are devoted to these courses.

The Royal College of Medicine and the College of Commerce teach applied statistics relating to medical and public health statistics and business statistics respectively.

The Syrian University was formed in 1946, its nucleus being the Law College and the College of Medicine. Statistics is taught for the diploma in political economy in the Faculty of Law. The course covers one academic year, with two hours each week. From 1955 it was proposed to make statistics a required subject for all candidates for the *licence* in law. Statistics is not taught in any other faculty except incidentally in courses in demography and sociology in the Faculty of Arts.

TRAINING

The Lebanese Academy of Fine Arts (Beirut) provides training in economic statistics in its School of Economics and Political Science. This appears to be available to persons in employment.

The International Statistical Education Centre, established in Beirut under the auspices of Unesco and the International Statistical Institute, is intended to serve the needs of the Middle East countries. The students are mostly government officials who are engaged in junior statistical work. The period of study is six months. The programme consists of elementary statistical theory and applied

statistics in economics, agriculture, demography and survey principles. There does not appear to be any field training. A good deal of emphasis is placed on laboratory practicals.

The Principal Bureau of Statistics of the Ministry of Economy, Baghdad, occasionally provides in-service training to the staff of government departments.

The Training Centre in the Ministry of National Economy, Damascus, has developed in-service training facilities for employees in the ministries and government agencies; in certain circumstances, private persons may also be admitted. Admission is open to those who have completed secondary school education. Classes are held after closing of government offices, on six days a week for eight months. As an inducement to trainees to undertake and carry through a substantial programme of study, they are assured by law of a post of a specified grade in government service. In the first term in 1954, 22 were selected—they were all of the junior professional level.

The programme of study is given below:

Statistical theory, including 50 lectures in statistical analysis, 25 lectures in sampling problems, and 25 hours of practical work and exercises.

Applied statistics, including 40 hours of demographic and vital statistics, and 25 hours each on agricultural statistics, economic statistics, financial and social statistics and methods of collecting, tabulating and presenting data.

Mathematics, 75 hours.

General knowledge, 100 lectures, designed to provide the necessary background in the fields of law, economics, social affairs, etc.

Languages, 25 hours—either English or French.

The teaching staff of the centre is drawn from the senior personnel of the ministries and from the faculties of the university. Strong emphasis is laid on the methods of instruction. Considerable time is given to practical work on realistic problems.

UNION OF SOVIET SOCIALIST REPUBLICS[1]

FACILITIES FOR TEACHING

Historical Review

Considerable importance is attached to the teaching of statistics in the Soviet Union. In the first thesis of the Central Statistical Bureau, signed by Lenin in July 1918, the need for spreading knowledge of statistics throughout the country was pointed out. According to this thesis, it was the responsibility of the Central Statistical Bureau 'to pay attention to the development of a correct system of statistics and the expansion of knowledge in statistics'.

The present system of higher education in statistics in the U.S.S.R. came into being as a result of persistent scientific and methodical work and represents a significant advance over the teaching of statistics in the first three years of Soviet Order, and a still more significant one as compared with the teaching of statistics in pre-revolutionary Russia. Statistics in pre-revolutionary Russia was included in the curricula of the faculties of law in universities. Later on, as more institutions of commerce and economics were opened in Russia, it was included in the teaching given at higher educational institutions. The lectures and seminars given at the Petersberg Polytechnique by the distinguished statistician, Professor A. A. Chuprov, and the courses by Professor Kablukov at the University of Moscow, are noteworthy examples. However, the teaching of statistics in higher educational institutions lagged far behind the demand for practical statistics, especially those necessary for local village self-government and city administration. In pre-revolutionary Russia, in the higher institutions there was, as a rule, only one course in statistics.

In the first years after the birth of the Soviet State, education in statistics developed comparatively slowly in the face of the great difficulties experienced by the country. During these years, however, preparations were being made for courses in statistics in special subject-fields. After 1929, the situation changed sharply. A network of special institutions for higher studies began to appear rapidly, after the period of recovery and with the revival of the whole of the

1. Based on an original paper entitled 'The Teaching of Statistics in the U.S.S.R.', by T. Koslov, V. Novikov and V. Ovsienko, professors at the Institute of Economics and Statistics, Moscow.

national economy on the basis of new techniques and scientific discoveries. Courses in economic statistics were started, and on the basis of experience in the use of statistics in industry, agriculture, trade, etc., it became possible to give different courses in statistics relating to the more important branches of the national economy. The opening of a large number of higher institutions for training economists and engineer-economists of various types, played an important role in the development of teaching statistical disciplines. A particularly important event was the formation in 1932 of the Institute of Economics and Statistics, in Moscow, which brought together in a single group many distinguished Soviet statisticians.

Teaching Centres: Degrees and Diplomas in Statistics

Training of highly qualified statisticians is carried out by special institutions of higher education and by special faculties and departments. Evening courses and correspondence courses are available to persons already engaged in professions. On completion of their studies, students must pass State examinations in the basic principles of Marxism and Leninism, in political economy and statistics. Those who complete the academic course and pass the State examinations are awarded the degree of 'economist', and those who complete the course in higher institutions for statistical study are appointed, according to their subject of specialization, to the Central Statistical Bureau or to other organizations.

Teaching of statistics is obligatory in higher institutions where specialists are trained in humanistic studies.

The way to a scientific or teaching career in statistics in the U.S.S.R. is through research work. The plan of research includes: (a) a minimum period for the candidate to prepare himself in philosophy, political economics, statistics and a foreign language; (b) a period for the preparation and defence of a thesis in order to obtain the degree of 'candidate of economics'. After the period of research work, students may be appointed to higher educational establishments or research institutions or they may accept practical work of some responsibility. Facilities are granted to scientific and teaching staff working on a doctorate at the Academy of Sciences of the U.S.S.R., or on a research project in an institution.

ORGANIZATION OF TEACHING

Requirements for Admission

In higher educational institutions providing statistical training, courses are open to all Soviet citizens who have completed education

in the ten-year school or at a technical school, i.e., those who have completed secondary studies and have passed the competitive examinations in the Russian language, the history of the peoples of the U.S.S.R., geography and mathematics. Those who have completed secondary studies, with honours, are exempted from the entrance examination.

Research posts in statistics exist in many faculties of statistics, at institutes of economics and economic engineering and in all statistics faculties at the Institute of Economics and Statistics, Moscow. Persons possessing higher education in statistics and having considerable experience are admitted only as research students. Students who complete higher courses with honours and are recommended by the councils of the respective institutions are exempted from the condition of practical experience. Those who are already engaged in professions are also exempted from a prescribed period of practical work.

Methods of Teaching

The organization of teaching and research work at the higher educational institutions in the U.S.S.R. is ensured through the chairs of statistics. On 1 January 1956, there were 35 chairs in the higher institutions staffed by 354 professors, lecturers and assistants. At the Institute of Economics and Statistics, there are special chairs of statistics for general theory of statistics and economic, population, industrial, agriculture and trade, and transport statistics, with a staff of six professors, 15 lecturers, six senior teachers and six assistants.

The teaching follows a fixed programme set up by the incumbent of each chair, consisting of lectures, practical work and seminars. Approximately equal time is spent on lectures and practical work. Students are also expected to do independent work at home. Attached to each chair there is a special study circle provided with necessary material for study as well as staff for consultation. Textbooks and school-books are used in almost all institutions. During the last few years, many works on general theory of statistics and economics, demographic and industrial statistics, etc., have been published. Literature is prepared by the State Publishing House. At the Ministry of Higher Education, a bureau for statistical methods is in charge of problems relating to teaching statistics at higher educational establishments.

Courses in Statistics

The present system of higher education in statistics in the Soviet Union may be classified as follows: (a) training of statisticians;

(b) statistical training of economists specializing in various branches of economics, engineer-economists and lawyers; (c) training of scientists and teachers in statistics.

The curricula for the training of statisticians provide for an initial training designed to form a general background for economic statisticians, covering both theoretical and practical knowledge in fields such as economics, law, philosophy, accountancy and statistics. In addition to this general training, specialization in a particular branch is also provided, such as in industrial, building, agricultural, commercial, transport, demography, community and housing, cultural and social or medical and health statistics. The general training includes statistical methods and economic statistics. Statistical method is first introduced generally, covering the role of statistics, fundamental concepts of statistics and the basic statistical tools available for analysing data. The topics covered under economic statistics aim at a statistical study of different phases of national economy, such as the processes of formation of the national product, distribution, circulation, consumption, accumulation, description of productive forces and theory of balances in national economy. The approximate time devoted to general training is 25 per cent for statistical methods and 30 per cent for economic statistics, the remainder being devoted to specialization and other courses.

Specialization in subjects other than those mentioned above is also possible. This has been introduced with the aim of broadening the specialist's training. Thus, for example, courses in agricultural and trade statistics are studied by students specializing in industrial and construction statistics. Those who are later to specialize in statistics also take a course on general theory of statistics. Those who intend to specialize later as economic statisticians receive instruction in mathematical statistics. Optional courses are provided in history of statistics and statistical quality control.

As regards the procedure of teaching, the theoretical classes are followed by *practicum* (practical classes). The *practicum* is given directly on the premises of industrial enterprises, state farms, collective farms, transport enterprises and other organizations. At a later stage, the *practicum* is given at statistical organizations in provinces, regions and republics and in the Central Statistical Bureau. A list of disciplines included in the curriculum of the Moscow Institute of Economics and Statistics is given in the Appendix.

Curricula of institutions giving training in statistics for economists, engineer-economists, lawyers, etc., provide for the study of at least two statistical subjects. Higher educational establishments which provide training for experts in the planning of national economy, finance and credit, give instruction in general theory of statistics and economic statistics. Those preparing for specialization in a particular

branch of national economy or culture follow a general course in statistics. Thus, those specializing in industrial economy study the general course in statistics as well as industrial statistics. Mathematical statistics is taught in all institutions which provide training for economists and engineer-economists.

RESEARCH

The training of a research worker follows the lines of individual interest, but conforms to plans approved by the respective councils of the institutions. Research projects within institutions play an important role by contributing material for research and for the advancement of statistics. The research work done in the various departments of statistics is utilized to solve actual theoretical and practical problems connected with the development of Soviet economy and culture. Results of such research are published periodically in such journals as the *Vestnik statistiki* and *Vaprosy ekonomiki*, in the publications of various institutions, in special collections of scientific work of departments and as individual monographs. Conferences on theoretical problems in statistics are held periodically. Scientific papers on statistics are published by the Institute of Economics and Statistics in Moscow and by the departments of economics, philosophy and law of the Academy of Sciences. Collections of scientific papers are published by the chairs of statistics at the Institute of Economics and Statistics, the Institute of Finance in Moscow and others. The Institute of Economics and Statistics in Moscow also publishes work by students of statistics. Research workers in the Academy of Sciences continue to retain any allowances drawn during previous service and obtain three months' leave with pay for completing their work.

CONCLUSIONS

In the U.S.S.R., higher education in statistics is carried on mainly with the aim of producing competent professional statisticians and developing statistical skill among specialists in the various branches of economics and others who will be called upon to solve practical and scientific problems. Education in statistics is based on the Marxist-Leninist scientific theory of social development as well as on current statistical knowledge with its indissoluble connexions with practical application.

The national economy of the U.S.S.R. requires a number of expert economists and statisticians and expects of them a high standard. This has led to a large-scale development of statistical education in the Soviet Union. The Institute of Economics and

Statistics in Moscow was established for the purpose of providing training facilities for highly qualified economists and statisticians. A number of statistical or statistical accounting departments and faculties have been set up in some of the higher educational institutions. In addition to these, statistical training is provided for those specializing in the various branches of economics. Statistics, as a necessary element in higher economics is taught in all institutions of economics and in all faculties of economics in technical institutes.

The teaching of statistics in the U.S.S.R. has a close bearing on the economic processes in a socialist society. Characteristic of the Soviet Union is current and long-term planning. One of the main tasks of Soviet statisticians, therefore, is the control of the fulfilment of such plans which cannot, of course, be carried out without objective, reliable and scientific statistics. There is an elaborate network of statistics in the U.S.S.R.; in addition to administrative statistics compiled by enterprises, ministries and other departments, there is a system for general State statistics operated by statistical officers connected with the Council of Ministers, and every Union and autonomous Republic, every region and district has its own statistical bureau. In each administrative region also, there is an inspectorate of the Central Statistical Bureau.

One of the chief aims of higher education in statistics in fact is to train statisticians for these institutions, to collect data of high quality and to make scientific inferences from them.

Problems of teaching statistics are also occasionally discussed at the All-Union Conferences of Statisticians. At the meeting of the Scientific Council of Statisticians, in March 1954, organized jointly by the Academy of Sciences of the U.S.S.R., the Ministry of Higher Education of the U.S.S.R. and the Central Statistical Bureau, there was a special discussion of a memorandum on teaching. This resulted in revised programmes for statistical disciplines and preparation of new literature. Questions of teaching statistics are regularly discussed in the meetings of the section of statistics at the Moscow House of Scientists. Problems of statistical education are also discussed in periodicals and journals such as the *Vestnic statistiki* and the *Vestnik Vyssci skoly*.

APPENDIX

List of subjects in the four-year curriculum of the Institute of Economics and Statistics, Moscow

Basic principles of Marxism-Leninism; dialectic and historical materialism; economics; history of economic theory; history of the national economy of the Soviet Union and of foreign countries; economic geography of the Soviet Union and of foreign countries;

higher mathematics; mathematical statistics; civil and labour law; a foreign language; planning of national economy; finance and credit; basic principles of the mechanization of accountancy; bookkeeping and analysis of balance sheets; general theory of statistics; economic statistics; optional subjects according to specialization. In addition to the courses mentioned above, tuition is given in: organization and planning of agricultural enterprise, economics, organization and planning of trade; statistics of different branches of national economy; industrial economics; agricultural economics; statistics applied to the cultivation of plants and cattle-breeding; physical education.

UNITED KINGDOM[1]

FACILITIES FOR TEACHING

Historical Review

England is perhaps the first country where statistics has been taught as a distinct university subject. The colleges of the University of London, particularly University College and the London School of Economics, have for quite a long time included the subject in the curricula of studies leading to various degrees. In 1915, the Department of Statistics of University College commenced teaching for the B.Sc. (Special) degree in statistics. Post-graduate teaching and research have been important functions of this department from the time when it was part of a larger department of applied statistics and biometry. It has been one of the most important centres of teaching and research in the world.

The London School of Economics has grown into a large teaching unit since World War II. It now has two chairs for statistics and has 36 courses given to audiences of from 10 to 300 persons. About 930 hours a year are devoted to lecture classes and seminars in statistics. At Cambridge University, the School of Agriculture started giving a diploma course in mathematical statistics in 1947. Manchester University set up a Department of Statistics after the war; its diploma, as also that of Oxford University, has only recently been instituted. There has been expansion in the teaching of statistics in

1. Based on original papers by the Royal Statistical Society ('A Discussion on the Teaching of Mathematical Statistics at University Level in the United Kingdom') and J. Durbin ('The Teaching of Statistics in the Universities in the United Kingdom').

practically all universities in the United Kingdom and it is reported that courses in statistics are offered at present in almost every university college.

Teaching Centres: Degrees and Diplomas in Statistics

There are as many as 37 institutions in different universities in the United Kingdom having one or more courses in statistics. This number excludes the post-graduate medical schools where some statistics is taught. University institutes and research institutions where no regular teaching is provided are not covered in this survey. The 37 institutions are distributed as follows: London University: post-graduate schools, 2, other colleges and schools, 8; Oxford and Cambridge universities, 2; other English universities, 13; English university colleges, 2; University of Wales, 5; Scottish universities, 4; Northern Ireland universities, 1.

In all the universities, the first degree (B.Sc. or its equivalent) is taken after three years of study. Generally the master's degree can be taken by a bachelor after a year's study through an examination which may include a thesis. The Ph.D. or D.Phil. is a research degree requiring study and research for a period of not less than two years for B.Sc. degree holders and one year for M.Sc. degree holders. A university would generally require longer periods for graduates of other universities, particularly of foreign universities. The D.Sc. or D.Litt. is the highest research degree awarded to a person holding a first research degree for outstanding published work. In one university it can be awarded only eight years after taking the first degree.

London University is the only university which awards a full degree (B.Sc. Special) in statistics. Courses for the degree are given by University College. In all other universities, statistics can be taken as an ancillary or minor subject for the first degree in mathematics, economics, biology, psychology, education, engineering or agriculture. To take some examples, at Cambridge, statistics appears as a 'whole subject' in mathematics for the natural science tripos. Two courses in mathematical statistics plus two probability courses form a group for part III of the mathematical tripos. The Faculty of Economics offers a course for part II of the economics tripos. In Manchester University, statistics is offered as a subsidiary subject for mathematics honours, and there is an advanced theoretical course intended primarily for third year mathematics undergraduates who have taken the subsidiary courses. Economic statistics is included in the economics courses.

Post-graduate and research facilities are available at University College, London, the London School of Economics, Imperial College, London, the universities of Oxford, Cambridge, Manchester

and Edinburgh and also the University College of South Wales (Swansea). The duration of study is one or two years. Statistics also forms part of the curricula for the diplomas in agriculture and agricultural sciences at Cambridge and the post-graduate diploma in public health given by the London School of Hygiene and Tropical Medicine.

ORGANIZATION OF TEACHING

Requirements for Admission

The qualification required for admission to the undergraduate courses in statistics of London University is the general certificate of education; advanced mathematics is required for students taking the B.Sc. (Special) degree. Similar admission requirements exist in all universities for taking undergraduate courses in mathematical statistics even though it is a subsidiary or minor subject. Elementary courses for students in economics and other subject-fields have no mathematical prerequisites. But those taking intermediate or advanced courses do require some algebra and calculus which is generally studied along with statistics or a little before.

The requirements for admission to the M.Sc. course of London University by examination or thesis is the B.Sc. (Special) in statistics, B.Sc. (Special) in mathematics or B.Sc. in mathematics; a student of the last type has to follow a selected course of lectures and practical work for one year before starting on the M.Sc. courses, which are covered in another year. Since there is no statistics major in any other university, the persons generally admitted for the M.Sc. in statistics are majors in mathematics or economics, but who have learned some statistics.

The requirements for registration for the Ph.D. degree in a statistical subject is the B.Sc. (Special or Honours) or the M.Sc. degree in any science subject including economics and psychology, but usually the degree is restricted to graduates in statistics, mathematics or economics who have already done some statistics at the intermediate level. For instance, for the Ph.D. in economic statistics, the London School of Economics prefers honours graduates in economics who have taken courses in mathematics and statistics. Regulations for students from overseas require a high master's degree in mathematics or statistics.

For joining the diploma course in mathematical statistics at Cambridge, one must have a high standard of general mathematics and a fairly good initial knowledge of statistics. The mathematical prerequisites are not so high for the diplomas at other universities.

These are generally open to graduates in any science subject, including economics and agriculture.

Courses in Statistics: Aims, Duration and Content

Among the 35 institutions about which information was received, the distribution during 1954–55 of the number of lecture courses intended mainly for undergraduate students was: 1–4 courses, 9 institutions; 5–9 courses, 13; 10–14 courses, 5; 15–19 courses, 0; 20–29 courses, 1; 30–39 courses, 1; not known, 6. Altogether 216 courses are included here. The meaning of the word 'course' is not uniform in all the universities. What one university may call a one-year course leading to a certain examination paper may correspond to two or three one-term courses at another, together covering roughly the same subject matter. The above list does not allow for these differences. However, in the list a two-year course has been treated as two one-year courses.

The duration of a course (including lectures, seminars and practical work) is very variable. About 35 per cent of the courses extend over a term (of about 10 weeks) or less, 10 per cent two terms, and the rest one year or more. The majority of courses in statistics were either for the complete academic year (three terms) or just for one term. The time devoted to a course in statistics is only one hour per week in about 50 per cent of courses, two hours in 30 per cent, three hours or more in the rest. A large number of courses were of about a term's duration and were given at the rate of one lecture per week; these are short courses given by an individual teacher on his own topic. Next in frequency are courses spread over one year with two or more lectures per week. These are given by departments which have only one or two full-time teachers of statistics.

Analysing the undergraduate courses by the faculties or departments in which they were given, it is seen that 18 courses in statistics are given for students taking degrees in statistics, chiefly the B.Sc. (Special) degree of the London University, 87 for economics, 49 for mathematics and science, 28 for psychology, 10 for sociology, 12 for biological sciences, 12 for agriculture, 11 for medicine and 28 for degrees in other subjects. Some of these courses are common to two or more departments.

It is reported that departments of economics without exception provide at least one course in statistics; the same is true of 80 per cent of departments of mathematics and about half of the departments of psychology.

Some general observations can be made with regard to the content of the courses in statistics for undergraduates in mathematics, economics, etc. Courses for students mainly of mathematics concen-

trate on mathematical statistics, usually of a fairly high theoretical level, concentrating on subjects such as probability, bivariate and multi-variate correlation and regression, sampling theory, estimation, tests of significance and analysis of variance. The aim of these courses is essentially the same as that of any subject in applied mathematics.

For the economics degree, the courses include elementary statistical methods (collection and classification of data, averages, measures of dispersion, correlation and regression, sampling, index numbers, time series), and economic statistics and sources (population, labour and employment, wages, prices, production, foreign trade). Advanced courses for economists include more mathematical statistics and cover demand analysis, econometrics, theory of sample surveys and analysis of time series. A good knowledge of mathematics is a prerequisite for these advanced courses. The general aim of all courses for students of economics is to acquaint them with the statistical methods useful in the study of economic phenomena.

Courses for undergraduates in sociology are generally elementary, covering descriptive statistics, large sample theory and tests, together with methods of social surveys. Both psychologists and agriculturists concentrate on topics such as correlation, tests of significance, design of experiments and special applications to their own fields.

How far these courses are obligatory for undergraduates majoring in different subjects is not known. But it appears that courses in statistics are essential for about half the number of degrees in economics.

A smaller proportion of degrees in mathematics and psychology include compulsory examination papers in statistics, but probably a majority include some questions on statistics in papers of pure or applied mathematics or psychology.

The aim of post-graduate courses in statistics is to give an advanced knowledge of one or two special fields through lectures, seminars and research work. Although there is provision for the post-graduate degrees of M.Sc. and Ph.D., at many of the universities in the United Kingdom, regular courses are not always organized for them. The M.Sc. student attends the advanced lectures and seminars given in the university and consults the teacher, but to a large extent he has to work on his own. London University arranges regularly advanced courses by the professors in the constituent colleges as well as visiting professors; these are attended by the post-graduate students.

The curricula for the post-graduate diplomas in statistics are fairly uniform in the different universities; there are slight variations in emphasis on mathematical or official topics. The diploma is of a lower standard than the M.Sc. degree and is mainly organized through lectures and seminars. At one or two universities there is practical work in fields of application; but no dissertation or thesis is required.

The organization of courses in statistics in a few important centres are indicated below.

University College, London. In the first year of the three-year B.Sc. (Special) course in statistics, one of the following ancillary subjects has to be studied: biology, chemistry, psychology, physics and zoology. In both the first and second years there is mathematics (80 hours). Statistics is taught in all the three years. In the third year, courses on statistical genetics (10 lectures) and economic statistics (15 lectures) are given regularly as part of the degree syllabus with the co-operation of other departments. Under part II, two special subjects are selected. In addition to this, for completion of his work for part II, a student must select a topic not covered by the lectures and write an essay using as illustrative material such fresh data as he can find. Details of the curriculum are given in Appendix A.

All students for B.Sc. (Special)-Mathematics in the university colleges attend a course of 12–15 introductory lectures in statistics in their second year. It is possible for students who have taken six papers for their final examination in mathematics after two years to study statistics wholly for their third year as part of the degree course in mathematics. The subject matter of the two papers at the end of the third year would be purely mathematical statistics. Such students can become good mathematical statisticians if they remain for a post-graduate year or two; but the average student would have absorbed too much of the mathematical discipline to find it easy to think statistically in one year.

As ancillary to other science subjects, one-year and two-year courses may be chosen by students whose main subjects are anthropology, botany, psychology, physiology and zoology. For the two-year courses, advanced mathematics in the school certificate is a prerequisite.

Elementary lectures for biologists as well as advanced lectures for research workers in University College or the Medical School in the evenings are also regularly arranged.

There is provision for taking the M.Sc. degree by examination at University College. A minor thesis is part of the requirements. No separate lectures are arranged for the small number of students; but they have to attend some of the advanced courses given for the B.Sc. (Special) students and participate in the various seminars. Like the Ph.D. students, they mainly study by themselves under guidance from the staff.

London School of Economics. In the year 1954–55, there were two general courses on statistical methods intended mainly for students of economics and sociology which are taken also by post-graduate students. Another course intended for sociology students, is given at two levels. There are advanced courses of lectures of 10 to 25 hours

on introduction to econometrics, methods of social investigation, and actual statistics. To supply the necessary mathematical equipment, two courses on mathematics (50 and 20 hours) are also given.

For the B.Sc. (Econ.) degree, students can specialize in statistics in the third year; they are taken through almost all the theoretical and relevant applied aspects of the subject. Details of the courses mainly intended for them are shown in Appendix B. Considerable post-graduate teaching and research in economic statistics is done at the London School of Economics and there is definitely a professional emphasis in the programme.

Imperial College, London. A good deal of mathematics (including numerical mathematics) and mathematical physics is taught along with statistics at the undergraduate level, and in the second half of the third year a student can engage himself in experimental work. The college 'teaches mathematical statistics in its natural setting—as a branch of applied mathematics closely related to experimental science and technology'. Besides courses for mathematics B.Sc. students, courses on elementary statistics are provided for different types of science students.

The courses for the diploma are built up from elementary levels. Two papers deal with principles, one on mathematical theory of statistics, another on statistical methods in experimentation and sampling and the last on statistical practice in biometry.

Cambridge University. The Faculty of Mathematics gives for the mathematical tripos a course on random variables (24 lectures), statistics I and II (48 lectures) and foundations of probability (24 lectures). The same faculty gives an elementary course to natural science tripos students. The faculty of economics offers a course for part II of the economic tripos at an intermediate level. There is also a general course taken by science students.

The diploma in mathematical statistics has a good coverage of theoretical subjects, some of the courses being common with the mathematical tripos. Details are given in Appendix C. An important requirement is that in addition to taking these courses, the student must work throughout the year in some applied field—economics, agriculture, medicine, psychology or genetics.

Oxford University. The main emphasis is not on mathematical statistics but on medical, biological, agricultural and economic statistics. There is some mathematical statistics forming part of a paper for the mathematics final. The diploma in statistics has four general papers (elements of statistical practice, principles of statistics I and II, and practical) and two special papers chosen from six relating to statistical methods in social studies, biometry, psychology, experimental sampling and mathematical theory of statistics.

Manchester University. Students taking an honours degree in

mathematics are required to take two subsidiary subjects, of which statistics may be one. The course is of 60 hours' duration (36 lectures and 24 practical classes). It is also open to students of other departments who have sufficient mathematical knowledge. This is the course for students of economics specializing in statistics and represents the minimum theoretical requirement for students proceeding to the post-graduate diploma. Being a common course for both mathematical and non-mathematical students, it has to be carefully planned (see Appendix D). In the last two years the class has been duplicated, the non-mathematicians being thus enabled to get more assistance on the mathematical side. There is an advanced theoretical course intended primarily for third-year undergraduates in mathematics who have already taken the above subsidiary course. It can also be attended by others including diploma and research students.

For the diploma course, which takes one year, in addition to the basic requirements in theory, candidates must take an optional subject which may be mathematical statistics, economic statistics, etc. Mathematicians normally take mathematical statistics but must then choose a field of application (e.g. economics) and undertake some study and fairly extensive practical work in that field.

Methods of Teaching

The relative emphasis on lectures, practical work and seminars differs from course to course and also from university to university. At Cambridge, lectures are closely integrated with the examination syllabus and courses of lectures are provided for each subject which is examined. Attendance is not compulsory, but most students attend the appropriate lectures on the subjects they have taken. The lecture method is the most important method for teaching mathematical statistics and also certain advanced topics in all universities.

Except for post-graduate research students, individual discussions and consultations do not play much part in the teaching. The tutorial system of the Oxford and Cambridge type (weekly tutorial of an hour to groups of one to three students) does not exist for statistics, as there are few men qualified to do tutorials in this subject.

In the United Kingdom practical work is given considerable importance in teaching programmes; for skill in computation and ability to apply theory to numerical data are regarded as essential for a student who is to work later as a statistician. At University College, London, after each lecture on statistical theory, students are given material on which to illustrate the technique and associated ideas developed in the lecture. A large number of hours are available for practical work. In fact each student is given a calculating machine which he locks in his desk and on which he can work at any time.

For the B.Sc. (Special) in statistics, the number of hours allotted to lectures and practical work are respectively 85 and 300 in the first year, 105 and 250 in the second year and 80 and 40 in the third year. The proportion of time for practicals is less in other institutions. At the post-graduate level, formal practicals appears to be rather limited.

The extent of field training in surveys or practical training in actual statistical work in government or elsewhere seems to be very small. The diplomas at Cambridge and Manchester have some requirements of this kind and there are proposals to introduce such training elsewhere. At one or two places, post-graduate students are encouraged to take up temporary employment during the three months annual vacation in some government statistical office or a business house, so as to get experience of actual working conditions in their fields of study.

The seminar method of teaching is widely used at the higher levels. At the Statistical Laboratory, Cambridge, seminars are held throughout the session and attract graduate students and visitors from mathematical and other faculties. At University College, London, besides seminars held by professors of the university and visiting professors, students are encouraged to study all the literature on some recent development in statistical methodology and to hold seminars which are attended by the other students and the staff. This method not only enables the participants to gain knowledge and understanding of the principles, but also gives training in presentation to a critical audience and in answering the points raised by them.

Written work of the essay type does not appear to be of any value in the teaching of theoretical statistics, but it can be of use in applied statistics. Writing an essay or a report based on the analysis and interpretation of statistical data arising in practice will be of great benefit to the student. This method, however, does not appear to be current in courses for economists and sociologists.

In the United Kingdom it is not usual to make available to the students of statistics notes of lectures delivered. They have to depend on books and published papers. Library facilities are well developed in all the universities. In London the university and college libraries, as also the library of the Royal Statistical Society, are available to advanced students.

Methods of Testing Competence

The usual method is an examination held at the end of each course. The final examination tests the student's knowledge through written papers and sometimes practical tests. Separate papers are devoted to statistics if it is taken as a major or a minor subject for the B.Sc.

degree; but sometimes when it forms part of a paper, it is possible for the student to omit statistics completely as, for example, in the case of the mathematics final at Oxford. The examination for the B.Sc. (Special) degree in statistics consists of part I, taken after two years for which there are four three-hour papers in theory and two seven-hour papers in practical. Part II examination, taken after one more year, has three three-hour papers in theory and two seven-hour papers in practical.

It is common to set a large number of questions in a theory paper and the candidate may answer any number of them. In the practical examination, the questions set are not just the laboratory type exercises but relate to actual situations. The candidate has to understand each problem and think out the proper statistical approach and then proceed to do the necessary computations and finally to set out the result or the conclusion. This method really tests the competence of a person to be a statistician.

A part of the M.Sc. examination consists of a thesis on a particular problem. It need not contain fundamental research but may be a disquisition or a reappraisal of results in a certain limited field. When the curriculum of a course requires work in a subject-field, the work done has to be written up and submitted at the final examination, as in the case of the diploma of Manchester University. The thesis is the main evidence of knowledge and research ability in a candidate for Ph.D. and one or two external examiners assisted by the supervisor judge the thesis.

Ordinarily the oral examination is restricted only to those who submit theses for post-graduate degrees. This *viva voce* follows the acceptance of the thesis and any written papers. There is no oral examination at undergraduate level.

Teachers

Little information is available on the conditions affecting teachers. It is known that there is a shortage of teachers of statistics and that this is hampering the development of statistics in some of the younger universities and colleges. There do not appear to be more than 10 professorships in all the centres and the ratio of this number to the rest of the staff is less than that in some departments on other subjects where post-graduate teaching is done.

In the 32 institutions from which information has been received, there were, in 1954–55, 69 full-time and 76 part-time teachers who gave at least one course in statistics. There were 20 institutions having between 1 and 4, and 5 between 5 and 9 full-time teachers. The part-time teachers had their main work in other subjects like mathematics, economics or psychology.

From the distribution of part-time and full-time teachers in the different departments, it is seen that practically all those who teach in the departments of statistics are full-time teachers of statistics; but only half of those in the mathematics and economics departments are so, while other departments including departments of psychology (where the study of statistics is widespread), rely mainly upon part-time lectures.

Centralization of Statistics Teaching and Co-ordination

At seven institutions there are departments of statistics; at others the courses are given by other departments, chiefly in mathematics and economics. University College, London, and the London School of Economics have independent departments with chairs for statistics. There is no department of statistics at Imperial College, London, but there is a professor of statistics in the Department of Mathematics. At Cambridge, statistics is within the Faculty of Mathematics. There are some advantages in this arrangement since many able students of mathematics are being attracted to the study of statistics. But it is reported that there are disadvantages also, that there is a lack of co-operation from the Faculty of Mathematics and lack of appreciation of the efforts to extend the service of statistics to the rest of the university. At Manchester, mathematical statistics forms a sub-department within mathematics.

There is evidence in some universities of co-ordination with regard to teaching statistics to students in the different subject-matter departments, as for example, London and Manchester, though the extent to which courses in statistics in a department are given by teachers belonging to other departments may vary considerably. From the information supplied, it is seen that of the courses for economics students, roughly 60 per cent are given by teachers of the economics departments, 30 per cent by statistics departments. For students of mathematics and science in general, about three-fourths of the courses are given by teachers of their own departments and about one-fourth by the statistics departments. Nearly all courses in statistics for psychologists were given by their own teachers; courses for students of agriculture were given by the departments of agriculture, statistics and economics in that order and for students of biology and medicine, mainly by the departments of statistics and their own departments.

TRAINING

Very little information was available on this aspect. The universities in the larger towns have provision for evening courses for persons

in employment. University College, London, periodically holds courses for civil servants after office hours. A good amount of theoretical statistics and applications are covered; training in computation is emphasized. Such courses do not require much mathematical knowledge—in fact, they do not include enough mathematical statistics. That more of it should be taught was suggested by one of the university professors, 'in view of the importance of statistics in industry and the fact that industrial chemists, physicists and others could gain much from an acquaintance with non-elementary statistical ideas'. Several of the polytechnics in London provide courses in statistics which are well attended.

There are a few research-type institutions devoted to different fields, e.g., the Rothamstead Agricultural Experimental Station, which provides training in statistics to senior workers. The report received for the United Kingdom does not make any reference to training in specialized institutions.

The extent of in-service training in statistics for employees in government or municipal offices, banks and commercial establishments seems to be rather limited. In industry, there is some training in statistical quality control for technical personnel.

RESEARCH

In all the larger centres of teaching referred to earlier, research students are admitted. The numbers are very small, partly for the reason that good students are not forthcoming and partly owing to the limited supervising staff. There is also the difficulty of adequate research fellowships. It is a special feature of British universities that a number of foreign scholars join each year for advanced study for the Ph.D. degree.

Whether the lines of work are in mathematical or applied statistics, a good mathematical background is expected of research students. Some institutions like the London School of Economics give special courses on advanced subjects like vector spaces and Fourier integrals and set theory. The M.Sc. and Ph.D. students also take some regular courses given for the undergraduates. Thus at University College, London, students holding the B.Sc. (Special) degree in statistics or the B.Sc. degree in mathematics with some statistical training have to take the specialized courses on combinatorial analysis, auto-regression and serial correlation, advanced sequential analysis, etc., given for the B.Sc. (Special) degree in statistics. Students holding a B.Sc. degree in mathematics have to follow a selected course of lectures and practicals for one year before proceeding to research.

Whether a graduate in mathematics taking up a statistical problem

for a Ph.D. degree can gain experience of the broader aspects of statistics is a debatable point. Dr. D.J. Finney in a discussion before the Royal Statistical Society[1] expressed the view that a man whose initial knowledge of statistics is small is apt to concentrate on the intricacies of one difficult piece of theory to the detriment of his general education in statistics and to become a mathematician whose special field is statistical mathematics rather than a statistician. He suggested that 'the ease with which a Ph.D. in statistics can be fitted into the existing regulations must not blind us to the importance of evolving a scheme of training in statistical techniques that will meet present and future demands for applied statisticians in many fields'.

One of the distinctive features of universities in the United Kingdom is the favourable atmosphere for research. All the members of the staff of statistics departments and those of other departments teaching statistics are engaged in research and many of them are in a position to guide research students in their work. Their association with practising statisticians and sometimes with official bodies in a consultative capacity invests their research work with realism and with a sense of utility. Very close contacts exist between the research students and the staff within a department as well as with the research students in allied departments.

Mention has to be made of the great benefit received by research workers from meetings of the various learned societies in the country. Particularly, the Royal Statistical Society and its sections on Research and Industrial Applications have contributed, if indirectly, to the training of persons for research.

CONCLUSIONS

The widespread use of statistics and statistical methods has stimulated the expansion of statistical studies in universities. Practically every institution gives courses in statistics. Apart from basic mathematical statistics, statistical theory specially relevant to the various university subjects is generally included as an obligatory or optional part of their curricula. Statistics has been recognized as a social science and is studied in close association with other social sciences —economics, psychology, education, anthropology and demography. As a subject ancillary to biology and agriculture, it has taken its proper place, but its importance in courses on medicine, engineering and technology does not appear to be well established, although there is some statistics at the post-graduate level.

1. 'The Teaching of Mathematical Statistics at University Level', *Journal of the Royal Statistical Society*, Vol. 118, Series A, Part 2 (1955).

The expansion of teaching to the present level has taken place in the last few years. The universities of St. Andrews and Aberdeen have introduced advanced courses only recently. At Birmingham University a degree course in mathematics, statistics and economics was started in 1955. Hull University has introduced a qualifying examination in economic statistics and one other compulsory subject, at the end of the second year of its B.Sc. (Econ.) course. Two London colleges have recruited full-time staff in 1955–56. At Imperial College, London, there is a suggestion for an honours degree in general science where it will be possible to combine pure mathematics, statistics, and physics (or some other experimental subject); this would be very valuable for anyone intending to enter industry as an applied statistician. The present post-graduate diplomas are too mathematical and it is found, as at Cambridge, that even if students are permitted to take two years over the diploma, they still need a fairly high mathematical standard at entry. It is suggested that for those who are not suited for this, a diploma in applied statistics may be introduced.

The view is generally held amongst university teachers of statistics that a good foundation in mathematics is necessary before a student is taught statistics. This partly explains the objection to starting full honours degrees in statistics. Dr. D.J. Finney[1] says 'The danger here lies in demanding too full a study of statistics from the immature mathematician and never giving him the breadth of mathematical knowledge that he may eventually need. Though statistics is a discipline in its own right, not merely a branch of mathematics, I am convinced that a firm grounding in mathematical outlook and technique is the surest foundation for a professional statistician; any proposal to award a first degree in statistics must guard against weakening this foundation by too early concentration on the utilitarian aspects of mathematics.'

Even when statistics is not taken as a major subject, courses in probability and mathematical statistics at intermediate level are given to undergraduates of mathematics and economics. But there seem to be several difficulties in teaching mathematical statistics which are summed up by Professor D.G. Champernowne[1] thus: 'Many of the difficulties arise from the fact that on the one hand, it is regarded by most statisticians as only a small part of the equipment of a statistician, and on the other, it is regarded by most mathematicians as a rather unimportant and uninteresting branch of mathematics.'

It appears that more field training should be arranged by uni-

1. ibid.

versities in collaboration with outside agencies. This will be particularly useful in respect of social and economic surveys, large-scale processing of data, agricultural experimentation and statistical quality control. The seminar method of teaching seems to be very successful for post-graduate and research students; it can also be introduced in the senior undergraduate classes, particularly as the number of students is in most cases limited. Regarding methods of teaching basic statistics, Professor M.G. Kendall thinks that axiomatic treatments are not what the students need in order to get a fundamental grasp of the basic ideas. He says:[1] 'I would guarantee to teach a student coming fresh to the subject more about probability with a pair of dice and a pack of cards in a week than he would learn in a month from set and measure theory. Naturally, I should prefer that he learn both approaches, but I think the experimental one comes first.'

In view of the growing importance of statistics as a university discipline in the United Kingdom, there is need to set up independent departments of statistics which will be responsible for advanced courses and research. They could also give common elementary or introductory courses, thus avoiding the necessity of appointing men of statistics in different departments. Centralization and co-ordination of teaching in statistics are among the problems yet to be tackled seriously.

The field of employment for statistics-trained graduates is very wide and there does not appear to be any fear of 'over production in universities. During 1954–56, the number of students who were awarded post-graduate degrees or diplomas in statistics was 26 and the number who were examined for at least one paper in statistics in the final examination for a first degree was 504. Even now, ten years after the War, there is a shortage of trained statisticians in Great Britain.

APPENDIX A

Curriculum for B.Sc. (Special) degree in statistics at University College, London

FIRST YEAR

The elements of statistical theory. Measurement of variation and correlation; sample and population; the normal curve. Applications of binomial, Poisson and hypergeometric series. The X^2 tests. The normal frequency surface and associated

1. ibid.

correlation problems. The elements of sampling theory and the analysis of variance. (About 40 lectures.)
Interpolation, quadrature and elements of finite difference theory. (About 15 lectures.)
Elementary probability. Fundamental theorems in probability with illustrations. Random variates. Theorems on expectation. Tchebycheff's theorem. Binomial and multinomial formulae; Poisson's limit. Estimation of parameters of a linear function. Derivation of standard errors. Elements of quality control and sequential analysis. (About 30 lectures.)
Practical laboratory course. Students are instructed in the use of tables and calculating machines, and are given illustrative problems to work out bearing on the subject-matter of the above lectures.

SECOND YEAR

Analysis of variation. Transformation of probability laws. Derivation of fundamental distributions. Analysis of variance appropriate to single, double and multiple classifications; analysis of regressions. Randomization; randomized block and Latin square layouts. (About 40 lectures.)
Second course on probability. Probability laws. Characteristic functions; the Laplace-Liapounoff theorem. Inequalities for moments. Composition of distribution functions. Generalized theorems on least squares. Application of Markoff method for test of a linear hypothesis. Sampling stratified populations. Probability theory in testing statistical hypothesis and in estimation. Stochastic processes. (About 30 lectures.)
Systems of frequency curves. (About 12 lectures.)
Problem class. (About 25 lectures.)

THIRD YEAR

The following courses are given regularly as part of the degree syllabus, the last two with co-operation of other departments: advanced analysis of variation, including multivariate analysis and special problems in the design of experiments (15 to 20 lectures); statistical genetics (10 lectures); economic statistics (15 lectures).

The student must also select, for Part II of the degree, two special subjects from a variety of alternatives. The advanced lectures given in the department in this category have varied from year to year and have included groups of 10 lectures on each of such subjects as: Combinatory analysis. Auto-regression and serial correlation. Advanced sequential analysis. Interpretation of statistical tests illustrated on special problems. Students may also attend appropriate lectures in this category at the London School of Economics.

To complete his work for Part II of the degree, a student in his third year must select a topic for study which is not covered by lectures, and write an essay on this topic using as illustrative material such fresh data as he can find. This scheme with associated tutorials and guide reading is designed as a preliminary training for later independent research.

Ancillary Mathematics

The first year of the ancillary course in mathematics is the same as that taken by physicists and chemists, excluding the lectures on applied mathematics. In the second year a course is arranged specially for statistics students, in which the following topics are covered:
Algebra. Elementary properties of determinants of any finite order. Multiplication of determinants. Matrices and elementary matrix algebra. Rank of a matrix. Latent roots of a matrix. Reduction to canonical form in the non-degenerate case. Solution of linear equations.
Calculus. Functions of several variables. Taylor's series for such functions. Superposition of small errors. Stationary values of such functions and discrimination between

maxima and minima. Lagrange's method of undetermined multipliers. Jacobians and their application to partial derivatives. Multiple integrals. Change of variables in a multiple integral. Dirichlet's integral and extensions. Use of orthogonal curvilinear co-ordinates. Line and surface integrals. Green's theorem for two and three dimensions. Differential equations. Ordinary equations of the first order. One-parameter families of curves. Ordinary linear second order equations and method of solution in series. Hypergeometric equation. Simple linear partial differential equations of the first and second orders. Special functions, finite differences, complex variables including conformal transformation and complex integration.

APPENDIX B

Courses for students specializing in statistics in their third year of the B.Sc. (Econ.) at the London School of Economics[1]

Introduction to probability (10). Development from an axiomatic basis. Conditional probability. Bernoulli trials. Generating functions. Laws of large numbers. Central limit theorems.

Introduction to mathematical statistics (20). A general treatment of frequency distributions and their properties. Binomial, normal, Poisson and other particular distributions. Interpolation and graduation. Curve fitting.

Numerical methods and interpolation (10). Description of various types of calculating machines and punched card equipment. The application of these machines to computing problems arising in statistics. Topics will include the computation of integration and interpolation.

Statistical relationship (10). Association, contingency and correlation. Regression and correlation analysis for two and for several variables.

Analysis of variance and covariance (10). One-, two- and three-way classifications. Arithmetical procedures. Theoretical background and assumptions involved. The use of transformations. Analysis of variance and regression. Analysis of covariance. Components of variance. Elementary notions of experimental design.

Introduction to quality control (8). Testing of industrial products and processes. Inspection by 100 per cent screening and sampling of raw materials and products and during manufacture. Continuous processes. Allowable variation. Need of warning that a process is getting out of control before rejection of the product becomes necessary. Control charts and specification limits; single, doubt and sequential sampling. Necessity of maintaining a reasonable balance between quality and cost and between the various qualities that are desired. Tests which indicate only some of the qualities desired.

Analysis of time series (10). The study of seasonal movements, oscillatory movements and trends in time series. Moving averages. Curve fitting. Auto-regressive systems. Correlogram and periodogram analysis. Variate-difference method. Tests for serial correlation.

Theory of sample surveys (10). Unrestricted random sampling; stratification and clustering; multi-stage sampling. Optimal allocation for given cost function. Selection with arbitrary probabilities. Ratio and regression estimates.

Estimation and tests of hypotheses (10). Point estimation: maximum likelihood estimators. Interval estimation; confidence intervals. Tests of hypotheses; likelihood ratio tests.

1. Numbers of lectures are given in brackets.

APPENDIX C

Courses offered for the diploma in mathematical statistics of Cambridge University[1]

Random variables (24). Probability theory at about the level of Feller's textbook; brief introduction to problems of inference.

Statistics I and II (48). Multivariate distributions; grouping corrections; cumulant estimates; significance tests, interval estimation; sampling distributions based on normal law and their uses; analysis of variance; regression; least squares; bivariate distributions; correlation; general theory of estimation; maximum likelihood; likelihood tests; general theory of inference.

Foundation of probability theory (24). Probability as the theory of additive set functions, central limit theorem; laws of large numbers; infinitely divisible laws; application to inference problems.

Stochastic processes (24). Stationary processes; autoregressive processes; sampling theory; evolutionary processes; Markoff Chains applications.

Design of experiments (24). General principles; randomization; factorial designs; Latin squares; incomplete block designs; series of experiments; rotation experiments.

Combinatorial statistics (24). Matching problems; combinatorial procedures; *k*-statistics; theory of ranking and other distribution-free tests.

Multivariate analysis (16). Discriminant analysis; multivariate analysis of variance, canonican-correlation analysis, factor analysis.

Sampling theory (16). Sequential tests for simple and composite hypotheses; sequential estimation; design of sample surveys.

APPENDIX D

Mathematical statistics (subsidiary course) of Manchester University

PART I. PROBABILITY THEORY

Introduction: definition of statistics and probability; examples of statistical data. Laws of probability (elementary treatment). Statistical dependence and independence contingency tables. Probability distributions, expectation values, moments, etc. Generating functions (probability, moment and cumulant). Binomial and Poisson distributions. Normal distribution. Bivariate distributions, moments, correlation coefficients. Introduction to multivariate distributions (very brief). Bivariate normal distribution.

PART II. MATHEMATICAL STATISTICS

Random samples. Statistical inference, basic concepts; sampling distributions of estimators; expected values and standard errors; tests of significance and confidence intervals; examples; sample mean of normal population, standard error of sampling mean, etc.

1. Numbers of lectures are given in brackets.

Theory of large samples. Tendency to normality of estimators in large samples; sample mean binomial and Poisson; central limit theorem (introductory). Standard errors of estimators in large samples (mean, variance, standard deviation, covariance, etc.).
Sampling techniques. Introductory treatment.
X^2-distribution and goodness of fit tests (no proofs). Properties of X^2-distribution; distribution of sample variance from normal population. X^2 test of goodness of fit; application to contingency tables.
Theory of small samples (no proofs). Exact sampling distributions for normal population; student's distribution (t-test); distribution of variance ratio (F and z tests); tests of significance in small samples (introductory).
Analysis of variance and design of experiments (methods). Introduction. One and two criterial of classification. Randomized blocks. Three criterial; Latin squares. Confounding. Factorial experiments (introductory).
Regression and least squares. Introduction. Linear regression; bivariate, multivariate. Distribution of means and regression coefficients (no proofs); tests of significance (introductory). Polynomial regression. Orthogonal polynomials. Harmonic analysis; least-square fitting of Fourier series.

UNITED STATES OF AMERICA[1]

FACILITIES FOR TEACHING

Historical Review

Adequate data are lacking for an account of the historical development of the teaching of statistics in the United States. A few broad features can, however, be observed. Elementary instruction in statistics has been common for many years in departments of economics, business administration and mathematics. A survey of 125 colleges and universities made in 1925 by a committee of the American Statistical Association showed that 60 per cent of economics and social science departments, and 4 per cent of departments of biology give such instruction. More advanced courses were found at that time in 30 per cent of the departments of mathematics but to only a minor extent in any other department.

During the period 1935–40, in a small number of universities, posts were created for teachers of statistics who could build a graduate

1. Based on original papers by William G. Cochran ('Present Status of Statistical Education in the United States of America') and the Southern Regional Education Board ('Statistics in Southern Colleges and Universities—Southern Regional Education Board').

programme for the training of professional statisticians. Previously, a young scientist wishing to specialize in statistics could obtain training only in a few departments, mainly in mathematics or economics departments, where some professors, although employed as mathematicians or economists, happened to be interested in statistics. The new posts, although located in departments of mathematics or economics, effected a change in that the incumbents of the posts were regarded as statisticians and were expected to devote themselves to work in statistics. Of the eight current leading centres of advanced instruction in the country, six started their graduate programmes after 1935. World War II, in which the application of statistical skill to many phases of military activity became evident, gave an impetus both to the training of career statisticians and to the provision of more courses in statistics for students in other branches of science.

The rapid and widespread use of statistics and statistical methods in the United States has brought about a critical shortage of persons trained in statistical methods. A great many jobs which were essentially statistical in nature were of necessity filled by persons having little or no formal training in statistics. Colleges and universities have responded to the increased demand for trained personnel, but the total need which is reported to be growing has not been met.

The Southern region consisting of 14 states[1] is particularly affected by the scarcity of persons trained in statistical methods. Southern colleges and universities have been trying to expand their programme in statistics to meet the region's needs. The Southern Region Education Board proposed, in 1952, to assist interested institutions in planning co-operatively the expansion and development of their programmes of statistical training and research. The Board sponsored a conference in 1952, and an Advisory Commission on Statistics was appointed to implement the recommendation of the conference.

Teaching Centres: Degrees and Diplomas in Statistics

In the United States there are a little over 1,000 colleges and universities which give courses of instruction leading to the bachelor's degree. Information relating to courses in statistics in all these institutions could not be secured. A sample of 44 of the 153 institutions each catering for more than 3,000 students, could however be taken. This sample which will be referred to hereafter as 'Sample of Large Institutions' would contain most, although not all, of the institutions that are well known outside the United States.

1. Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas and Virginia.

Another source of the information used here is the report entitled 'Statistics in Colleges and Universities of the South; Instruction, Research, Facilities' prepared by H. H. Chapman and Ruth G. O'Steen for the Southern Regional Education Board. This covers 193 out of 272 institutions in the 14 Southern States.

The 44 'large' institutions and the 193 Southern institutions analysed in regard to the number of courses given by each are enumerated in the following table.

No. of courses	Frequency of large institutions (over 3,000)	Frequency of Southern institutions		
		Over 300	Under 300	Total
0	—	—	36	36
1	—	—	57	57
2	—	—	40	40
3–5	10	2	19	21
6–10	13	9	8	17
11–20	13	9	1	10
21 and above	8	12	—	12
	44	32	161	193

The above table shows that every institution with more than 3,000 students gives at least three courses; of the Southern institutions, 80 per cent give at least one course.

The extent to which statistics figures in the courses given by different departments can be seen from the percentage given in the following list of departments in large institutions that offer at least one course in statistics:[1] business administration and economics, 95 per cent; mathematics, 77; psychology, 64; education, 58; sociology, 40; biology (including agriculture), 25; engineering, 24.

In the larger institutions it appears that some statistical instruction has come to be regarded as essential in business administration and economics. The high percentage given by mathematics departments is not surprising. Not only are courses in statistical theory usually given by mathematics departments, but in the smaller colleges, introductory training at a fairly low mathematical level may also be provided by the mathematics faculty. Both under psychology and education, about 60 per cent of the departments offer courses, while sociology has a slightly lower figure.

The figure given for biology does not cover schools of medicine or public health. Only a small proportion of the schools of medicine

1. The word 'department' is used here in a general sense—sometimes the university has a school or college of business administration rather than a department.

give a formal course in statistical methods. Some schools give a few lectures as part of the instruction in public health or preventive medicine. Schools of public health, on the contrary, uniformly require a course in biostatistics and most of them also provide a number of more advanced or more specialized courses.

Further information on the extent to which undergraduate instruction in statistics has entered various fields of study, is available from the following table showing number of courses offered by different departments.

Department	Larger institutions	Southern institutions
Business administration and economics	169	256
Mathematics	144	192
Statistics	96	179
Psychology	52	73
Education	58	63
Sociology	26	50
Biology (including agriculture)	19	79
Engineering	9	34
Physics and chemistry	0	8
Total	573	934

The relative importance given to statistics by the various departments in large institutions and Southern institutions is fairly equal, except in biology (including agriculture); this is perhaps owing to the fact that the Southern institutions have a far larger proportion of schools of agriculture. Both in the large and the Southern institutions, departments of statistics take the third place in respect of the number of courses taught. This does not, however, indicate that the number of courses per statistics department is less than that of a mathematics or business administration department. Actually the statistics departments give a larger number of courses, but the number of separate departments of statistics is small.

It is not easy to obtain an accurate idea as to how frequently the departments in the various subject fields regard some training in statistics as essential for the award of a bachelor's degree. Departments vary widely in this respect. From the catalogues, it appears that at least one course in statistics is nearly always regarded as essential for graduation in business administration and economics. In psychology, education and sociology, a substantial number, though still a minority, of departments have some statistics, while in biology and engineering it is even rare.

Information is not available on the particular colleges and universities in the United States where teaching in statistics is given at intermediate or advanced levels nor as to which department includes

statistics. The liberal arts colleges which are the principal institutions of higher education in the United States, offer programmes of study which can normally be completed in four years and which lead to the bachelor of arts or bachelor of science degree. The master's course requires two years, with the whole of the first year and part of the second devoted to lectures. The programme usually includes a thesis. For the Ph.D. degree usually a minimum of three years of study after the bachelor's degree is required. A number of prescribed courses have to be taken and a thesis based on original research must be submitted.

The bigger centres of teaching and research in the United States are North Carolina, California, Columbia, Iowa State College, Princeton, Michigan, Stanford, Johns Hopkins and Chicago.

Careers for Statisticians

The doctor's degree is the usual requirement for persons seeking university posts in statistics and also for careers in institutions predominantly devoted to research. The master's degree often leads to a career as statistician in government or business, starting at a junior professional level. Those who have taken majors and specialized programmes in statistics, whether qualified as bachelors in statistics or in any other subject, find a good demand in their respective fields—business, industry, agriculture, scientific institutions—as well as in government and other public bodies.

During the past 10 years, the demand for graduates (masters and doctors) has exceeded the supply. The universities, business and government have been employing statisticians in increasing numbers. A classifying of the employers of the 117 Ph.D. graduates (listed in the *Annals of Mathematical Statistics*) during 1950–53, shows that 73 went to the universities, 21 into business, and 16 into government (2 were employed outside the United States and the employment of 5 was not known). The predominant position of the university as an employer of the Ph.D. graduate is perhaps a reflection of the extent to which universities are strengthening their teaching staff.

Owing to the shortage of qualified statisticians, persons without adequate training are reported as being employed in good posts. The conditions of service for statisticians are quite attractive; in fact, the salaries offered to young statisticians are generally somewhat higher than for those with corresponding qualifications in other branches of science. Promotions also tend to be more rapid in the case of statisticians. The economic rewards and opportunities are high enough to compete favourably with other branches of science. The difficulty appears to be that not enough young people hear about statistics as a potential career early in their university training.

ORGANIZATION OF TEACHING

Requirements for Admission

Students who have completed a required academic programme in a secondary school may join an institution of collegiate rank. Formal general education ends with the liberal arts college. A student continuing beyond this will join a vocational or professional institution or enter a graduate school of a university.

For introductory courses in statistics, the prerequisites are varied; some courses require none, some require algebra, geometry and even calculus. A number of courses demand a prerequisite in business mathematics. According to the report on the Southern universities, 'The mathematical prerequisities for the bachelor's degree programmes with a major in statistics varied from no requirement to one year of calculus. The tendency, however, seemed to be to require at least a full year of college mathematics with a preference for some introduction to calculus either in the form of a mathematical analysis course or a first course in calculus.' One result of this variety of prerequisites is that students working in statistics in different institutions and even in different departments in the same institution, have widely varying backgrounds.

The master's degree programmes require mathematics more often than those for the bachelor's degree. The programme offered by the departments of mathematics and statistics naturally requires more mathematical preparation than the programmes of subject fields such as business administration and economics.

To enter a graduate school of statistics, students must have completed satisfactorily a certain amount of study in statistics, mathematics and sometimes in such other subjects as economics. The requirements for admission to the Ph.D. course are higher than for the M.A. In most universities, a qualifying examination is taken at the end of the first year before proceeding to graduate work.

Courses in Statistics: Aims, Duration and Content

Introductory courses. Many of the courses in statistics are introductory, in that no previous knowledge of statistics is needed for admission. In most instances, the introductory course is taken in the third or fourth year of the bachelor's curriculum.

The most common length of course is between 40 and 50 hours spread over one semester (half an academic year). A substantial minority of the courses are somewhat shorter. In about 60 per cent of the courses, both lectures and laboratory work by the students are included, while nearly all the remainder rely upon lectures alone.

The contents of the courses, as judged from the syllabuses, vary greatly from one subject field to another and to a lesser extent within a single field. The textbooks most commonly used provide an indication of the level and nature of syllabuses.

Business administration and economics: Croxton and Cowden, *Practical Business Statistics;* Simpson and Kafka, *Basic Statistics;* Nieswanger, *Elementary Statistical Methods.*

Mathematics: Mode, *Elements of Statistics;* Hoel, *Introduction of Mathematical Statistics.*

Psychology and education: Garrett, *Statistics in Psychology and Education;* Edwards, *Statistical Analysis.*

Biology: Snedecor, *Statistical Methods.*

In sociology and engineering there is no single textbook which is usually prescribed.

Major courses. With regard to the table showing the distribution of courses in different departments in the samples of 'large' institutions and Southern institutions, some of these are courses for those who take statistics as a major subject for the bachelor's degree. In 13 of the 44 'large' institutions and 18 of the 193 Southern institutions, undergraduate majors are in schools or departments of business administration and economics, the remainder being in departments of mathematics or in separate departments.

The amount of work required in statistics varies from 12 to 24 semester hours; in other words, from three to six hours per week for two academic years. The mathematical level of the curriculum is usually low. A common requirement is one year of university mathematics with some introduction to calculus.

The extent of major work in statistics offered at the three degree levels in the South is indicated by the following list: bachelor's programmes: 18 universities, 21 programmes; master's programmes: 15 universities, 24 programmes; doctor's programmes: 10 universities, 14 programmes. The aim of these is to train professional statisticians.

More advanced applied courses. In the larger institutions, more than one course is provided in most departments of business administration, economics and mathematics that teach statistics. In psychology, education and sociology, this statement holds for about less than half the departments concerned, and in engineering and biology, for a still smaller proportion. Many of the intermediate and advanced courses are continuations of the introductory courses, although in some cases they are on specialized topics. In business administration and economics, the most common topics for specializations are econometrics, industrial statistics and quality control, sampling and time series analysis; in psychology, construction of tests, theory of measurement, design of experiments and factor analysis. 'Methods

of research in social science' is a frequent title for courses in sociology departments, 'experimental design' in departments of agriculture, and 'quality control' in engineering courses.

At the graduate level, statistics is becoming more common as a minor field for students working for their master's or doctor's degrees. This may suggest that statistics is necessary for those students who intend to engage in research in subject fields, but is less essential for students not intending to undertake research. A minor in statistics usually implies from three to five courses in the subject.

Graduate Courses

The objective of graduate courses in the United States is a career in a university or in the profession of statistics. The nature of courses taken is determined largely by the type of career the student desires to take up later.

The master's programme consists almost entirely of courses in statistics and mathematics and a thesis for which original research is usually required, although an expository review of some branch of statistics is sometimes adequate. The course of study for the Ph.D. degree in statistics requires, besides the final thesis, successful completion of a number of courses in mathematics and statistics.

The report for U.S.A. states: 'Most of the students entering doctoral training in statistics have completed their major undergraduate work in mathematics, although occasionally students from other fields, such as biology or sociology, have already become so interested in statistical applications that they plan to concentrate on statistical training in graduate work. Most students have already had on entering some undergraduate courses in statistics, but these vary so much in content and quality that the major centres of advanced statistical training plan their courses so that the student may begin with no previous knowledge of the subject. Thus graduate training in statistics, unlike that in other disciplines, starts from the beginning instead of from an already moderately advanced level. This situation is likely to continue until undergraduate instruction in statistics becomes much more widespread than it now is.'

In general, the Ph.D. curriculum is divided between mathematics, theoretical and applied statistics, work in some substantive field, and the preparation of a thesis. Institutions differ in the extent to which emphasis is given to these four types of work: a substantial number require, for instance, no work in fields outside mathematics and statistics.

In mathematics the following are common as minimum requirements: algebra (including matrices and quadratic forms), advanced calculus, and theory of functions of a real variable. Additional topics

highly recommended at some centres which concentrate on mathematical statistics are: functions of a complex variable, theory of measure and of sets of points, and topology. In statistics, the basic courses are usually as follows: probability and distribution theory, estimation, tests of hypotheses, least squares and analysis of variance, multivariate analysis, sample survey theory and practice, and design of experiments.

More specialized courses may also be provided, for example sequential analysis, stochastic processes, decision theory, nonparametric estimation, operations research and analysis.

Work in the subject field usually consists of about three courses. It is intended to give the student some insight into the problems and the research methods of the branch of science in which he hopes to make his career. This requirement does not exist in some centres as many teachers of statistics do not believe in the necessity for such specialization.

The schedule of courses described above usually occupies most of the first two years of the programme of study. A common practice is to give the student a preliminary examination, during the second year of his programme. This examination covers the domain of knowledge which the student professes and in addition provides the opportunity for a preliminary discussion of his intended research thesis. The student must pass this examination before he is definitely admitted to the Ph.D. candidacy. Sometimes the examination reveals deficiencies in training which may be removed by further course work. Thereafter the student concentrates on his thesis, which requires from one to two years to complete. The great majority of the research problems undertaken for the thesis are problems in mathematical statistics.

For the master's degree, the mathematical level is in general lower than for the doctor's degree and the course of study is less intensive.

An indication of the type of courses offered by departments of mathematics and statistics is available from the report on the Southern institutions already referred to. The courses and the frequency with which they are offered are shown in the Appendix.

The *Annals of Mathematical Statistics* has listed annually, since 1950, the titles of the doctoral theses of successful candidates. These lists appear to cover all the major centres of training in mathematical statistics, but they omit some cases in which the Ph.D. programme in statistics is given by a department such as business administration.

Methods of Teaching

In the undergraduate teaching of statistics, both introductory and intermediate courses tend to combine lectures and discussions in

varying proportions. At the graduate level, some classes or parts of classes are devoted to discussions in which the students join. The lecture method, however, still continues to be important.

The seminar method is proving to be an important aid in the process of learning; it enables latest developments in statistical methodology and applications to be explained and discussed in a group of teachers, research assistants and advanced students. The seminar also establishes close association between professor and students.

In some places undergraduate students in their third year have tutorial arrangements, either individually or in groups of three or four with an instructor for questioning, advice on work and discussion. For graduates, there is continuous and close contact between each student who is preparing a master's essay or doctoral thesis and his major professor.

Practical training is given due importance in undergraduate training. The majority, though not all of the institutions giving courses in statistics are reported to have desk calculators for students and many of them have mechanical tabulation installations. In the South, 28 institutions are reported to have set up installations for research programmes consisting of card punchers, verifiers, sorters, collators and printing tabulators.

A large range of textbooks in English is available. Library facilities are excellent in American universities. It is also a practice to prepare and issue notes of lectures, particularly of advanced lectures covering recent developments as well as the results obtained by the lecturer himself.

No information is available on the extent to which students are given field experience, that is, training in the actual applications of statistics in life situations. Some federal and state agencies have offered to receive young statisticians as internees during their applied training, although the number of participants is still small. Opinions differ amongst teachers of statistics as to the extent to which training in the subject-matter field is necessary. It is held by some that a student trained in general principles can successfully apply them to any branch of science.

Methods of Testing Competence

It is customary in the colleges to have a written examination of from two to four hours in each course at the end of a semester. In most courses, one-hour 'quizzes' are also given two or three times during the semester. Practical tests or examinations usually accompany written ones to test the students' progress and his knowledge and competence at the end of a course.

The thesis for the Ph.D. should be based upon the results of

original research. In the case of the M.A., the thesis need not be of a high order; it should indicate the student's thoroughness, organizing ability and penetration. The thesis for a master's or doctor's degree in other subjects may include a large amount of statistical work applied to the topic of study. The thesis is judged by an *ad hoc* departmental or interdepartmental committee. The candidate is then required to make an oral defence of his thesis before this committee.

Teachers

In universities and colleges in the United States the teachers fall into four categories—instructors, assistant professors, associate professors and full professors.

The conditions of service of university teachers compare favourably with those of statisticians of similar abilities in the profession. The salaries offered are attractive enough to keep a large proportion of doctors in teaching.

The Southern report states that the major administrative problem facing small colleges is to find qualified teachers desiring to teach statistics. A small college may not be able to appoint a specialist in statistics to give a general course. It is therefore obliged to use a teacher whose primary duties will be in a department other than statistics.

The larger American universities have a system of inviting foreign professors for periods of six months to one year, particularly from Europe. This not only enriches the teaching programmes but stimulates research activity.

Centralization of Teaching in Statistics and Co-ordination

Although in a majority of institutions the teaching of statistics is still decentralized, there are indications of a trend towards centralization. Since the end of the war, a number of larger universities have organized departments of statistics or statistical laboratories, some of them intending ultimately to give training in statistics up to the doctorate level. In the smaller universities, the limited number of faculty members weighs in favour of some centralization of teaching which often takes place under the aegis of the department of mathematics.

According to Professor W.G.Cochran, there is much debate among teachers of statistics as to whether the introductory course is best taught as a general course in a department of statistics or mathematics, or whether it should be taught in the individual subject-matter field. This kind of problem is common to most countries and is discussed in the general survey in this report.

The Committee on Applied Mathematical Statistics of the National Research Council (1947) and the Committee on the Teaching of Statistics of the Institute of Mathematical Statistics (1947) discussed the best method of organizing teaching within a university. They tended to favour some degree of centralization through a statistical laboratory or department of statistics. The advantages cited for a central department are that it gives statistics a more definite status in the teaching programme of the university, it provides the opportunity for co-ordinated planning that is necessary in a rapidly developing field, it leads to a high quality of teaching and it helps to prevent unnecessary duplication of courses. The second Southern Regional Conference (1954) recommended that 'larger institutions proceed as rapidly as is feasible in each individual situation to integrate and co-ordinate teaching, research, and consulting services in statistics in order to attain the following objectives: to make the most efficient use of available equipment; to make the most constructive use of personnel; to avoid unnecessary duplication or multiplication of courses; to support a more adequate programme of statistical research; to permit the pooling of staff for consulting services'. The conference did not recommend any specific organizational pattern by which integration can be achieved in all institutions.

TRAINING

For those who cannot attend universities as full-time students, some opportunities are available for elementary instruction in statistics and for keeping up to date with recent developments. In most of the larger cities, evening courses are given by the universities. These are usually introductory courses of about the same scope and level as the introductory courses offered to full-time students of a university. Naturally, the number of courses available in any one city during a single year is small.

Except in the larger cities there are few evening courses of instruction and workers must depend mainly on individual study of textbooks. It might be possible to serve this group by means of correspondence courses, but these do not appear to have been tried on any large scale in the United States.

Information on in-service training has not been made available. It is known that some of the federal agencies arrange for courses of lectures for their employees. For instance, the Graduate School of the Department of Agriculture in Washington has a programme similar to that of leading university departments. In 1954–55 this school had given 22 courses, it had also made arrangements with two universities to give evening courses for federal employees in New York and Boston.

Some of the outstanding statistical centres have developed attractive summer school programmes. Summer school courses usually last six weeks with concentrated teaching on five days of the week. In addition to introductory courses, such sessions may give advanced instruction in some special field, for instance, experimental design, or sample survey techniques. Employed persons can attend these courses by forgoing part or all of their usual summer vacation.

Both universities and professional societies have experimented with attempts to provide instruction or discussion of statistical problems during very short periods of time. For instance, the University of North Carolina has conducted a number of successful one-week work conferences, each devoted to a specialized application of statistics. They are intended for workers who already have a good background in applied statistics and who desire to know some of the newer developments and discuss their own problems.

RESEARCH

The main research degree is the Ph.D. The M.A. or M.Sc. degree involves some research. There are at present more than 30 universities where a doctor's degree in mathematical statistics can be taken. A greater number give training for the master's degree. The Ph.D. programmes are limited in scope in some of these institutions but they are gradually being strengthened.

During the four years, 1950–53, there were 117 doctoral graduates in statistics in the United States, that is about 30 a year. The four larger centres, North Carolina with 26 graduates, California with 14, Columbia with 9 and Iowa State College with 8, together accounted for almost half the total number. The four other institutions, Princeton, Michigan, Stanford and Johns Hopkins contributed a further 20 per cent. The years after 1953 must have produced a large number of graduates. The number of master's degrees is expected to be substantially larger than the doctor's degrees. In the Southern institutions 15 offer master's degrees as against 10 offering doctor's degrees.

In the United States, there are ample opportunities for post-doctoral studies and research. The leading centres of statistics in the universities welcome such students. Since statistical research receives substantial financial support from the government by means of grants or contracts, funds are usually available for stipends for post-doctoral fellowships. A number of the major private foundations also support advanced research of this kind. The good proportion of foreign students and research workers in statistics is a distinctive feature of some well known universities.

There are several important centres of research outside the universities at which applied statistical problems are studied, as for example the National Bureau of Economic Research in New York, the Cowles Commission at Yale, in the field of economics. These institutions work in close co-operation with universities.

The Southern Regional Conference (1954) recognized that a complete educational programme in statistics, as in any science, rests upon research and suggested a co-operative research programme amongst the colleges and universities of the region.

CONCLUSIONS

Teaching of statistics at pre-university level is practically non-existent in the United States. The need for giving to as many citizens as possible some training in quantitative thinking about social affairs is stressed by several statisticians. Dr. S.S.Wilks in his presidential address to the American Statistical Association in 1951 expressed the view that a place could be found for instruction in statistics by omitting certain parts of the high-school teaching in algebra, trigonometry and geometry that are of little use to the student, whether he goes to a university or not. Proposals are being put forward and discussed but no real progress has been achieved in this direction.

There is need for more undergraduate instruction in statistics. Although courses in certain departments such as business administration, economics and psychology are fairly general and extensive, training for students of physics, chemistry and engineering is very limited. Nor does agriculture appear to be well served.

The number of university departments in which statistics can be taken as a major subject for the bachelor's degree is not large enough to supply the career statisticians required by the country. If their number is increased and major undergraduate programmes become more common, it will also be possible for graduate training programmes to begin at a moderately advanced level rather than at the beginning as they now have to do.

There is considerable diversity in university organization for work in statistics. Some have independent statistics departments but they are not always responsible for co-ordinating the teaching and research work of the other departments. There is not much evidence of centralization of statistics work, even at the introductory level. Clearly, there are definite gains in the integration of statistical work particularly in a small institution. But each has to develop and adopt the method best suited to its own objectives, organization and administrative structure.

As a consequence of the greatly increased use of statistical

methods, many persons in positions of responsibility who have had no training or only very inadequate training in the subject now use statistics. Part-time university courses specially designed for such persons are greatly needed. The work of societies like the American Statistical Association and the American Society for Quality Control is helpful in this direction.

Junior statistical staff in government service or in business and industry should receive in-service training to make them better fitted for their immediate and future work. The expansion of statistical activity in every branch of public life and the widespread use of statistical methods in science and technology call for intensive effort in this type of training for different levels of workers.

It is perhaps a little surprising to know that even in the U.S.A. there is a shortage of statistically qualified men. Although the supply has been increasing, the demand is always in excess of supply. University facilities are there; but they need to be properly expanded and geared to the requirements of the nation.

APPENDIX

Intermediate and advanced statistics courses in the colleges and universities of the South in U.S.A.

1. For mathematical students given in mathematics departments

Title of course	Frequency of institutions
Advanced statistics	1
Advanced mathematical statistics	8
Analysis seminar	1
Curve fitting	1
Directed reading and investigation	1
Elementary statistics– second term	1
Elementary statistics principles—second term	1
Interpolation and graphical methods	2
Introduction to statistics—second term	1
Introduction to mathematical statistics	3
Introduction to the theory of probability	1
Mathematical statistics	20
Mathematical theory of statistics	1
Mathematical theory of strategy	1
Probability	3
Seminar in statistics	1
Smoothing experimental data	1
Statistics	3
Statistical methods	2
Statistical theory	1

Title of course	Frequency of institutions
Theory of means	1
Theory of probability	1
Theory of probability and theory of sampling	1

2. For statistics students including intermediate and advanced statistics

Title of course	Frequency of departments offering course		
	Statistics	Business statistics	Mathematics
Advanced analysis of variance and covariance with applications to experimental designs	1	—	—
Advanced experimental statistics	2	—	—
Advanced multivariate analysis	1	—	—
Advanced probability	1	—	—
Advanced research	2	—	—
Advanced statistical analysis	2	—	—
Advanced statistics seminar	—	3	—
Advanced topics in construction and analysis of experimental designs	1	—	—
Analysis of variance	1	1	—
Applied multivariate analysis	4	—	—
Basic statistical analysis	2	—	—
Basic statistical theory	2	—	—
Combinatorial problems of the design of experiments	1	—	—
Correlation and contingency	1	—	—
Correlation analysis	—	1	—
Directed study	1	—	—
Elementary probability	1	—	—
Elementary statistics	1	—	—
Experimental designs	1	—	—
General theory of statistics decision	1	—	—
Inference	—	2	—
Introduction to statistical analysis	—	1	—
Introduction to statistical theory	2	—	—
Methods of operations research	1	—	—
Multivariate analysis	2	—	—
Nonparametric inference	1	—	—
Probability	1	—	—
Random sampling distributions	—	1	—
Rank order statistics	1	—	—
Regression and correlation	—	1	—
Research	1	—	—
Research and dissertation	1	—	—
Research and thesis	1	—	—
Sample survey methods	1	—	—
Sample survey theory	1	—	—

Title of course	Frequency of departments offering course		
	Statistics	Business statistics	Mathematics
Sampling	1	—	—
Sampling theory	—	—	2
Sampling theory and practice	—	2	—
Selected techniques of approximation	1	—	—
Seminar	1	—	—
Seminar in statistical analysis	2		—
Seminar in theoretical statistics	2	—	—
Special problems	4	—	—
Special problems in multivariate analysis	1	—	—
Special studies	—	1	—
Statistical inference	1	—	—
Statistical methods	2	—	—
Tests of hypotheses	1	—	—
Theoretical statistics	2	—	—
Theory of estimation	1	—	—
Theory of least squares	1	—	—
Theory of sampling applied to survey design	1	—	—
Theory of sequential methods	1	—	—
Thesis	—	3	—

YUGOSLAVIA[1]

FACILITIES FOR TEACHING

Historical Review

Statistical education in Yugoslavia has undergone very rapid expansion since the close of the second world war. The growth in the teaching programme is partly due to a general increase in educational facilities and student enrolment but also to a greatly enlarged demand for statistically trained personnel in the development of the country as a socialist State. This demand has come not only from government agencies but also from factories, commercial

1. Based on an original report by Hildegarde Kneeland entitled 'Statistical Education in Yugoslavia'.

establishments, agricultural co-operatives and other types of producers' organizations.

The main agencies of statistical education and training are: (a) the universities at the undergraduate level in several faculties and extending to the post-graduate level in one instance; (b) the vocational schools of economics and agriculture at the secondary level, and (c) statistical offices of the Federal Government and governments of the four Republics through programmes of in-service training ranging from the elementary level to advanced post-graduate level.

Three of the universities of Yugoslavia are of long standing. The University of Zagreb was founded in 1874, the University of Belgrade in 1905 and the University of Ljubljana in 1919. The two other universities teaching statistics are Skoplje founded in 1946 and Sarajevo in 1949. The University of Norvi-sad, which was set up in 1954, has not yet started teaching statistics.

The teaching of statistics at the secondary-school level in Yugoslavia is a development of the post-war period. Following the establishment of the Federal Republic, a large number of vocational schools were opened to provide a certain amount of specialized training in connexion with the usual intermediate school education. In 1953-54, there were 49 schools of economics and 27 schools of agriculture. Statistics has been taught in some of these schools for the last three or four years. The outstanding feature of Yugoslav education is the very large number of students going into various types of institutions. More than 6,000 students took university courses in statistics during one of the semesters of 1953–54. Of these, 4,000 were in the faculties of economics, 1,700 in faculties of law and 300 in faculties of agriculture; the rest in other faculties. In the secondary vocational schools of economics and agriculture about 3,000 pupils study statistics during a year. These strikingly large numbers may be partly due to the fact that tuition is free to all students.

Teaching Centres: Degrees and Diplomas in Statistics

University teaching of statistics exists, as stated above, in the universities of Belgrade, Zagreb, Ljubljana, Skoplje and Sarajevo. The system of university organization is substantially the same in all the universities. The undergraduate curriculum covers at least four years (six years for medicine, engineering and veterinary sciences). A diploma corresponding to the bachelor's degree is granted at the end of the course. There is no master's degree, but the doctorate is conferred after two or more years of post-graduate study and the completion of a thesis.

Statistics is taught in several faculties, the most important being those of economics and agriculture. In the Faculty of Economics

at the Belgrade University, all the undergraduates have to take courses in statistics in the first two years; in the last two years, it is optional for those taking economics major. At the post-graduate level, instruction for the doctor's degree with specialization in statistics is provided.

In the Faculty of Agriculture, there is a compulsory one-year course for all undergraduate students. For the doctor's degree in agricultural economics, advanced courses in statistics have to be taken. There is a compulsory course in the Faculty of Law for undergraduates. The students of mathematics and psychology are given some minor courses.

The teaching of statistics in other universities follows the same general pattern as in Belgrade with respect to the obligatory courses in the faculties of economics, agriculture and law.

At the vocational schools of economics and agriculture, the course of study lasts for four years. Gradually statistics is being introduced into the curriculum in all the schools, generally in the third or fourth year of study.

Careers for Statisticians

There is apparently a large demand for statistically trained persons at various levels. It is reported that students trained in schools of economics, the majority of whom are girls, take up jobs as bookkeepers, cashiers and clerks in commercial and industrial establishments, with a considerable number going into government service. Many of these qualify themselves further in statistics by continuing study as full-time or part-time students in the universities. Those trained in schools of agriculture go into work on co-operative and State farms, in food processing and other industries relating to agriculture, and in community agencies and government offices. The university-trained graduates with statistical qualifications get absorbed in government offices or industry, while a good many go for teaching in the economics and agriculture schools and university departments.

ORGANIZATION OF TEACHING

Requirements for Admission

Admission to the vocational schools of economics and agriculture requires completion of eight years of compulsory elementary education. For admission to university faculties, graduation from the general educational secondary school is required. A graduate from

the vocational schools can join the faculty corresponding to the vocational subject of the school.

Information is not available on the mathematical prerequisites, if any, for taking courses in statistics in universities.

Courses in Statistics: Aims, Duration and Content

There is considerable uniformity amongst the universities in regard to the aim, duration and content of the courses in statistics in each faculty. At Belgrade, undergraduates in economics are given, in the first year, lectures on general statistical methods, statistical analysis, index numbers, time series and regression analysis. There are two hours of lectures and two hours of exercises each week. The course is divided into two parts. Part I covers concepts of economic statistics and Yugoslav official statistics; statistics of demography—sources, distribution of populations and movement of populations; statistics of economic capacity. In Part II are covered concepts of production; national income and product; dynamics of production; and statistics of labour and prices. The courses take up four hours, weekly—two for lectures and two for exercises. The syllabus at the Belgrade University is given in the Appendix.

About 2,500 first-year students were admitted in the autumn of 1954, but more than half of these are part-time students. Since attendance is not compulsory even for full-time students, only a quarter of this number are usually present for the classes.

In the third year an optional course in mathematical statistics is offered and in the fourth year, courses of sampling theory, design of experiments and quality control. Only four hours (two hours lectures and two hours practical are given each week). The number of students is generally small; in 1954–55 it was only 25.

At Zagreb University, the compulsory two-year course has the same content as in Belgrade. There is no provision yet for advanced courses. At Ljubljana statistics is given in the second and third undergraduate years, general statistical theory (four hours a week) being given in the second year and population and economic statistics (three hours a week) in the third year. In the first year an elementary course in mathematics for economists and statisticians is given in elements of calculus, probability and analytical geometry. At the post-graduate level, special courses are provided in advanced mathematics and advanced statistics.

In the Faculty of Agriculture at Belgrade, statistics is given in the Agricultural Economics Department in the third year of study. In 1954–55 owing to temporary adjustments in the teaching programme it was also taken by second-year students. In the second year there are 160 students and in the third year 80. Two hours a week are allotted

to statistics. Advanced work in statistical analysis and sampling was planned for all candidates for the doctor's degree in agricultural economics. The departments of genetics and crop production give some time to statistical mathematics in combination with work on design of experiments. At the other universities, statistical work in agriculture is similar to that in Belgrade.

In the faculties of law compulsory one-semester courses in general statistics are taken during the first half of the second year. At Ljubljana a course of one year's duration in general and social statistics is provided.

In Yugoslav universities, statistics does not appear to be closely associated with mathematics, and is not taught to any extent in mathematical departments. Only at Belgrade is there a one-year course on probability for undergraduates in mathematics.

Teaching of statistics is fairly widespread for psychology students although it is not comparable with that for students of economics. A compulsory one-semester course is given in the second year at Belgrade, while at other centres some time is devoted to statistics in various courses on psychology where methods of statistical measurement and analysis are required.

The courses described above have a definite professional aim and are intended to prepare students to work in economics, agriculture, psychology and sociology. Mathematical statistics is not taught as a subject to be studied for its own sake and there does not appear to be any degree or diploma purely in statistics.

Methods of Teaching

Nearly half the time for the courses in statistics is devoted to lectures and half to exercises. Emphasis is given to practical work, but it is doubtful whether computational training with machines could be provided for the large number of students in the various departments.

A number of textbooks written by professors at Belgrade and Ljubljana in local languages are used. A few standard books in English have also been translated. For reference reading, books in English, French and German are used.

The extent of field training or training in the government offices is not known. It can, however, be assumed that students are given opportunities to study the work of the statistical offices of the Republics and of the Federal Government.

Teachers

Most of the statistical staff in Yugoslav universities have received advanced training in such countries as the United Kingdom, U.S.A.

and Germany. Some of them are also specially qualified in statistics, although few are full-time teachers of statistics. At Belgrade University, for instance, of four staff, three hold positions in government statistical agencies and the fourth is a teacher in economics.

Statistics in the faculties are usually taught by a professor having his main qualification only in the subject of his own faculty. Thus, in the Faculty of Law at Belgrade, the course in statistics is given by a professor who has a doctorate in law from Paris; similarly, in the Mathematics Department by a professor who has a doctorate in mathematics and in the Psychology Department by a doctor in psychology. At Zagreb also, the teaching of statistics in the Faculty of Agriculture is done by an agricultural engineer.

Centralization of Teaching in Statistics and Co-ordination

At Belgrade and Ljubljana, there are separate departments of statistics only in the faculties of economics. At the universities of Skoplje and Sarajevo, statistics has only recently been developed and the statistical work in connexion with such studies as economics and law is organized in a single faculty and taught by a single person. With a few such exceptions, the work in each faculty is handled independently by the staff belonging to it.

TRAINING

It is a special feature of Yugoslav universities that classes are open to part-time students who are in employment. This enables persons requiring statistics in various posts to qualify themselves.

Although the work in statistics in the universities and intermediate schools of Yugoslavia is exceptional in scope, the most outstanding programme is the system of in-service training in statistics provided by the staff of government statistical offices. The first courses in this field were started shortly after the second world war to meet the immediate needs of the newly established Federative State and the Constituent Republics. During this initial period the work was mainly of an elementary level dealing with the questions of how to organize a statistical office, what type of staff are required for various purposes and how to collect, tabulate and process data; little attention could be given to methods of analysis or to statistical theory. Since those early years, the programme has been modified and extended to meet the improved situation, and it now covers all levels of training from introductory courses for junior employees without university qualifications to advanced post-graduate work.

In the immediate post-war period, most of the courses were given

by the Federal Statistical Office either in Belgrade or in regional training centres, but work was also started fairly early in the statistical offices of Serbia, Slovenia and Croatia and recently in Bosnia-Herzegovina. At present all the work at elementary and intermediate levels and some specialized work on more advanced levels is given by these Republics while the federal office in Belgrade limits its programme to intensive advanced courses in statistical theory.

The training programmes within Republics are planned to meet the needs of three groups of employees: (a) those working in the small administrative districts into which a Republic is divided; (b) members of the staff of the Central Statistical Office, and (c) more senior members who are qualified for specialized work. The employees in the district offices are generally taken to the central offices of the Republic for a full-time course of several months' duration. The subjects usually covered are mathematics, general statistical methods, and applied statistics, laying emphasis on methods of applying various statistical techniques to the special problems encountered by them in the work in the district.

Many of the employees of the central offices of a Republic are qualified in vocational schools or through previous in-service training. The new entrants have to pass a State statistical examination and therefore provision is made for them for training after office hours. During office hours also, brief courses are given to selected groups of employees at a fairly advanced level in special fields of statistics.

In the Federal Statistical Office at Belgrade the system of giving advanced courses was started in 1953–54. The training is intended for the officials from various federal agencies and from statistical offices of the Republics. The sponsored candidates should have received university training with mathematics as a prerequisite. In future, admission is likely to be limited to those with knowledge of statistical theory. The period of training is 12 months, during nine months of which there is an intensive programme of lectures, seminars and special assignments. The remaining three months are spent on individual work on a diploma problem or on a thesis. Examinations are regularly held and there is a final oral examination before the diploma is granted. The syllabus is mainly mathematical, with emphasis on mathematical theory. The subjects covered are given in Appendix B.

The training programme is directed by the professor of statistics in the Faculty of Economics, Belgrade University, who is also the specialist in sampling for the Federal Statistical Office. He is assisted by other professors and staff of his office.

CONCLUSIONS

The expansion of statistical education and training in Yugoslavia has been spectacular. That statistics is compulsory for students in various faculties, particularly those taking economics and psychology, shows the importance attached to statistics in the Yugoslav education system. The predominant aim of the courses in statistics is vocational. The students are definitely being trained while at the university for statistical posts at various levels. The objective is the same in statistics courses in vocational schools of economics and agriculture.

It is not clear to what extent Yugoslavia is training teachers and theoretical statisticians who would ultimately be responsible for university teaching and research. There is no special degree in mathematical statistics and it appears that the most advanced courses in mathematical statistics are available only in the training programme of the Federal Statistical Office. Clearly, a programme of post-graduate research work not connected with the training of office staff is needed.

There is close co-ordination between universities and government statistical offices in the matter of providing training to persons employed in those offices and also in giving courses in universities. This co-ordination should be fruitful and it is hoped that those trained are finding suitable opportunities for progressing as statisticians and utilizing the theoretical and professional knowledge they have acquired.

APPENDIX A

Faculty of Economics, University of Belgrade

ELEMENTARY COURSE IN GENERAL STATISTICS

Introduction (8 lessons): statistical methods, statistical populations (mass phenomena), statistical observation, statistical analysis.

Methods of static analysis (18 lessons): mass structure and series of structure, research on frequency distributions, estimations by means of samples, problems of homogeneity (analysis of variance, stratification).

Methods of dynamic analysis (16 lessons): dynamics of mass phenomena and time series, index numbers, research of the trend, fluctuations about the trend (seasonal, cyclical and irregular).

Methods of regression analysis (16 lessons): linear regression, curvilinear regression, multiple and partial correlation, correlation between time series.

COURSES IN ECONOMIC STATISTICS

General questions: concept and object of economic statistics; statistical documentation; development of Yugoslav economic statistics.

Part I. *Productive forces in the economy and their statistical measurement*

Statistics of demography, as a source of data about the population: general questions (demography, economy and statistics; sources of statistics of demography; history of censuses of Yugoslav population); distribution and structure of population (size of population and its distribution; town and country population; structure of population); natural movement of the population (nationality, fertility, reproduction and nuptiality of the population; mortality, rate of mortality and table of mortality); migration (national and international migration).

Statistics of economic capacities: classification of industries; concepts of economic capacities and their measurement (in the basic industries--manufacture, agriculture, transport and commerce).

Part II. *Economic activity and its measurement*

Concept of production: sources of data; different ways of measurement; specific problems of measurement of production in different industries.

National income and product: possibilities of their different concepts; methodology of national income in Yugoslavia, U.S.A. and other countries; national accounting system--financial flows, input, output system (Leontief); principles of analytical research in economic activity.

Dynamics of production: index of physical volume, seasonal variations, secular variations, irregular variations, cyclical variations.

Statistics of labour: employment and its measurement, measurement of labour time, productivity of labour, wage and salary statistics.

Statistics of prices: prices as instruments in the distribution of goods and services, indexes of prices, statistics of the level of living.

APPENDIX B

Advanced course in statistical theory given in the Federal Statistical Office

Theory of matrices, during 2½ months—4 hours per week. Professor Dr. Antelic, Department of Mathematics, University of Belgrade.

Probability calculus, during 2½ months—4 hours per week. Dr. Ivanovic, assistant professor, Faculty of Economics, University of Belgrade.

Mathematical statistics, during 6 months—4 hours per week. Dr. Ivanovic.

Selected problems in mathematics, during 2 months—4 hours per week. Professor D. Karamata, Geneva, Switzerland.

Theory of sampling I, during 4 months—4 hours per week. V. Balaban, Federal Statistical Office, Belgrade.

Theory of sampling II, during 2 months—4 hours per week. Professor Dr. S.S. Zarkovic, Faculty of Economics, University of Belgrade and Federal Statistical Office.

Presentation and discussion of the most important sampling surveys in the world, during 2 months—4 hours per week. Professor Dr. Zarkovic.