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BIRKBECK
University of LONDON

MSc APPLIED STATISTICS programmes

MSc Applied Statistics

(with additional pathways:

M.Sc. Applied Statistics and Computational Data Analytics;
M.Sc. Applied Statistics and Operational Research).

MSc Applied Statistics and Financial Modelling

CONTENTS

1. GENERAL INFORMATION

This handbook should be read in conjunction with the Birkbeck College Postgraduate Prospectus. The information contained in the handbook is subject to the terms and conditions set out in the College Prospectus. **None of the items discussed in this handbook should be construed necessarily to have any binding authority (except where underpinned by College regulations), but rather only limited persuasive authority, in relation to the interpretation of any contractual obligations owed by the College to the student.**

1.1 About Birkbeck

Birkbeck College was founded in 1823, and incorporated by Royal Charter in 1926. It is one of the multi-faculty Schools of the University of London. Birkbeck is the only college whose principal objective is the provision of part-time degree courses. Its academic staff are engaged in research as well as teaching, and they and the administrative staff take pride in providing a sympathetic environment for part-time evening studies.

Birkbeck College provides university education primarily for mature students engaged in earning their livelihood during the day. Lectures, leading to an MSc in one of the Applied Statistics Programmes, are given in the evenings, between 6pm and 9pm and students study for an internal degree of the University of London.

1.2 Fees

The fees presented here are approximate and subject to revision.

M.Sc. Applied Statistics

Part-time fees for 2018/19 are £4375 for part-time Home and EU students and £7425 for part-time international students.

M.Sc. Applied Statistics and Financial Modelling

Part-time fees for 2018/19 are

Yr 1:- £4375 for part-time Home and EU students and £7425 for part-time international students.

Yr 2:- £8050 for part-time Home and EU students and £10775 for part-time international students.

For both programmes, certain eligibility criteria must be fulfilled before students can study part-time. Fees can be paid in instalments, by direct debit.

http://www.bbk.ac.uk/mybirkbeck/finance/money

1.3 Academic staff associated with M.Sc. Applied Statistics programmes

Brad Baxter, MA (Cantab), MMath (Cantab), PhD (Cantab).
Anthony Brooms, BSc (Manchester), MSc (Sheffield), PhD (Bristol).
Swati Chandna, BA(Hons)(Delhi), M.Sc.(Houston), Ph.D (Imperial).
Hélyette Geman, B.Sc.(Ecole Normale Supérieure), M.Sc. [Theoretical Physics] (University Pierre et Marie Curie), Ph.D. [Probability] (University Pierre et Marie Curie), Ph.D. [Finance] (Sorbonne).
Georgios Papageorgiou, BSc (Athens UEB), MS (Florida), PhD (Florida).
Richard Pymar, MA (Cantab), MMath (Cantab), PhD (Cantab).

PROGRAMME ADMINISTRATOR

Beverley Downton, BA (Chichester)

CURRENT TELEPHONE & ROOM NUMBERS, MALET STREET

Programme Administrator	716	020 7631-6403	*b.downton@bbk.ac.uk*
Brad Baxter	755	020 7631-6453	*b.baxter@bbk.ac.uk*
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Swati Chandna	TBC	TBC	*TBC*
Georgios Papageorgiou	735	020 7631 6410	*g.papageorgiou@bbk.ac.uk*
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2. M.Sc. PROGRAMMES

MSc APPLIED STATISTICS (MAS)
MSc APPLIED STATISTICS AND FINANCIAL MODELLING (MASFM)

2.1 General Information

These two year part-time MSc programmes have been specially designed to meet the needs of part-time students in employment. Many students, as part of their everyday work, are involved in data analysis, the interpretation of statistics, the optimal design and control of systems or the modelling and prediction of time dependent phenomena. Over two years, in lectures and in practical computing sessions, the courses cover both the theory and the application of modern statistical and mathematical modelling techniques required to solve applied problems in industry, the public services, commerce and research. While practically oriented, the programmes all proceed from a strong theoretical background so as to develop the ability to tackle new and non-standard problems with confidence. The mutual dependence of practice and theory is emphasised throughout.

All <u>new</u> students are registered either on MSc Applied Statistics or M.Sc. Applied Statistics and Financial Modelling. After a common first year of core modules in theoretical and applied statistics, the second year allows students to orient their programme of studies towards their own particular interests and career objectives. Students typically select four modules (each running over a single term) from a range of specialist streams including (depending on research expertise of staff in post): **Computational Data Analytics**; **Operational Research**; and **Financial Modelling** [MASFM students only]. If desired, one of the four modules may be replaced by a supervised, individually prescribed reading course. In addition to following their four chosen modules, students are required to undertake a project, a sustained, independent investigation carried out over eleven months from October 1 at the beginning of the second year, to the following September 1.

The curriculum is designed to provide a broad education and training in statistics at postgraduate level during the common first year before specialization in the second year. Thus the first year provides an excellent stopping off point, in the form of a Postgraduate Certificate in Applied Statistics, for those who do not need more advanced or more specialized training.

The MSc is a two-year part-time programme that involves attending lectures on two evenings per week throughout the academic year (approximately 25 weeks). Computing/practical sessions are held on a third evening for approximately 5 weeks in Year 1. Lectures and practical sessions are from 6.00pm until 9.00pm, with a break halfway through the evening.

The Royal Statistical Society, since its merger with the Institute of Statisticians, awards Professionally Qualified status to those statisticians who meet specified criteria. Chartered Statistician status (CStat) is for those who satisfy both academic and practical experience criteria, while Graduate Statistician status is for those embarking on their statistical careers who currently satisfy only academic criteria.

The MSc programmes at Birkbeck are not conversion courses. Applicants should have a first degree at 2(i) honours level or above, with Mathematics or Statistics as a main field of study or with substantial mathematical or statistical content. Other equivalent qualifications may be accepted, for example the Graduate Diploma of the Royal Statistical Society.

Applicants who do not fully satisfy the entrance requirements, but who have a degree or equivalent qualification and some knowledge of statistics, may be admitted to the part-time Graduate Certificate in Statistics programme. To qualify for entry to the MSc programmes, the Graduate Certificate in Statistics must be passed at the Merit level or above (average of at least 60%).

2.2 Applications and Admissions

Applications are submitted on-line at
http://www.bbk.ac.uk/study/2018/postgraduate/programmes/TMSSTAPP_C/ or
http://www.bbk.ac.uk/study/2018/postgraduate/programmes/TMSASFMO_C/

and eligible candidates may be asked to attend interview. Candidates may also be sent an admissions test paper to be returned before coming for interview. Interviews normally take place from April onwards.

All formal offers of a place on the MSc are made by the College Registry and are sent by email. On acceptance, students will be asked to enrol on-line before starting the programme. Enrolment will provide a College Membership Card, which is essential for access to College facilities, including the library and computing services.

If you have any problems with enrolment or fees, please contact the Student Advice Service: http://www.bbk.ac.uk/student-services/student-advice-service

Before term starts the MSc programme administrator will email a class timetable, a preliminary reading list, a set of mathematical and statistical notes and an invitation to a pre-session induction evening. Information on optional September pre-session mathematics and statistics courses will also be made available and some students find these useful as preparation for the first term of the MSc. Early in the autumn term students will also receive an email assigning them a personal tutor, whose role will be to advise them and monitor their progress throughout the programme.

2.3 Withdrawal from the College

http://www.bbk.ac.uk/mybirkbeck/services/administration/withdrawing

2.4 Communication

Notice boards

There are notice boards in the department where course information is posted. Lecture timetables and information about coursework, such as which assignments are ready for collection and confirmation of whose work has been received will be placed on these noticeboards. Careers and programme information as well as job vacancies may also be found there.

Email

You are expected to monitor your email account on a regular basis as this will be used for official communication from the Department and the College. You can use your own nominated email account for all contact with Birkbeck**.** To ensure that we are using the email address you want us to use, please check your details on the My Birkbeck Profile.

If you want to, you can also apply for a Birkbeck student email account, which you will be able to access via the web. Please see http://www.bbk.ac.uk/its/ or contact its@bbk.ac.uk for further information.

The Web

There are many resources for students both on the Department website http://www.ems.bbk.ac.uk/for_students and on the My Birkbeck student intranet http://www.bbk.ac.uk/mybirkbeck.

On the MSc Applied Statistics website http://www.ems.bbk.ac.uk/for_students/msc_stats you will also find timetables, items of news, a list of personal tutors and tutees and information about modules. The online resources for individual modules will vary depending on the lecturer and how long the module has been running. However you will always find a syllabus, learning outcomes and a list of recommended books. Additionally all assignments will be available to download, as well as being distributed in lectures (for the most part).

3. DRAFT TIMETABLE 2018/19

FIRST YEAR COURSES 2018/19

Autumn Term	***Spring Term***
Mondays **Statistical Analysis (SA)** Descriptive Statistics; Designed Experiments; Multiple Linear Regression	**Tuesdays** **Probability & Stochastic Modelling (PSM)** Stochastic Models & Time Series
Thursdays 5 Computing/Practical sessions R (Weeks 1 - 5)	**Thursdays** **Statistical Analysis (SA)** Multivariate Analysis and Generalized Linear Models
Fridays **Probability & Stochastic Modelling (PSM)** Probability and Inference	

SECOND YEAR COURSES available in 2018/19

<table>
<tr><td><u>Autumn Term</u></td><td><u>Spring Term</u></td></tr>
<tr><td colspan="2">60 credits worth of taught modules. One 15 credit module may be replaced by a supervised, Individually Prescribed Reading Course</td></tr>
<tr><td>Bayesian Methods [15 credits]
Linear and Nonlinear Optimization [15 credits]
Either Continuous Time Stochastic Processes (MASFM only; compulsory; Autumn term) [15 credits], <u>or</u> Mathematical and Numerical Methods (MASFM only; compulsory; Autumn+Spring terms) [30 credits]
Stochastic Systems: Theory, Methods and Applications [15 credits]</td><td>Stochastic Processes & Financial Applications (MASFM only; compulsory) [15 credits]
Analysis of Dependent Data [15 credits]
Computational Statistics [15 credits]
Statistical Learning [15 credits]</td></tr>
</table>

4. SYLLABUS

The timetable on the preceding page gives an outline of the structure of programme over the two years. The first year lecture courses, combined with the practical sessions, aim to provide a broad education and training in statistics at postgraduate level. In particular they aim to provide students with:

1. a deeper knowledge of the principles of statistical inference, probability theory, random processes and design;
2. an understanding of how these principles are applied to the statistical modelling of systems, the design of experiments and surveys and the analysis and interpretation of experimental and observational data, including multivariate analysis and the analysis of time series;
3. experience in the use of a high level computing package with programming capability for statistical data analysis.
4. the ability to incorporate the results of a technical analysis into a clearly written report form that may be understood by a non-specialist.

The two first year modules, *Probability and Stochastic Modelling* and *Statistical Analysis* (each worth 30 credits) comprising the courses outlined on the previous page are designed with the above objectives in mind. An outline of the syllabuses is given on the following pages, together with an indicative list of recommended texts. These listed texts provide good starting points for exploring the subject. In some cases the lecture courses follow a particular text reasonably closely; where this is not the case lecturers will usually provide course notes. However, in each subject there are many other texts, some of which are also included here, some of which students will discover for themselves. To get full value from a postgraduate programme of this kind, students are encouraged to read as widely as possible in order to develop a personal image and 'feel' for the subject, rather than that projected by someone else.

4.1 YEAR ONE

4.1.1 PROBABILITY AND STOCHASTIC MODELLING

(30 credits)

Examined by one three-hour written examination (Paper 1) worth 80% plus coursework amounting to 20% of the final mark

Aims and Outline Syllabus

Autumn Term

(1) Probability & Distribution Theory (5 lectures plus coursework)

Aims

To provide a solid grounding in the fundamentals of random variables and their distributions, together with an introduction to axiomatic probability theory and the convergence of sequences and sums of random variables. These form the foundations of statistics. It is assumed that the ideas are familiar, so that the pace is fairly fast, but that the subject may not have been covered at this level before.

Syllabus

Introduction to probability spaces. Conditional probability and Bayes' Theorem. Independence. Random variables and their distributions. Specific discrete and continuous distributions, and the contexts in which they arise, especially those arising in inference from normally distributed data. Multivariate distributions, especially the properties of multivariate normal distributions. Functions of random variables.

The moment generating function and the characteristic function. Weak convergence of random variables. The Weak Law of Large Numbers and the Central Limit Theorem.

(2) Statistical Inference (5 lectures plus coursework)

Aims

The inference lectures cover the theory underlying modern statistics and aim to give the student a solid grounding in (mathematical) statistics and the principles of statistical inference. Emphasis is placed on demonstrating the applicability of the theory and techniques in practical applications.

Syllabus

The likelihood function and sufficiency. Point estimation and the method of maximum likelihood. Minimum variance unbiased estimation and efficiency. Hypothesis testing: Neyman-Pearson theory, power, optimal tests, confidence sets. The Bayesian approach to statistical inference.
Comparison of approaches.

Recommended Textbooks:

Casella A and Berger R L, Statistical Inference, Duxbury (2nd Edition), 2002.
Cox D R and Hinkley D V, Theoretical Statistics, Chapman & Hall/CRC, 1979.
Gaithwaite P.H, Joliffe I T & Jones B, Statistical Inference, OUP (2nd Edition), 2002.
Grimmett G R and Stirzaker D R, Probability and Random Processes, Oxford University Press (3rd Edition) and the accompanying Problems and Solutions book One Thousand Exercises in Probability, 2001.
Ross S M, First course in Probability, MacMillan (6th Edition), 2001.
Tuckwell H C, Elementary Applications of Probability Theory, Chapman and Hall, 1995.
Young G A & Smith R L, Essentials of Statistical Inference, Cambridge University Press, 2005.

Spring Term

Introduction to Stochastic Models & Time Series (10 lectures plus coursework)

Aims

The main aims of these lectures are: (i) in the context of univariate time series and discrete time stochastic models, to extend the static ideas of the probability lectures to a dynamic framework in which randomness unfolds over time; (ii) to introduce students to the properties of ARMA models and the principles of ARIMA modelling, including model identification, estimation and forecasting; (iii) to introduce some of the properties and applications of Markov chains.

A variety of models are discussed together with examples of their application, and students use advanced statistical software to analyse time series data.

Syllabus

Stochastic Models (~ 3 lectures)

Markov chains; stationary transition probabilities; Chapman-Kolmogorov equations; classification of states: transience, null recurrence and positive recurrence; limiting and stationary distributions; embedded Markov chains in the context of continuous time discrete-state space stochastic processes.

A range of examples will be considered to illustrate the material which will likely be drawn from inventory theory, and/or queueing theory in which either the inter-arrival times are Markovian but the service times are General Independent (or vice-versa).

Time series and forecasting (~ 7 lectures)

Stationary processes and autocorrelations. Autoregressive, moving average and mixed autoregressive moving average processes; integrated models for non-stationary processes. Fitting an ARIMA model, parameter estimation and diagnostic checking. Forecasting. The analysis of time series using R.

Recommended Textbooks:

Brockwell P J & Davis R A, Introduction to Time Series and Forecasting, Springer (2nd Edition), 2002.

Chatfield C, The Analysis of Time Series: An Introduction, Chapman and Hall (6th Edition), 2003.

Harvey A C, Time Series Models, Harvester Wheatsheaf (2nd Edition), 1993.

Biggs N L, Discrete Mathematics, Oxford University Press (2nd Edition), 2002.

Grimmett G R and Stirzaker D R, Probability and Random Processes, Oxford University Press (3rd Edition) and the accompanying Problems and Solutions book One Thousand Exercises in Probability, 2001.

Ross S M, Applied Probability Models with Optimization Applications, Dover, 1992.

Ross S M, Introduction to Probability Models, Academic Press (8th Edition), 2002.

Learning Outcomes

On successful completion of the module Probability and Stochastic Modelling, students should be able to demonstrate:

- knowledge and understanding of the theory of random variables and their distributions, together with knowledge of a wide range of standard distributions;
- knowledge and understanding of the axiomatic approach to probability;
- the ability to recognize the appropriate distributions to use when modelling data that arise in different contexts and applications;
- knowledge and understanding of the principles and theory of statistical inference and the ability to use the theory and available data to estimate model parameters and formulate and test statistical hypotheses;
- knowledge and understanding of the theory and properties of ARMA and ARIMA models, and the ability to apply the theory to the analysis of times series data, to model fitting, model choice, interpretation and forecasting;
- the ability to use advanced statistical software for the analysis of time series data;
- knowledge and understanding of the theory of Markov Chains with stationary one-step transition probabilities;
- the ability to recognise when a system that behaves according to a discrete-time discrete-state space stochastic process can be modelled by a Markov Chain;

- some ability to recognise when a continuous-time discrete-state space stochastic process can be characterized, to some extent, by an embedded Markov Chain, and to construct and make calculations based on that Markov Chain where appropriate.

4.1.2 STATISTICAL ANALYSIS

(30 credits)

Examined by one three-hour written examination (Paper 2) worth 80% plus coursework amounting to 20% of the final mark

Aims and Outline Syllabus

- To provide a solid grounding in the fundamental theory and practice of statistical modelling and the analysis of observational and experimental data (including continuous, binary and categorical data). The course covers multiple linear regression, analysis of variance with fixed and random effects, generalized linear models (including logistic regression and log-linear models for contingency tables) and an introduction to the theory and analysis of multivariate data.
- To provide practical training and experience in the application of the theory to the statistical modelling of data from real applications, including model identification, estimation and interpretation.
- To enable students to use advanced statistical software to analyse real data from observational studies and designed experiments.

The first section is an introductory series of 5 lectures in parallel with 5 computing sessions designed to revise basic statistical concepts and models, including 1-way ANOVA and multiple regression, while introducing students to the use of R for the statistical analysis of experimental and observational data. These 10 sessions are also intended to motivate some of the theory in the first term courses on Probability & Distribution Theory and Statistical Inference. Underlying theory is developed (or anticipated) in the lectures and illustrative practical examples fully analysed. The associated computing sessions are self-paced. They are designed to introduce the statistical package R and its programming language and to allow students to carry out for themselves exercises and examples that are carefully chosen to illustrate the theory and reinforce the examples in lectures.

The remaining lectures build on this introduction, introducing more complex statistical data, models and designs for data collection, and developing both the theory and practice more fully.

Introduction to the analysis of statistical data (5 lectures plus 5 computing sessions):

- Basic statistical concepts and introduction to R. Multiple regression and the general linear model. ANOVA for multiple linear regressions. Goodness of fit and residual analysis. Stepwise procedures. Applications and examples.

Analysis of designed experiments (5 lectures):

- The completely randomised design, one-way ANOVA and treatment effects. Comparison of treatment effects. Factorial and nested models, the analysis of variance with fixed and random effects. Introduction to principles of experimental design. Examples and applications.

Generalized linear models (introductory lectures followed by 2/3 lectures on more advanced theory):

- The concept of the generalized linear model; parameter estimation via maximum likelihood and the iterative weighted least squares algorithm; goodness-of-fit (deviance); model interpretation, model checking and model selection. Examples include logistic regression, log-linear models, Poisson regression.

Multivariate analysis (introductory lectures followed by 2/3 lectures on more advanced theory):

- Definition and derivation of principal components in the sample using the covariance matrix. The problem of non-uniqueness of principal components with respect to scale. The pros and cons of using the original covariance matrix, the correlation matrix - or of re-scaling the variables. Interpretation of components and choice of how many to retain. Examples of the use of principal components.

- Revision of the multivariate normal distribution, its density function and moments. Sampling from the multivariate normal. Maximum likelihood estimation of the mean vector and covariance matrix. The maximum likelihood and union-intersection approaches to multivariate hypothesis tests. One and two-sample tests, Hotelling T2 and Wishart distributions, Fisher's linear discriminant function and Mahalanobis distance. Introduction to 1-way MANOVA and canonical variate analysis.

- Use of R to carry out multivariate analyses using both the matrix manipulation facilities and the tailored commands.

Recommended Textbooks

- Krzanowski W J, Introduction to Statistical Modelling, Arnold, 1998.
- Montgomery D C, Design and Analysis of Experiments, (5th Edition), Wiley, 2001.
- Christensen R, Analysis of Variance, Design and Regression, Chapman & Hall/CRC, 1996.
- Chatfield C and Collins A J, Introduction to Multivariate Analysis, Chapman and Hall, 1980.
- Krzanowski W J, Principles of Multivariate Analysis, Oxford University Press (2nd Edition), 2000.
- Mardia K V, Kent J T and Bibby J M, Multivariate Analysis, Academic Press, 1979.
- Dobson A J, An Introduction to Generalized Linear Models, Chapman and Hall. (2nd Edition), 2001 reprint
- McCullagh P and Nelder J A, Generalized Linear Models, Chapman and Hall, (2nd Edition), 1989.
- Lindsey J K, Applying Generalized Linear models, Springer, 1997.

Also recommended more generally for applied statistics

- Chatfield C, Problem Solving - a Statistician's Guide, Chapman & Hall, (2nd Edition), 1995.
- Cox D R and Snell E J, Applied Statistics: Principles and Examples, Chapman and Hall, 1981.

The following web resources provide excellent guides to the R language at different levels

- http://cran.r-project.org/doc/contrib/Short-refcard.pdf
  is a 4 page summary of key functions and functionality.
- http://cran.r-project.org/doc/contrib/R_language.pdf
  is a very concise introduction to, and reference for, the structure of the language.
- http://cran.r-project.org/doc/manuals/R-lang.html
  is the main reference manual for the language.

Learning Outcomes

On successful completion of the module Statistical Analysis, students should be able to demonstrate:

- substantial knowledge and understanding of the theory of the general linear model (including multiple regression and designed experiments with fixed and random effects) and of generalized linear models (including logistic regression and log-linear models for contingency tables);
- knowledge of the fundamental distributions in multivariate normal theory: the multivariate normal distribution, the Wishart distribution and Hotelling T^2 distribution;
- knowledge and understanding of the maximum likelihood and union-intersection approaches to multivariate hypothesis tests and applications to one-sample, two-sample and 1-way tests for mean vectors;
- knowledge and understanding of linear discriminant analysis and the relationship between Fisher's linear discriminant function, the Mahalanobis distance between samples and the two-sample Hotelling T^2 test;
- knowledge and understanding of principal components analysis and its uses and applications;
- the ability to apply principles and theory to the statistical modelling and analysis of practical problems in a variety of application areas, and to interpret results and draw conclusions in context;
- the ability to abstract the essentials of a practical problem and formulate it as a statistical model in a way that facilitates its analysis and solution;
- the ability to use advanced statistical software for the analysis of complex statistical data.

4.2 YEAR TWO

On passing Part I of the examination, students may progress to the second year of the MSc programme. Year two builds on the foundations set in year one, developing a deeper theoretical understanding and knowledge in chosen areas of statistics, operational research and stochastic modelling, and promoting the ability to tackle new and non-standard problems with confidence. The mutual dependence of theory and practice continues to be emphasised wherever possible. In the second year students are able to orient their programme towards their own particular interests and career objectives. Each student selects modules, up to an overall credit value of 60. The range of modules offered *normally* covers advanced statistical analysis; computational data analytics; operational research; and mathematical finance [MASFM students only]. The module choice determines the potential award title for the MSc. If desired, a single 15 credit module may be replaced by a supervised, *individually prescribed reading course*.

IMPORTANT NOTE: We do not guarantee that any of the following modules will be running when you reach year 2 of the programme. Details of proposed second year modules are made available soon after the Year 1 examinations.

As well as following the selected modules, students are required to complete a Project, a sustained, independent investigation. The Project is worth 60 credits and is carried out over eleven months, from October 1 at the beginning of the second year, to the following September 1. The Project is intended to show that a student is able to tackle a substantive problem requiring an analysis using statistical, stochastic modelling or operational research methods, and can give a well-organized, clear and convincing exposition of the problem, the analysis, and the conclusions, in terms that can be understood by a non-specialist, but with sufficient detail to allow the results to be understood and/or replicated by an expert.

Details of the Project, Individually Prescribed Reading Course and the modules likely to be offered in 2018/19 are given on the following pages.

4.2.1 PROJECT

(60 credit module; core for all MSc programmes)
Examined by a written project report (worth 80%) plus an oral presentation (worth 20%).

Aims

- To give students the opportunity of undertaking a sustained, independent investigation involving the application of methods of statistics, operational research or financial engineering to a specific problem.

- To give students practice in writing up and presenting the results and conclusions of an investigation in a report where the problem, final results and conclusions can be understood and appreciated by a non-specialist, but which includes sufficient technical detail for the results to be replicated by a specialist in the field.

- To give students practice in the oral presentation of the background, results and conclusions of an investigation in a way that may be understood by a non-specialist.

Outline

The project gives students the opportunity to identify and, with some guidance, carry out a practical investigation of the type that might be expected of a professional statistician, operational researcher or stochastic modeller. Each student is required to submit a project proposal at the beginning of the second year of study and a supervisor is then allocated. Once project and supervisor are agreed, and an initial meeting has taken place, students are expected, over the remainder of the autumn term, to complete (i) background reading on the application area and on the mathematical and statistical techniques required for the project, (ii) assembling of data and locating and becoming familiar with the necessary software, and (iii) final specification of the questions that are of interest and can feasibly be investigated in the time.

At the start of the spring term, each student is required to submit a preliminary project report, giving the relevant background to their project, the problem to be investigated, methods to be used, and progress to date. A written progress report is also required by the end of the spring term and the final project report of between 8,000 and 14,000 words must be submitted by (the earliest business day starting from and including) September 1st, at the end of the two years of study. Individual oral presentations of 25 to 30 minutes, including 5 minutes for questions, are then scheduled to be completed by September 30.

Throughout the duration of the project, students are advised to discuss progress and obtain feedback from their supervisor on three/four occasions after the initial meeting, including feedback on the preliminary project presentation, the written progress report, and a draft plan and at most one draft section of the final project report.

Learning Outcomes

On successful completion of the core Project module, students should have demonstrated:

- breadth of knowledge of different methods and techniques of statistical analysis, operational research, or stochastic modelling, and the ability to decide when and how they should be used in the sustained investigation of a practical problem;
- the ability to abstract the essentials of a practical problem and formulate it as a mathematical or statistical model in a way that facilitates its analysis and solution;
- a working knowledge of available numerical and statistical software relevant for the proposed analysis and the ability to use an appropriate package or programming language;
- the ability to complete a substantial and sustained piece of investigation;
- the ability to incorporate the results of such an investigation involving technical analysis into a clearly written report that may be understood by a non-specialist;
- communication and presentation skills tailored to a designated audience.

Important Dates

- Project Proposal, to be submitted in the first week of autumn term.
- The Preliminary Project Report, to be submitted at the start of the spring term.
- Interim Project Report, to be submitted before the beginning of the summer term.
- Final Project Report, to be submitted by (the earliest business day starting from and including) 1st September.

- Final Project Presentation, given towards the end of September.

4.2.2 BAYESIAN METHODS
(15 credit module; compulsory for MAS-CDA and available on MAS/MASOR/MASFM)

Aims

To introduce students to a wider range of more advanced models and techniques in multivariate analysis and give a practical introduction to methods of Bayesian analysis. Bayesian methods are of general interest, now being widely adopted and implemented in statistical packages such as R. They are also being increasingly used in medical statistics. Emphasis is placed on understanding the theory and computational background of the methods covered so that students will find it easy to read more widely in the literature to extend their knowledge and range of tools. An equal emphasis is placed on exposing students to a variety of examples in which the methods and models are deployed in the context of real problems. A number of such examples are presented in lectures, and computing exercises provide the opportunity to gain further experience in applying the techniques and interpreting the results.

Syllabus

- The Bayesian Approach to Statistical Inference.
- Choice of Prior Distribution.
- Multi-parameter models.
- Markov Chain Monte Carlo Methods.
- Bayesian Model Selection.
- Practical Bayesian Analysis in R.

Learning Outcomes

On successful completion of this module a student will be expected to be able to:

- appreciate the fundamentals principles of Bayesian statistics;
- discuss the differences between Bayesian and traditional statistical methods;

- derive prior, posterior and predictive distributions for standard Bayesian models;
- derive summaries from the (fitted/estimated) posterior distribution;
- implement computational and simulation-based methods to Bayesian inference;
- undertake Bayesian decision theory and model choice;
- use a statistical package with real data to facilitate an appropriate analysis and write a report interpreting the results.

Recommended Textbooks:

Gelman A, Carlin J Sterne H and Rubin D, Bayesian Data Analysis, Chapman and Hall (2nd Ed.), 2003.
Lee P, Bayesian Statistics: An Introduction, WileyBlackwell (3rd Ed.), 2004.
Gilks WR, Richardson S and Spiegelhalter DJ, Markov Chain Monte Carlo in Practice, Chapman and Hall, 1995.
Albert J, Bayesian Computation with R, Springer (2nd Ed.), 2009.
Spiegelhalter D, Best N, Thomas A and Lunn D, Bayesian Analysis Using Bugs, Chapman and Hall/CRC, 2010.

General Interest:
Spiegelhalter D, Abrams D and Myles J, Bayesian Approaches to Clinical Trials and Health-care Evaluation, WileyBlackwell, 2003.

4.2.3 COMPUTATIONAL STATISTICS
(15 credit module; compulsory for MAS-CDA and available on MAS/MASOR/MASFM)

Aims

The course is designed to introduce students to the modern computational methods of statistics, which have had an enormous impact on statistical practice over the past 30 years. These methods, sometimes called Monte Carlo methods, are computationally intensive techniques, and the breadth of such methods and their application is extensive. The course aims to give students an understanding and appreciation of many of the ideas underlying these methods. It aims to review a range of techniques, illustrate how they may be applied in practice, and give students computational experience in applying them using a high level programming language such as R.

Syllabus

This is likely to include most of the following: The uses and aims of simulation in statistical inference. Pseudo-random numbers. Generation of random variables: principles, techniques and examples. Inversion and rejection methods for obtaining random samples from arbitrary distributions (given uniform random samples). Application to include binomial, Poisson, gamma and normal distributions. Variance reduction methods. Randomization tests. The bootstrap and the jackknife: bootstrap for estimation, bootstrap confidence sets and hypothesis tests. The EM algorithm and its uses: examples of applications, implementational issues. An introduction to non-parametric regression, smoothing and kernel density estimation.

Learning Outcomes

On successful completion of this course students should be able to demonstrate:

- knowledge and understanding of the theory, techniques and computational methods for simulation in the context of statistical inference;
- knowledge and understanding of the theory and application of re-sampling techniques such as the bootstrap;
- knowledge and understanding of the theory and practical issues involved in modern non-parametric modelling;
- the ability to make sensible use of a range of modern computationally intensive techniques and algorithms to model and draw inferences from statistical data;
- the ability to program and use advanced mathematical and statistical software to carry out computationally intensive statistical methods;
- the ability to incorporate the results of a technical analysis into clearly written report form that may be understood by a non-specialist.

Recommended Textbooks

Davison A C & Hinkley D V, Bootstrap Methods and their Application, Cambridge University Press, 1997.

Efron B & Tibshirani R J, An Introduction to the Bootstrap, Chapman & Hall, 1993.

Manley, B F J, Randomization, Bootstrap and Monte Carlo Methods in Biology, Chapman & Hall, (3rd Edition), 2006.

Kleijnen J P C and van Groenendaal W, Simulation: a Statistical Perspective, Wiley, 1997.

Morgan B T J, Elements of Simulation, Chapman and Hall, 1984.

Morgan B T J, Applied Stochastic Modelling, Chapman and Hall (2nd Edition), 2009.

Ripley B D, Stochastic Simulation, Wiley, 2006.

Rizzo M L, Statistical Computing with R, Chapman and Hall (2nd edition), 2014

Robert C P and Casella G, Introducing Monte Carlo Methods with R, Springer, 2010

Ross S M, Simulation, Academic Press (5th Edition), 2012.

Silverman B W, Density Estimation for Statistics and Data Analysis, Chapman and Hall, 1986.

4.2.4 STATISTICAL LEARNING

(15 credit module; available on MAS/MAS-CDA/MASOR/MASFM)

Aims

The course is designed to introduce students to the techniques of statistical learning. The module aims to give students a unified treatment and understanding of the mathematical and statistical basis of a variety of methods for classification, regression and cluster analysis. It also gives students computational experience in applying the relevant methods using a high level programming language such as R.

Syllabus

Supervised learning:

- Linear regression and locally weighted linear regression
- Generalized linear models for binary and multi-class classification
- Discriminant analysis
- Support vector machines
- Neural Networks
- Learning theory, assessing performance and cross validation
- Classification and regression trees

Unsupervised learning:

- Introduction to cluster analysis
- Hierarchical clustering methods.

Learning Outcomes

On successful completion of this course students should be able to demonstrate:

- knowledge and understanding of the methodology, the main techniques and the underpinning mathematical and statistical theory in statistical learning
- the ability to make sensible use of a range of suitable techniques, models and algorithms to elicit useful relations or structure within datasets
- the ability to use advanced mathematical and statistical software to explore datasets
- the ability to incorporate the results of a technical analysis into clearly written report form that may be understood by a non-specialist.

Recommended Textbooks:

1. Elements of Statistical Learning, by T. Hastie, R. Tibshirani & J. Friedman
2. Applied Predictive Modeling, by M Khun & K Johnson
3. Deep Learning, by I Goodfellow, Y Bengio & A Courville
4. Pattern Recognition and Neural Networks, by B Ripley.

4.2.5 ANALYSIS OF DEPENDENT DATA
(15 credit module; available on MAS/MAS-CDA/MASOR/MASFM)

Aims

To introduce students to more advanced theory, models and techniques for the analysis of data with complex dependency structure; for example hierarchical, repeated measures, longitudinal and spatial data. Practical examples, mainly in medical and biometric applications will be presented, and there will be opportunities to explore the use of software for fitting such models using SAS and R.

Syllabus

Clustered observations and dependency, both ordered and exchangeable. The need for appropriate techniques to account for correlation between observations. Generalized Least Squares, including models for the covariance structure of the data. Maximum likelihood and REML estimation. The General Linear Mixed Model, including fixed and random effects. Subject-specific models. Use of the variogram as a means of identifying a suitable covariance structure. The robust approach and the empirical 'sandwich' estimator.

Models for discrete data, including a review of the generalized linear model and an introduction to quasi-likelihood. Marginal models using generalized estimating equations, GEEs, and alternating logistic regressions for binary data. The Generalized Linear Mixed Model, including both fixed and random effects. Numeric integration using Gaussian quadrature.

Learning Outcomes

On successful completion of this course students should be able to demonstrate:

- substantial knowledge and understanding of the theory, models and techniques used for the analysis of data with complex structure and dependency, including repeated measures, longitudinal data, hierarchical and spatial data.
- knowledge and understanding of a range of methods for exploring and visualizing structured data.
- the ability to apply the theory to the statistical modelling and analysis of practical problems involving structured, dependent data, and to interpret results and draw conclusions in context.
- the ability to use advanced statistical software for the analysis of complex statistical data.

- the ability to incorporate the results of a technical analysis into a clearly written report that may be understood by a non-specialist.

Recommended Textbooks:

Fitzmaurice, Laird and Ware, Applied Longitudinal Analysis, Wiley, 2004.
Verbeke and Molenberghs, Linear Mixed Models for Longitudinal Data, Springer, 2000.
Molenberghs and Verbeke, Models for Discrete Longitudinal Data, Springer, 2006.
Diggle, Heagerty, Liang and Zeger, Analysis of Longitudinal Data, OUP (2nd Ed.), 2002.
Pinheiro and Bates, Mixed-Effects Models in S and S-PLUS, Springer, 2000.
Brown and Prescott, Applied Mixed Models in Medicine, Wiley (2nd Ed.), 2006.

4.2.6 LINEAR AND NONLINEAR OPTIMIZATION
(15 credit module; compulsory for MASOR and available on MAS/MAS-CDA/MASFM)

Aims

This course is designed to introduce students to ideas of mathematical modelling and optimization for problems in industry, business and science. The methods covered are all deterministic. The aim is to develop the ability to formulate fairly complex optimization models in the context of practical problems, to provide an understanding of the main classes of problems that are practically solvable and a detailed coverage of some of the most important solution methods. The coverage is not comprehensive but aims to give students a firm foundation in the theory on which they can build more detailed knowledge in areas of particular interest in their work. Examples are used throughout to illustrate the theory and the range of its practical application.

Syllabus

This is likely to include most of the following:
Outline of the history and scope of operational research. Problem formulation.
Linear programming: geometrical ideas and graphical solution; the simplex method; duality; degeneracy and cycling; the Big-M and Two Phase methods; post-optimal analysis. Introduction to Interior Point methods.

Integer programming: introduction to the wide variety of contexts in which practical problems can be formulated as integer or mixed integer programming problems. The Branch and Bound approach.

Network optimization: introduction to optimization problems on networks, in particular maximum flow problems, and their relationship with linear programming, shortest path and minimal connector problems.

Introduction to computational complexity and order notation. Application to some problems of operational research.

Nonlinear optimization: convexity and concavity, constrained and unconstrained optimization, conditions for optimality, introduction to optimization algorithms. Algorithms for one-dimensional optimization. Newton and quasi-Newton methods. Lagrangian methods and the Kuhn-Tucker conditions. The Generalised Reduced Gradient method; Steepest descent (and its limitations). Quadratic programming problems and their solution. Introduction to Penalty Functions. Application of these techniques to some practical problems.

Learning Outcomes

On successful completion of this course students should be able to demonstrate:

- knowledge and understanding of the mathematical theory underlying the main classes of unconstrained and constrained optimization problems: linear and nonlinear programming problems, network optimization problems and integer programming problems;
- knowledge and understanding of some of the most important algorithms and solution methods for optimization problems, including the simplex algorithm, steepest descent and quasi-Newton methods, network algorithms, branch-and-bound;
- the ability to formulate and solve fairly complex optimization problems in the context of practical applications;
- the ability to incorporate the results of a technical analysis into clearly written report form that may be understood by a non-specialist;
- the ability to abstract the essentials of a practical problem and formulate it in a way that facilitates its analysis and solution;
- the ability to use software for the solution of optimization problems;
- the ability to interpret the results of an optimization problem, explore the solution, carry out a sensitivity analysis and draw conclusions in context.

Recommended Textbooks:

Bazaraa M S, Jarvis J J, Sherali H D, Linear Programming and Network Flows, Wiley, 2005.

Bazaraa M S, Sherali H D, Shetty C M, Non-Linear Programming: Theory and Algorithms, (3rd edition) Wiley, 2006

Bertsimas D and Tsitsiklis J N, Introduction to Linear Optimization, Athena Scientific, 1997.

Ecker J G, Kupferschmid M, Introduction to Operations Research, Krieger, 2004

Hillier F S, Liebermann G J, Introduction to Operations Research, (8th edition) McGraw-Hill, 2004

Luenberger D G, Ye Y, Linear and Nonlinear Programming, Springer, 2008.

Taha H A, Operations Research: An Introduction, Pearson, 2006.

Williams H P, Model Building in Mathematical Programming, Wiley, 2013.

Vanderbei, R J, Linear Programming: Foundatuions and Extensions, Wiley, 2013

Winston W L, Operations Research: Applications and Algorithms, TBS, 2003

4.2.7 STOCHASTIC SYSTEMS: THEORY, METHODS AND APPLICATIONS
(15 credit module; compulsory for MASOR and available on MAS/MAS-CDA/MASFM)

Aims

This course is designed to introduce students to ideas of stochastic modelling in the context of practical problems in industry, business and science. It aims to give a firm foundation of the relevant theory and to develop the ability to formulate practical problems in terms of appropriate stochastic models. Examples are used throughout to illustrate the theory and the range of its practical application.

Syllabus

- Distribution theory and the Poisson process
- Markov chains in continuous time
- Markov chain models of queueing systems

- Examples of Markov and non-Markov models
- Renewal processes
- Regenerative and renewal-reward processes
- Queues and the M/G/1 model
- Multi-class queueing systems
- Open and Closed Networks of Queueing Systems
- (Time permitting) Fluid Approximations
- Application areas for the use of Stochastic Systems will be discussed throughout
- For illustrative purposes, discrete event simulation will be carried out for some the systems discussed, using the R package.

Learning Outcomes

On successful completion of this course students should be able to:

- understand the theory of Markov processes in continuous time with discrete state space, including the global balance equations for systems in equilibrium and the detailed balance equations for reversible processes;
- understand and apply the theory of birth and death processes;
- understand the basic properties of renewal processes, and apply them to situations for which they would be appropriate;
- understand basic queueing system models, and apply them to situations for which they would be appropriate;
- apply ergodic theory and Little's result to calculate relevant performance measures in regenerative systems.
- understand the properties of a queueing system network under equilibrium conditions, and apply such network models to situations for which they would be appropriate;
- understand the basic principles of discrete event simulation for continuous time systems and, for very simple systems, know how such techniques could be implemented in R.

Recommended Textbooks:

Mitrani, I. Probabilistic Modelling, (2nd Edition), Cambridge University Press, 2008.
Grimmett, G. & Stirzaker, D. Probability and Random Processes (3rd Edition), Oxford: Oxford University Press, 2001.
Ross, S. M. Introduction to Probability Models (9th Edition), London: Academic Press, 2007. (The relevant sections of earlier editions are just as good for the purposes of this course.)
Tijms, H. C. A First Course in Stochastic Models, Chichester: Wiley, 2003.

4.2.8 CONTINUOUS TIME STOCHASTIC PROCESSES

(15 credit module; compulsory for MASFM if Mathematical and Numerical Methods not taken; may not be taken with Mathematical and Numerical Methods; available on MASFM only)

Aims

To introduce students to continuous time stochastic processes and to stochastic differential calculus, in particular the stochastic differential equations (SDE) that arise in quantitative finance, as well as many other applied areas. To introduce students to some of the main numerical solution techniques used to solve SDE.

Syllabus

Review of probability theory, notion of a stochastic process.
Examples of stochastic processes: Brownian motion and the Poisson process.
Stochastic differential calculus: heuristic approach to stochastic differentials, Ito's lemma, rigorous approach to Ito's stochastic integral, multivariate Ito calculus.
Stochastic differential equations (SDE), examples from financial modelling.
Conditional expectation and martingales.
Connection with partial differential equations (PDE): Kolmogorov-Focker-Planck equations, Feynman-Kac formula.
Extensions of Ito calculus: jump diffusions, more general processes.
Monte Carlo simulation of stochastic processes, Brownian motion.
Numerical solutions of SDE.

Learning Outcomes

On successful completion of this course students should be able to demonstrate:

- understanding of the basic theory of continuous time stochastic processes, in particular Brownian motion and the Poisson process;
- understanding of stochastic differential calculus (Ito calculus) and the concept of a stochastic differential equation (SDE);
- knowledge of how to numerically simulate solutions to an SDE;
- the ability to manipulate stochastic integrals and use Ito's lemma;
- the ability to use and solve SDE.

Recommended Textbooks:

Liptser R S and Shiryaev A N, Statistics of Random Processes I (General Theory) and II (Applications), 2nd edition, 2001, Applications of Mathematics, Springer.
Kloeden, P. E. and Platen, E., Numerical Solution of Stochastic Differential Equations, corrected 3rd printing 1999, Applications of Mathematics 23, Springer.
Mikosch T, Elementary Stochastic Calculus, with Finance in View, Adv. Series Stat. Science & Appl. Prob, World Scientific, 1998
Oksendal B, Stochastic Differential equations, B., 5th edition, 1998, Springer.
Pollard D, A User's Guide to Measure Theoretic Probability, Cambridge Series in Statistical and Probabilistic Mathematics, 1998, Cambridge University Press.

4.2.9 MATHEMATICAL AND NUMERICAL METHODS

(30 credit module; compulsory for MASFM if Continuous Time Stochastic Processes not taken; may not be taken with Continuous Time Stochastic Processes; available on MASFM only)

Aims

AS THE AUTUMN TERM+additionally:-

- Further expand on some of the mathematical techniques used in quantitative finance.
- Introduce the main numerical techniques used in quantitative finance.

Syllabus

AS THE AUTUMN TERM+additionally:-

- The Binomial Model Universe.
- The Partial Differential Equation Approach: The Diffusion Equation; Finite Difference Methods for the Diffusion Equation; The Fourier Transform and the von Neumann Stability Test; Stability and the Fourier Transform; Option Pricing via the Fourier transform; Fourier Transform Conventions.
- Mathematical Background Material: Probability Theory; Differential Equations; Recurrence Relations; Mortgages – a once exotic instrument;
- Numerical Linear Algebra: Orthogonal Matrices and Fundamental Algorithms.

Learning Outcomes

AS THE AUTUMN TERM+additionally:-

On successful completion of this course students should be able to demonstrate:

- solve SDEs using Monte Carlo simulation.
- understand the fundamental algorithms for the numerical solution of parabolic partial differential equations (PDEs).
- understand the binomial method for option pricing as a finite difference method, particularly its disadvantages.
- appreciate the importance of stability in numerical algorithms for PDEs.
- understand numerical methods for the solution of nonlinear equations and some basic optimization techniques.
- know the basics of relevant numerical methods, eg data fitting.
- illustrate the above by examples and exercises in a high level programming language/package, such as Matlab for e.g.

Recommended Textbooks:

Liptser R S and Shiryaev A N, Statistics of Random Processes I (General Theory) and II (Applications), 2nd edition, 2001, Applications of Mathematics, Springer.

Kloeden, P. E. and Platen, E., Numerical Solution of Stochastic Differential Equations, corrected 3rd printing 1999, Applications of Mathematics 23, Springer.

Mikosch T, Elementary Stochastic Calculus, with Finance in View, Adv. Series Stat. Science & Appl. Prob, World Scientific, 1998.

Oksendal B, Stochastic Differential equations, B., 5th edition, 1998, Springer.

Pollard D, A User’s Guide to Measure Theoretic Probability, Cambridge Series in Statistical and Probabilistic Mathematics, 8, Cambridge University Press.

4.2.10 STOCHASTIC PROCESSES AND FINANCIAL APPLICATIONS

(15 credit module; compulsory for MASFM; available on MASFM only. Pre-requisite: Continuous Time Stochastic Processes or Autumn Term portion of Mathematical and Numerical Methods)

Aims

To understand the theory of continuous time stochastic processes and stochastic differential calculus and be able to apply it to solve problems in mathematical finance, in particular contingent claim pricing by martingale methods.

Syllabus

- Options: basic examples and simple arbitrage relationships
- The binomial model
- Hedging and the Black and Scholes Equation
- Solving the Black and Scholes equation and deriving the Black and Scholes formula.
- The Greeks of an option, their interpretation and their computation
- Path Dependent Options
- Monte Carlo Pricing

Learning Outcomes

On successful completion of this course students should be able to:

- demonstrate understanding of how to price financial assets using martingale methods;
- demonstrate understanding of the role and importance of absence of arbitrage in setting up the models;
- demonstrate knowledge of the difference between complete and incomplete market models and the implications for the valuation of derivatives;
- demonstrate problem-solving abilities to value derivative securities
- understand standard derivative and bond pricing models
- understand equivalent martingale measures and their role in option pricing
- understand valuation techniques based on change of numeraire
- understand the concepts of complete and incomplete markets
- apply the martingale approach to a variety of contexts: option pricing, term structure models for both defaultable and non-defaultable bonds
- understand the main types of structured credit derivatives and their pricing methodology.

Recommended Textbooks:

Baldi P, Mazliak L, Priouret P, *Martingales and Markov Chains: Solved Examples and Elements of Theory, CRC Press, (2002).*
Baxter and Rennie*, Financial Calculus*, *Cambridge University Press, 1996.*
Bingham N and Kiesel R, *Risk-neutral Valuation: Pricing and Hedging of Financial Derivatives, Springer Finance (2nd Edition), 2002.*
Bjork, *Arbitrage Theory in Continuous Time, Oxford University Press, 1998.*
Duffie D, *Dynamic Asset Pricing Theory, Princeton (3rd Edition), 2001.*
Geman H, *Commodities and Commodity Derivatives: Pricing and Modeling Agriculturals, Metals and Energy, Wiley Finance, 2005.*
Kijima M, *Stochastic Processes with Applications to Finance, CRC Press (1st Edition), 2002.*
Lamberton D and Lapeyre B, *Introduction to Stochastic Calculus applied to Finance, Chapman & Hall, 1996.*
Musiela M and Rutkowski M*, Martingale Methods in Financial Modelling, Appl. Math. 36, Springer Verlag, 1998.*
Wilmott P, *Derivatives: The Theory and Practice of Financial Engineering, J. Wiley, 1998.*

4.2.11 INDIVIDUALLY PRESCRIBED READING COURSE
(15 credit module for MAS/MAS-CDA/MASOR/MASFM)

Aims

The idea of the individually prescribed reading course is to give flexibility and to be responsive to the interests and needs of students. It allows each student to choose a subject related to their own personal interests or the requirements of their work, allowing a much wider range of choice than would be possible with just the options offered as lecture courses. The form of examination is an essay, not exceeding 7,500 words, summarizing, evaluating and criticising the material.

The aims of the reading course are: (i) to introduce students to the technique of learning for themselves some specialized branch of probability, statistics, operational research or stochastic modelling, (ii) to allow students to tailor their second year studies more closely towards their specific interests and career needs, and (iii) to give students practice in locating and integrating a number of different sources and producing a well presented piece of academic writing, organizing and summarizing the material.

Syllabus

The topic of the individual course can be any specialized subject within the field of probability, statistics, operational research or stochastic modelling. Initial guidance on source materials may be obtained from the assigned supervisor, normally the member of staff whose research interests are nearest. Students are then required to locate other material, including recent work in the area, from a variety of sources (eg recent monographs, survey articles, research papers) and should put in about 90 hours of private study, reading and understanding the material, integrating the different sources, evaluating, comparing and criticizing different approaches, and writing up the results in an extended, expository essay. Students are advised to discuss their progress with their supervisor on two/three occasions after the initial meeting and to obtain comments on a draft plan and on one draft section of their essay before submitting a final version.

Learning Outcomes

On successful completion of this course students should be able to demonstrate:

- a substantial knowledge and understanding of some chosen specialist area of statistics or operational research or mathematical finance;
- the ability to understand advanced, specialist material;
- the ability to locate relevant materials, books and academic papers on a topic of interest;
- the ability to learn independently by study of a range of sources including learned journals;
- the ability to produce a substantial, well structured and well presented expository document covering complex material.

The Autumn Reading Course is submitted near the first week of the spring term.
The Spring Term Reading Course is submitted near the first week of the summer term.

IMPORTANT NOTE: We do not guarantee that any of the above modules will be running when you reach year 2 of the programme. Details of proposed second year modules are made available soon after the Year 1 examinations.

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5. NOTES ON ASSESSMENT

5.1 COURSEWORK

Mathematics and Statistics Coursework Policy

For most course modules students will do coursework in addition to answering examination questions. It is important to note the deadlines for submission of coursework and realise that there are penalties for late submission. Full details of the penalties are outlined below and are available on our website.

The rules covering late submission of work are governed by the College-wide coursework policy. This policy primarily covers assignments: however, other items of coursework will be treated in a similar way.

- You will be allowed a minimum of 3 weeks to complete each assignment.
- Every assignment will be placed on the web as well as being distributed in lectures.
- Where possible we will return work within 4 weeks of the submission date; students will be notified of any exceptional delay in marking a piece of coursework.

Submission and Receipt of Coursework

- Coursework should be neatly written or typed in black or blue ink on A4 paper.
- You should submit your work by placing it inside the Assignment Box (which is on the 7th floor).
- Plastic documents wallets, folders, etc. are non-returnable.
- The Assignment Box will be emptied at 10 am in the morning and any assignment scripts found there will be stamped with the date of the previous working day.
- You will be able to check that your work has been received by looking your name up on a list (which will be on the noticeboard opposite the lift on the seventh floor.) It is your responsibility to check that submission has been acknowledged within a day or so of handing it in.
- If you cannot deliver the assignment personally, then you can, at your own risk, either arrange for somebody else to do it for you, or have it sent by post. Note that irrespective of the date of posting, the date of arrival will be deemed to be the date

of submission. Electronic submission of coursework (for e.g., via fax, or as an email attachment) is not acceptable and such submissions will not be considered eligible for examination.

- Only the first submission of an item of coursework will be considered. Later substitutes, or additions, to the original submission will not be accepted or considered for examination except by the invitation of the relevant examiner.
- You must keep a copy of your assignment for your records.
- You are advised to have marked coursework returned to you in person only. Requests to have work left in the student pigeon hole must be made by email to the Postgraduate Mathematics and Statistics administrator; it is understood that work that is returned via the pigeon hole is done so at your own risk.
- All marked coursework will need to be returned to the Mathematics and Statistics Section during the summer term, for moderation by the visiting (external and/or intercollegiate) examiners. You will be contacted by email in good time and asked to return your marked coursework by a given date.

Late Submission

- If you submit work late (but not more than 14 days late), **your mark will be capped at 50% (the pass mark).** That is, your work will be marked as normal and you will be told this mark, which is the ‘real’ mark that would have been awarded if the work had not been late. If the work is *not* of a pass standard this is the mark that will be awarded. However, if the work *is* of a pass standard, you will be given the capped pass mark of 50%. If there are mitigating circumstances you can request that the penalty be lifted. You must do this by filling in a Mitigating Circumstances Claim Form, available to download from the website http://www.ems.bbk.ac.uk/for_students/msc_stats, outlining the reasons for special consideration to be given, and submitting it, along with relevant supporting documentation (e.g. medical certificate, employer statement etc.) to your programme administrator. If the form and documentation are found to be in order, they will be sent for consideration by a sub-committee meeting of the relevant Sub-Board of Examiners. The sub-committee meeting usually takes place early in the summer term. If no such documentation is received prior to this meeting the ‘real’ mark will not be considered and the penalty mark will stand.
- If the assignment is handed in late by *more than 14 days*, for whatever reason, then it cannot be considered for examination. If this is the case, or the assignment is not handed in at all, then the default position is that the assignment will be given

a score of 0 (zero). If there is a case to be made for being awarded a 'nominal substitute' mark for an assignment falling into this category, then, as for submission up to 14 days late, you will need to put this case in writing for consideration.

Note: Any part of this policy may be suspended, or modified, on a case-by-case basis, in line with disability provision, and/or upon advice from appropriate College authorities.

For each piece of marked coursework, the lecturer will be the first marker and a second member of staff will act as moderator of the marks, to ensure that the marking is of the correct standard. Coursework will be returned with comments and some indication of the provisional mark. Note, however, that any mark given is provisional since it is subject to confirmation by the MSc Sub-Board of Examiners.

5.2 EXAMINATIONS

The registration process for the June examinations is controlled by the College Examinations Office. Late in the autumn or early in the spring term you will be emailed a computer link which you will be required to access in order to confirm on-line the modules you are taking. It is important that students make sure that their examination entry proceeds correctly, and that on-line confirmation is completed by the required date. Once an entry is made, some flexibility exists for subsequent alteration. However, given the administrative difficulty of making such changes, this is not desirable.

Examination admissions notices are emailed to candidates by the College Examinations Office. These contain the student's examination number and the examination dates as well as other general information. Students should check immediately to make sure that they have been entered for the correct examinations.

Permission to withdraw from the examination or any part of the examination, including submission of the Essay for the Individually Prescribed Reading Course, or the Final Project Report, may only be granted at the discretion of the College, and for reasons judged adequate in the particular case. Application for permission to withdraw from examination(s) shall be made in the case of summer examinations **at least 14 days in advance of the first examination or by 1 May whichever is the**

earlier. Application must be made in writing to the Programme Director for the degree or diploma for which the student is registered. The Programme Director shall exercise on behalf of the College the discretion to grant or refuse such applications and may consult as necessary before doing so and may require the completion of a Mitigating Circumstances Claim form and the submission of documentary evidence in support of the application.

In cases where permission is granted the relevant examination entries shall be designated as 'withdrawn'. All other candidates will be regarded as having made an entry or re-entry, except that in the case of illness or other adequate cause, for which certification must be provided*, a candidate may be permitted at the discretion of the College to withdraw his/her entry to the examination in the week before the commencement of the examination and up to and including the date of his/her first paper provided that (s)he has not entered the examination hall. Candidates who do not attend an examination or who do not submit written work without being granted permission to withdraw their examination entry shall be deemed to have failed the examination on that occasion.

Withdrawal from an examination, Individually Prescribed Reading Course or Project is not a right, and each case is judged on its merits. **The earliest that an examination can be re-sat or Individually Prescribed Reading Course re-examined is the next summer. The earliest that a deferred or failed Project can be examined is the next September.** A candidate given permission to withdraw will in general be required to retake the deferred module(s): this would involve re-enrolling, attending associated lectures and redoing all assessment associated with that module (both coursework and exam). In exceptional cases, at the discretion of the Programme Director, a candidate may be allowed simply to defer assessment of the relevant element until the following year, in which case a re-assessment fee may apply. Note, however, that deferment is generally not a sensible option - modules often change slightly from one year to the next, if only in the emphasis given to particular topics, and students who are permitted to defer may end up being at a disadvantage.

*A certificate from your GP or Consultant will be needed in all medical cases.

Past examination papers are available via the Library website in the Birkbeck Electronic Library: http://www.bbk.ac.uk/lib/elib/exam

5.3 PLAGIARISM

In the context of the assessment of projects, essays and course work, we would like to draw your attention to the College Policy on Assessment Offences in respect of plagiarism. The following extract is taken from that Policy:

- Plagiarism is defined by the College as “the submission for assessment of material (written, visual or oral) without correct acknowledgement, in such a way that the work could be assumed to be the student’s own, or could be assumed to have been originally produced by the student for the purposes of the assessment in question, where this is not the case.” Plagiarism includes the unattributed use of another person’s work, ideas, opinions, theory, statistics, graphs, models, paintings, artefacts, performance, computer code, drawings, quotations of another person’s actual spoken or written words, or paraphrases of another person’s spoken or written words. It may also include the submission of unattributed work previously produced by the student towards some other assessment, or published in some other forum.
- Plagiarism can occur in any piece of work. This policy applies for any alleged case of plagiarism in any piece of work submitted for formal assessment at the College.
- A student who knowingly assists another student to plagiarise (for example by willingly giving them their own work to copy from) is committing an assessment offence.

5.4 REASSESSMENTS AND RETAKES

The pass mark for modules on postgraduate programmes is 50%. Students are allowed two attempts at each module. Once the module has been passed, students are not permitted to retake the exam in order to improve their grade (except, for example, when a mitigating circumstances claim has been accepted and a deferral opportunity has been granted). An “attempt” occurs when a student registers for a module and does not subsequently formally withdraw from that module before the published deadline. So failure to submit coursework by the deadline, or failure to attend the examination without accepted mitigating circumstances will count as a failed attempt. If you fail a module on your first attempt one of two paths will normally be offered:

- **Reassessment** – usually as a result of being offered a "deferral opportunity" (in individual elements, such as for the written paper, or the whole module) means that you will be assessed again at the next *available* opportunity as determined by the sub-board of examiners, at its sole discretion – it is not an entitlement that can be relied upon by the candidate; usually this means sitting the written paper again. However if you passed the coursework element you will not have to repeat it, and you will not have to attend lectures for the module if the reassessment is being offered for the following summer (rather than around September), albeit it would be highly advisable to re-enrol, upon payment of the appropriate fees, and at least attend the lectures again prior to taking the said elements of assessment again.

- **Retake** means that you will re-enrol on the module, attend lectures and retake all assessment associated with that module (both coursework and written paper(s)).

The final result for a module will be the sum of the marks obtained in all elements passed at the first attempt, plus the appropriate mark for any element of assessment taken more than once, either reassessed or retaken.

Note: Reassessment is not an automatic entitlement and the decision to offer it is at the discretion of the sub-board of examiners. **It is the policy of the sub-board for this programme <u>not</u> to offer a reassessment (except in some very specific, limited instances), but instead require the candidate to retake the module.**

Furthermore, and as an aside, it is now the College policy that reassessments are capped at a mark of 50% (except for cases in which a deferral opportunity for the module in question has been awarded due to a successful mitigating circumstances claim).

5.5 ASSESSMENT CRITERIA

For all four award titles of the MSc Applied Statistics programme, the distinction between grades of achievement lies chiefly in:

1. the depth of understanding of concepts, theory and techniques;
2. the amount of guidance and support needed to undertake an extended task, either of theoretical argument and proof, or of modelling, analysis and interpretation in applications of statistics, operational research or stochastic modelling;
3. breadth of knowledge;
4. clarity of expression and quality of presentation.

Distinction (at least 70%)

Outstanding work that reveals a breadth and depth of theoretical understanding, an analytic, modelling and interpretive ability, clarity of expression, and insight and independence of thought at a level that suggests that the student is highly capable of successfully completing a research degree or of practising as an independent professional statistician or operational researcher - with a particular expertise in stochastic modelling for MASSM graduates.

Merit (at least 60% but less than 70%)

Good quality work in all, or almost all, aspects that suggests the student is capable of completing a research degree or practising as an independent professional, but does not reveal the same breadth and level of theoretical understanding, analytic and modelling ability, insight and independence of thought as a distinction-level candidate.

Pass (at least 50% but less than 60%)

Satisfactory in most aspects, demonstrating that the student understands and can use the more important theoretical material and analytic techniques, and is capable, with some guidance, of working as a professional in the field, but without demonstrating the kind of clarity, insight, analytic ability, and breadth and depth of theoretical understanding required to undertake a research degree.

Fail (less than 50%)

Poor work that demonstrates lack of basic knowledge and comprehension of the material.

5.6 ASSESSMENT SCHEME

Part I of the examinations for the MAS programmes covers year 1 of the programme which comprises the modules Probability and Stochastic Modelling [PSM]; and Statistical Analysis [SA]. These are examined by:

(i) Two 3-hour written papers, Papers 1 and 2

Paper 1 – worth 80% of PSM
Paper 2 – worth 80% of SA

(ii) Assessment of coursework during the year
(worth 20% of the mark on each of PSM and SA)

Marks for both modules are reported as **percentages** and the pass mark is set at **50%**.

Note 1: To move into the Second Year a pass in both First Year modules (Part I) is required.

Note 2: Satisfactory completion of Part I would entitle candidates to exit with the Postgraduate Certificate in Applied Statistics provided that this is confirmed by the appropriate (sub-) board of examiners.

Part II of the examinations for the MAS programmes covers year 2 of the programme and consists of the Project along with the 4 selected 15 credit modules. These are examined in the following way:

(i) Project:

A Written Report	**(80%)**
An Oral Presentation	**(20%)**

and is then given a percentage mark where:

	Distinction	***at least 70%***
	Merit	***at least 60% but less than 70%***
	Pass	***at least 50% but less than 60%***
or	***Fail***	***less than 50%***

(ii) Each of the 4 selected (compulsory or optional 15 credit) modules not designated as an Individually Prescribed Reading Course will be examined by a two-hour written paper (80%) and coursework (20%). A percentage mark is given for each of these modules, with the pass mark set at 50%.

(iii) For a (maximum of one) selected module designated as an Individually Prescribed Reading Course, this will be examined by an extended essay (100%).

To obtain an MSc a pass is normally required in all of the modules, the two from Part I (Probability & Stochastic Modelling; and Statistical Analysis) and the five from Part II (the Project; 4 selected modules).

The field of study of the MSc is determined by the modules selected in Part II, as indicated in the preceding pages; the nature of the project undertaken may be taken into account.

The MSc may also be awarded with Merit or with Distinction. Criteria for Pass, Merit and Distinction are given in the next section.

5.7 CLASSIFICATION SCHEME

All modules are assessed on a scale in which a mark of at least 50% but less than 60% represents a *pass*, a mark of at least 60% but less than 70% represents a *merit* and a mark of at least 70% represents a *distinction*.

The final MSc degree classification is derived from the seven elements:

1. Probability and Stochastic Modelling (30 credits)
2. Statistical Analysis (30 credits)
3. Compulsory or Optional* Module (15 credits)
4. Compulsory or Optional* Module (15 credits)
5. Optional Module (15 credits)
6. Optional Module (15 credits)
7. Project (60 credits)

*(*dependent on pathway)*

Classification is normally according to the following scheme, although in making its recommendation the Exam Board will take into account all aspects of a student's performance on the programme.

<u>Pass with Distinction</u>
1. At least a Pass is required in all elements.
2. Weighted Average (as specified by CAS) of the **7** percentage marks for elements **1-7** should be **70% or more.**
3. The Project should be assessed as **Distinction (≥ *70%*).**

<u>Pass with Merit</u>
1. At least a Pass is required in all elements.
2. Weighted Average (as specified by CAS) of the **7** percentage marks for elements **1-7** should be **60% or more.**

<u>Pass</u>
1. At least a Pass is required for elements 1 and 2 (Core modules).
2. At least a Pass is required for the Project.
3. A Pass is required for all other Compulsory modules taken in accordance with a named award title.
4. Weighted Average (as specified by CAS) of all **7** percentage marks for elements **1-7** should be at least **50%** with no more than 30 credits as compensated fail.
5. A compulsory module which is taken in relation to one of the award titles other than M.Sc. Applied Statistics that has been failed may instead be considered for credit as a compensated fail toward the award of M.Sc. Applied Statistics if warranted by the overall performance on the programme.

6. STUDENT COMMITMENT AND SUPPORT

The MSc Applied Statistics programmes are demanding and require considerable commitment from students. Attendance at lectures (normally two evenings per week) and at additional computing/workstation sessions is important. Students are also expected to complete coursework, which may involve computing, and should also carry out further reading at home. All this usually requires a further commitment of about 6 to 10 hours per week.

The department is committed to providing a supportive environment for students studying part-time. Each student is assigned a personal tutor who is responsible for monitoring their progress and providing advice and guidance in case of difficulty. The arrangements by which a student and personal tutor meet depend on the individuals concerned, but students should make a point of seeing their personal tutor at least once a term and more often if facing particular difficulties. If you require a reference from us, then the first port of call would be your personal tutor; if a second referee is needed, then the usual port of call would be your project supervisor (if already assigned and not the same person as your personal tutor); otherwise, you are free to approach another member of the group.

Individual lecturers are always willing to discuss any academic problems that students may have with particular course modules. Students should not hesitate to make an appointment when necessary since individual sessions with lecturers, together with workstation classes, are the main vehicle for tutorial support. Alternatively an appointment can be made to see the MSc Programme Director to discuss issues arising from the course. In addition, and despite the difficulties of part-time attendance, students themselves usually provide one another with considerable mutual support. We are keen to remedy any problems with courses, and to help us do this we ask students to express their views through returning evaluation questionnaires, through class representatives and the Student/Staff Exchange meetings.

Information on the Students' Union Welfare/Counselling Service and other student services is contained in the Birkbeck College Postgraduate Prospectus and in the Students Union Handbook. Other **communication is mainly via email**, particularly when we need to contact students directly and at short notice, but sometimes by post.

Students should therefore ensure that the programme administrator is informed of any change of address during their period of study. Occasionally it is necessary to contact students very quickly, if, for instance, there is no alternative but to cancel a lecture. As well as communicating this via email it can also be helpful to have a daytime telephone number for each student.

It is worth noting that the Students' Union has designed a series of 'Skills for Study' workshops on weekday evenings. Sessions given in the past included: essay writing skills; presentation skills; getting the most out of lectures; time management; memory skills; exam stress management; revision skills. Further information is available from the programme administrator.

7. MSC QUALIFYING COURSE

7.1 Requirements

Applicants whose qualifications are insufficient to begin the MSc course directly, e.g. with degrees lower than Second Class Honours level or degrees which, although relevant, do not contain sufficient mathematics and statistics, may take a one year Qualifying Course. This involves two evening lectures per week devoted to theoretical and applied statistics, and subsidiary mathematics.

The two modules are:

1. Statistics: Theory and Practice
2. Advanced Mathematical Methods

Passing the corresponding examinations entitles the candidate to a Graduate Certificate in Statistics. To qualify for entry to the MSc, the examinations must be passed at the level of an upper second class honours degree.

An outline of the modules is given below. See the Certificate and Undergraduate Handbooks for further details.

7.2 STATISTICS: THEORY AND PRACTICE

Course taught over 16 evenings spread over the autumn and spring terms.

Course outline

Introduction to R;
Design and analysis of simple experiments: to include (but not necessarily restricted to) one and two-way randomized designs;
Joint distribution of several variables and likelihood functions: with special emphasis on the effects of variables being i) mutually independent, or ii) drawn from the same distribution, or both; multivariate normal distribution, with particular attention to the bivariate normal;
Further distribution theory: sums of independent Chi-squared variables, F-distributions, and how they relate to analysis of variance techniques;
Introduction to the theory of statistical inference: likelihood, sufficiency, estimation; hypothesis testing;
Simple and multiple linear regression

Recommended Textbooks:

Ugarte M D, Militino A F and Arnholt A T, Probability and Statistics with R, CRC Press, 2008.
Krzanowski W J, An Introduction to Statistical Modelling, Arnold, 1998.
Krause A and Olsen N, The Basics of S-Plus, Springer (4th edition), 2005.
Montgomery D C, Design and Analysis of Experiments, 7th edn, Wiley, 2009.
Casella A and Berger R L, Statistical Inference, Duxbury (2nd Edition), 2002.
Gaithwaite P.H, Joliffe I T & Jones B, Statistical Inference, OUP (2nd Edition), 2002.
Young G A & Smith R L, Essentials of Statistical Inference, Cambridge University Press, 2005.

7.3 ADVANCED MATHEMATICAL METHODS

Course taught over 16 evenings spread over the autumn and spring terms.

Course outline:

Multivariable Calculus and Differential Equations

Functions of more than one variable. Partial differentiation and its applications. Multiple Integrals. Differential equations.

Recommended Textbook:

Adams R A, Calculus of Several Variables, Addison-Wesley

Adams R A, Calculus: A Complete Course, Addison-Wesley

Linear Algebra

Matrices & Systems of Linear Equations

Determinants: evaluating the determinant of a square matrix, properties of the determinant.

Real Vectors: the dot product, the length of a vector, linear combinations, spanning subspaces, linearly independent vectors, bases, orthogonality, the angle between two vectors, orthogonal bases and the Gram-Schmidt process

Eigenvalues & Eigenvectors: finding eigenvalues and eigenvectors of a square matrix, the characteristic equation, diagonalization and powers of square matrices.

Markov Chains: transition matrices, state vectors, Markov matrices, regular transition matrices, steady state vectors.

Linear Programming: Linear inequalities, formulation of a linear programme, objective function and constraints, graphical solutions, introduction to the simplex method.

Recommended Textbooks:

H. Anton, & C. Rorres, *Elementary linear algebra with applications*, Wiley

B. Kolman, *Introductory Linear algebra with Applications (6th edition)*, Prentice Hall

C. Whitehead. *Guide to Abstract Algebra (Macmillan Mathematical Guides)*, Macmillan

8. COMPUTING FACILITIES

All students are given an account on the College network which is activated on payment of fees. This gives access to College and Department resources, the web and an email account. Usernames and passwords will be sent to you within a few days of enrolling at Birkbeck, or can be obtained from the Department Help Desk (see below) on production of a College Membership Card.

Student email addresses are username@students.bbk.ac.uk

College staff email addresses are initial.surname@bbk.ac.uk.

The Department provides computing support for all Department students.

Information Technology Services (ITS) (see http://www.bbk.ac.uk/its) is a College service that supports students throughout the College. The seventh floor noticeboards have information on courses, software and hardware offers and other computer services.

Department Student Help Desk

The Help Desk is run by Awuku Danso (room 758), tel 020 7631 6433, or email helpdesk@ems.bbk.ac.uk
It is *normally* open at the following times:

Term:	Mon – Fri	16.00 – 18.30
Out of Term:	Mon – Fri	16.00 – 18.00

ITS Service Desk and Reception

Tel: 020 7631 6543

Email: its@bbk.ac.uk

In person: Ground floor, in the Student Centre, Malet Street Main Building.